# Geothermal Assessment as Part of California's Renewable Energy Transmission Initiative (RETI)

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***Keywords***

*Transmission planning, MW capacity, development cost*

## ABSTRACT

Geothermal assessments and cost estimates were performed as part of California's Renewable Energy Transmission Initiative (RETI) to help guide transmission planning. The RETI assessments identified approximately 5,300 gross megawatts (MW) of additional electrical-generation capacity that could be brought on line from geothermal sites within 10 years, including 2,440 gross MW within California. The RETI study area spanned 5 western states and parts of Canada and Mexico. Geothermal assessments were performed for 116 sites in California, Nevada, Oregon, and southern British Columbia. MW capacity estimates were made on a regional basis for Arizona, Washington, and the northern portion of the Mexican state of Baja California Norte ("Baja"). Capital costs and costs for Operations and Maintenance (O&M) were estimated primarily as a function of MW capacity. For most sites, estimated capital costs ranged from $3,000 to $5,500 per gross MW installed, and estimated O&M costs ranged from $22 to $35 per gross MWh (2008 dollars). These costs were converted to a net-MW basis in the RETI analysis for purposes of comparison with other renewable energy sources. The Levelized Cost of Energy (LCOE) for most geothermal sites ranged from $65 to $130 per net MWh.

## Introduction

California has adopted one of the most aggressive Renewable Portfolio Standard (RPS) requirements in the United States. The state's Energy Action Plan sets a goal that 33% of the electricity consumed in the state should come from renewable sources by 2020. To help meet this goal, the RETI effort has sought to quantify potential sources of electrical generation from renewable sources in California and surrounding areas. Sites for several different types of renewable energy (including geothermal, wind, biomass, solar photovoltaic, and solar thermal) have been aggregated into Competitive Renewable Energy Zones (CREZs) as an aid to transmission planning. The RETI effort has entailed over a year of analysis and collaboration among stakeholder groups, including utilities, generators, regulatory agencies, public-interest groups, environmental advocates, and the general public, convened under the aegis of a coordinating committee consisting of the California Public Utilities Commission (CPUC), the California Energy Commission (Energy Commission), and the California Independent System Operator (CAISO), together with publicly owned and investor owned utilities. The RETI study area has extended across state lines and international boundaries, from southern British Columbia in Canada to Baja California Norte ("Baja") in Mexico, including the states of California, Nevada, Oregon, Washington, and Arizona. Black & Veatch has coordinated the technical analysis for all renewable resource types, and GeothermEx has acted as a sub-contractor to Black & Veatch for the geothermal portion of the work (identification of geothermal sites and estimation of MW capacities and development costs).

Progress reports on the RETI effort have incorporated the geothermal assessments into a framework of economic and environmental analyses that allow ranking of the CREZs. A full discussion of the CREZ rankings is beyond the scope of this paper; interested readers are referred to RETI reports for Phases 1A and 1B (Black & Veatch, 2008 and 2009). The RETI effort is of potential interest to the geothermal community, both for the information presented about the study area, and as an example of a regional, multi-stakeholder approach that may be applied elsewhere. The intent of the current paper is to highlight the methodology and conclusions of the geothermal portion of the analysis.

## Site Identification

Geothermal resource sites were identified from a variety of sources in the public domain, including government assessments of geothermal potential, research papers and maps by universities and national labs (particularly the National Renewable Energy Lab, the Great Basin Center for Geothermal Studies, and Southern Methodist University), industry publications (particularly Geothermal Resource Council Transactions and reports of the

Geothermal Energy Association), press releases, leasing records, and direct responses from geothermal developers to solicitations for information as part of the RETI effort. The focus was on specific tracts of land about which there was enough public information to make a quantitative estimate of MW potential over a development horizon of about 10 years, consistent with timing for transmission planning decisions.

The geothermal resource sites included existing geothermal plants with expansion potential, Known Geothermal Resource Areas (KGRAs) historically published by the United States Geological Survey (USGS), geothermal databases published by state regulators (such as the California Division of Oil, Gas and Geothermal Resources, and the Nevada Division of Minerals), geothermal leases published by the United States Bureau of Land Management (BLM), and geothermal areas with associated MW estimates for specific regions (including GeothermEx, 2004; Western Governors' Association, 2006; California Geothermal Energy Collaborative, 2006; Shevenell et al., 2008; and Nevada RETAAC, 2008). Geothermal site locations (latitudes and longitudes) within the US portions of the RETI study area were checked with reference to a list of geothermal systems developed by the USGS in connection with its current update of the US geothermal assessment (Colin Williams, pers. comm., 17 Sep 2008). Resources in British Columbia were located principally based on a map published by the Geological Survey of Canada (Fairbank and Faulkner, 1992); for the purposes of the RETI study, only geothermal sites in the southern portion of British Columbia were considered. Figure 1 shows the location of the geothermal sites considered within the RETI study area. Isolated hot springs and warm wells were not treated as geothermal sites unless there was some expression of developer interest, such as the leasing of geothermal development rights on specific tracts.

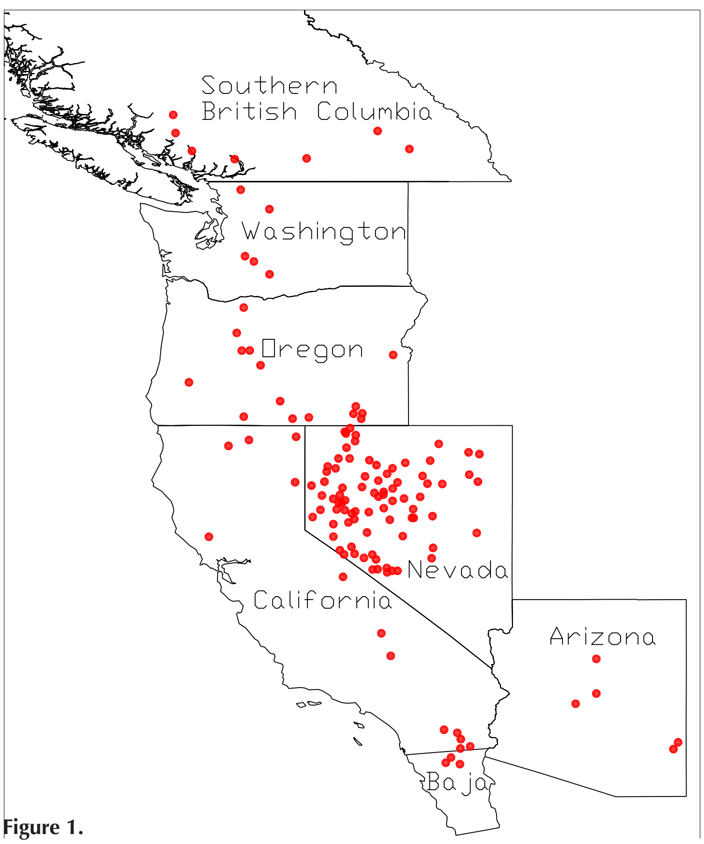


**Figure 1.**

Undiscovered conventional resources and enhanced geothermal system (EGS) resources were not identified with this approach. For the purposes of near-term transmission planning, it is not possible (in the authors' opinion) to accurately and reliably quantify the locations of undiscovered conventional potential and EGS potential. Although the aggregate potential of undiscovered conventional geothermal sites has been estimated, the locations and magnitude of such sites are by definition not known. EGS technologies are not yet commercially proven, and it is too early to plan transmission for these resources. That said, it is recognized that various research efforts have estimated the generating potential of undiscovered conventional resources and EGS resources in the US in the hundreds of thousands of MW. In California alone, the potential of undiscovered conventional resources is estimated to be as high as 25,439 MW, and the potential of EGS resources in California is estimated to be as high as 67,600 MW (Williams et al., 2008). These resources would greatly increase the estimates of geothermal potential in the RETI study area. As additional information is learned about the quantity, quality and location of these resources, it should be included in future transmission studies.

## MW Capacity

The initial phase of the RETI effort entailed a regional review of the MW potential of the states and provinces within the study area. This review drew on the regional studies cited above for areas within the US, as well as BC Hydro (2002) for British Columbia, and Gutierrez-Negrin and Quijano-Leon (2005) for Baja. Based on the regional review, California and three out-of-state areas (Nevada, Oregon, and southern British Columbia) were deemed to have sufficient geothermal potential to warrant more detailed assessments for purposes of large-scale, interstate transmission planning. Table 1 shows a summary of the regional estimates. The values in this table have been adjusted from those in the RETI Phase 1A report (Table 6-42 in Black & Veatch, 2008), to reflect the totals from the more detailed assessments in RETI Phase 1B (Black & Veatch, 2009). Table 2 shows the results of the more detailed assessments for a total of 116 specific sites.

**Table 1.** Geothermal MW Capacity Estimates for RETI Study Area.

| State / Province | Installed Capacity as of Feb 08 (Gross MW) | Estimated Incremental Capacity Within 10 Years (Gross MW) | Total Capacity (Installed + Incremental) Within 10 Years (Gross MW) |
|---|---|---|---|
| California | 1,884 | 2,440 | 4,324 |
| Nevada | 297 | 1,785 | 2,082 |
| Oregon | 0 | 600 | 600 |
| Washington | 0 | 50 | 50 |
| Arizona | 0 | 50 | 50 |
| Baja California, Mexico | 730 | 80 | 810 |
| Southern British Columbia | 0 | 280 | 280 |
| Total | 2,911 | 5,285 | 8,196 |

Estimation of MW capacities for specific sites relied on volumetric estimation of heat in place wherever sufficient information was available to justify this approach. The methodology has been described in detail in GeothermEx (2004), which was a study of California and Nevada geothermal resources for the Public Interest Environmental Research (PIER) program of the California Energy Commission (CEC), referred to herein as the CEC-PIER Report. In brief, the heat-in-place approach entailed estimation of the area, thickness, and average temperature of the geothermal resource. Recovery factors based on industry experience were applied to estimate the proportion of heat that could be recovered as electrical energy over an assumed project life of 30 years. Uncertainty in the input parameters was handled by a probabilistic approach that yielded a range of possible MW values and associated probabilities. The modal value of the probability distribution was considered the "most likely value" of MW capacity for the geothermal site concerned. If no existing plant was operating at a site, the most likely value was considered to be the incremental MW capacity available. If a site had an existing plant, the incremental capacity was considered to be the most likely capacity minus the capacity of the existing plant.

When there was insufficient resource information to apply the heat-in-place method, estimates of MW capacity were made by analogy to better-known projects in similar geologic environments. If the only public information about a project was that it contained geothermal leases or had been the subject of a geological reconnaissance study, the project size was estimated at a minimum size of 10 gross MW. Larger estimates of MW capacity were made in some instances even in the absence of published resource data if there was evidence of active geothermal development efforts. For certain large volcanic centers in northern California, Oregon, and southern British Columbia, MW capacities of 50 gross MW were estimated based on potentially favorable geologic conditions, even in the absence of current development efforts.

Incremental capacity estimates were first developed on a gross capacity basis and then converted to a net capacity basis assuming a net:gross ratio of 90% (i.e., 10% auxiliary load) for flash plants, and 80% (i.e., 20 % auxiliary load) for binary plants. The assumption of flash versus binary was primarily a function of resource temperature, though for some high-temperature resources binary plant equipment was assumed to minimize environmental impact (for example, to avoid visible plumes from cooling towers). On a gross basis, the total incremental capacity from the areas of detailed evaluation was 5,105 gross MW, or which 2,440 gross MW was from California. On a net basis, the total for areas of detailed evaluation was 4,317 net MW, of which 2,102 net MW was from California. Including the regional estimates from Washington, Arizona, and Baja, the total incremental capacity available was 5,285 gross MW, or approximately 5,300 gross MW.

## Development Costs

Characterization of geothermal projects as to capital and O&M costs was based as much as possible on current industry experience. The costs of drilling and plant equipment have risen markedly in recent years, though this has been tempered somewhat by the recent economic downturn. A comparison of cost estimates from the 2004 CEC-PIER Report with actual development costs as of 2008 indicated that the CEC-PIER estimates had escalated by about 20%. Moreover, a correlation of the CEC-PIER cost estimates with estimated MW capacities showed generally higher costs per kW installed for smaller projects (Figure 2). This correlation of cost with project size was the primary basis for estimating the cost of projects not considered by the CEC-PIER study, and the 20% escalation factor was used to express all project costs in 2008 dollars. In some instances, cost estimates from the CEC-PIER study were adjusted by something other than a 20% escalation factor, to account for more recent information or site-specific constraints (such as a high level of environmental opposition). For British Columbia, a 30% escalation factor was applied to account for development challenges associated with colder climate and rugged topography. This analysis yielded capital cost estimates generally ranging from $3,000 to $5,500 per gross kW installed.

O&M costs for geothermal projects were estimated to range generally from $22 to $30 per MWh, with higher costs characterizing the smaller project sizes. The hyper-saline brine resources of the Salton Sea field were estimated to have O&M costs of $35 per kWh. These O&M cost estimates included site costs, general and administrative overhead, workovers, royalties, and insurance. They did not include costs of financing or interest payments, though such costs were accounted for in comparisons of geothermal projects with projects for other renewable energy types (Black & Veatch, 2009).

The capital and O&M cost estimates were used to calculate levelized costs of energy (LCOE) for the geothermal sites with incremental MW capacity. In making the LCOE calculation, initial capacity factor estimates for plants were assumed to be 90% for flash plants and 80% for binary plants. The resulting LCOE values generally ranged between $65 and $130 per net MWh (Table 2, overleaf).

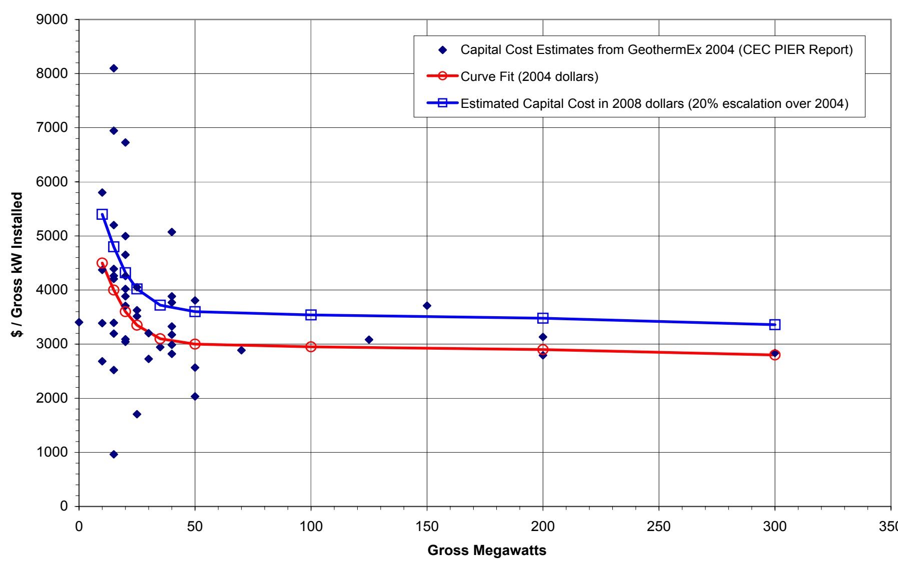


**Figure 2.**

**Table 2.** Geothermal Project Characteristics.

| Project | Latitude | Longitude | Installed Capacity as of Feb 08 | Incremental Capacity Within 10 Years (Gross MW) | Assumed Binary or Flash | Net : Gross Ratio Based on Plant Type | Incremental Capacity Within 10 Years (Net MW) | Estimated Capital Cost in 2008 dollars ($/gross kW installed) | Estimated Capital Cost in 2008 dollars ($/net kW installed) | Estimated O&M Costs as of 2008 ($ / gross MWh) | Estimated O&M Costs as of 2008 ($ / net MWh) | Capacity Factor Based on Plant Type | Levelized Cost of Energy ($ / Net MWh) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **California** | | | | | | | | | | | | | |
| Brawley (sum of Brawley, East Brawley, and South Brawley) | 32.990 | -115.520 | | 200 | B | 0.8 | 160 | $3,352 | $4,190 | $22.00 | $27.50 | 0.8 | $74.36 |
| Coso | 36.030 | -117.800 | 300 | 0 | F | 0.9 | 0 | NA | NA | $25.00 | $27.78 | 0.9 | NA |
| East Mesa (incl. Dunes & Glamis) | 32.780 | -115.250 | 73 | 40 | B | 0.8 | 32 | $6,087 | $7,609 | $25.00 | $31.25 | 0.8 | $137.54 |
| Geysers (incl. Calistoga & Clear Lake / Sulphur Bank) | 38.800 | -122.750 | 1,000 | 150 | F | 0.9 | 135 | $3,528 | $3,920 | $22.00 | $24.44 | 0.9 | $58.64 |
| Heber (incl. Border, Mount Signal, & Superstition Mountain) | 32.720 | -115.530 | 115 | 40 | B | 0.8 | 32 | $3,384 | $4,231 | $25.00 | $31.25 | 0.8 | $79.50 |
| Honey Lake | 40.368 | -120.274 | 6 | 10 | B | 0.8 | 8 | $3,221 | $4,026 | $30.00 | $37.50 | 0.8 | $83.36 |
| Lake City / Surprise Valley | 41.672 | -120.246 | | 40 | B | 0.8 | 32 | $3,992 | $4,991 | $25.00 | $31.25 | 0.8 | $92.55 |
| Long Valley (Mammoth Pacific Leases) | 37.650 | -118.900 | 40 | 50 | B | 0.8 | 40 | $3,000 | $3,750 | $25.00 | $31.25 | 0.8 | $71.24 |
| Medicine Lake | 41.580 | -121.600 | | 480 | B | 0.8 | 384 | $3,600 | $4,500 | $25.00 | $31.25 | 0.8 | $84.13 |
| Mt Shasta (incl. areas around Lassen: Growler & Morgan) | 41.410 | -122.188 | | 50 | F | 0.9 | 45 | $3,800 | $4,222 | $25.00 | $27.78 | 0.9 | $67.19 |
| Randsburg | 35.380 | -117.530 | | 30 | B | 0.8 | 24 | $3,272 | $4,091 | $25.00 | $31.25 | 0.8 | $77.09 |
| Salton Sea (incl. Niland & Westmoreland) | 33.170 | -115.620 | 350 | 1,300 | F | 0.9 | 1170 | $4,400 | $4,889 | $35.00 | $38.89 | 0.9 | $90.50 |
| Truckhaven (incl. San Felipe prospect) | 33.260 | -116.000 | | 50 | B | 0.8 | 40 | $3,600 | $4,500 | $25.00 | $31.25 | 0.8 | $84.13 |
| **Nevada** | | | | | | | | | | | | | |
| Adobe Valley | 40.207 | -118.916 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Alkali Hot Springs | 37.823 | -117.336 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Alum | 37.903 | -117.645 | | 40 | B | 0.8 | 32 | $3,586 | $4,482 | $25.00 | $31.25 | 0.8 | $83.82 |
| Antelope (aka Bartholomew Hot Springs) | 39.392 | -116.330 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Aurora | 38.292 | -118.869 | | 125 | B | 0.8 | 100 | $3,700 | $4,625 | $22.00 | $27.50 | 0.8 | $81.84 |
| Baltazor | 41.921 | -118.696 | | 15 | B | 0.8 | 12 | $6,240 | $7,800 | $30.00 | $37.50 | 0.8 | $148.20 |
| Beowawe | 40.547 | -116.616 | 17 | 25 | F | 0.9 | 22.5 | $4,352 | $4,836 | $25.00 | $27.78 | 0.9 | $76.57 |
| Blue Mountain (aka Faulkner) | 41.000 | -118.144 | | 50 | B | 0.8 | 40 | $3,518 | $4,398 | $25.00 | $31.25 | 0.8 | $82.36 |
| Boulder Valley | 40.987 | -116.399 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Brady's | 39.782 | -119.029 | 27 | 10 | B | 0.8 | 8 | $4,064 | $5,081 | $30.00 | $37.50 | 0.8 | $101.48 |
| Buffalo Valley | 40.362 | -117.335 | | 30 | B | 0.8 | 24 | $3,870 | $4,838 | $25.00 | $31.25 | 0.8 | $89.92 |
| Candelaria Hills | 38.152 | -117.952 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Colado | 40.230 | -118.355 | | 20 | B | 0.8 | 16 | $5,582 | $6,978 | $30.00 | $37.50 | 0.8 | $134.08 |
| Crescent Valley | 40.326 | -116.476 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Darrough Hot Springs (aka Big Smokey Valley; incl. Raser projects: Trail Canyon, Truckee, Devil's Canyon) | 38.819 | -117.185 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Delcer Buttes | 40.383 | -115.028 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Desert Peak | 39.771 | -118.938 | 11 | 50 | B | 0.8 | 40 | $3,079 | $3,849 | $25.00 | $31.25 | 0.8 | $72.94 |
| Desert Queen | 39.847 | -118.839 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Devil's Punch Bowl (north of Deeth) | 41.226 | -115.296 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Dixie Valley | 39.953 | -117.883 | 70 | 200 | F | 0.9 | 180 | $3,759 | $4,176 | $22.00 | $24.44 | 0.9 | $62.56 |
| Double (Black Rock) Hot Springs | 41.050 | -119.030 | | 20 | B | 0.8 | 16 | $5,996 | $7,496 | $30.00 | $37.50 | 0.8 | $142.97 |
| Dyke Hot Springs | 41.548 | -118.552 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Emigrant | 37.870 | -117.909 | | 50 | B | 0.8 | 40 | $4,570 | $5,712 | $25.00 | $31.25 | 0.8 | $104.95 |
| Empire (aka San Emidio) | 40.382 | -119.433 | 5 | 10 | B | 0.8 | 8 | $5,246 | $6,558 | $30.00 | $37.50 | 0.8 | $126.86 |
| Excelsior | 38.311 | -118.567 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Fallon (aka Carson Lake) | 39.469 | -118.645 | | 30 | B | 0.8 | 24 | $3,844 | $4,805 | $25.00 | $31.25 | 0.8 | $89.36 |
| Fish Lake | 37.860 | -118.050 | | 40 | B | 0.8 | 32 | $4,660 | $5,825 | $25.00 | $31.25 | 0.8 | $106.88 |
| Fly Ranch (Hualapi Flat & Granite Ranch) | 40.821 | -119.340 | | 15 | B | 0.8 | 12 | $9,719 | $12,148 | $30.00 | $37.50 | 0.8 | $222.90 |
| Gerlach (aka Great Boiling Springs) | 40.672 | -119.368 | | 20 | B | 0.8 | 16 | $4,824 | $6,030 | $30.00 | $37.50 | 0.8 | $117.79 |
| Grass Valley (Lander County) | 39.948 | -116.685 | | 25 | B | 0.8 | 20 | $4,020 | $5,025 | $25.00 | $31.25 | 0.8 | $93.14 |
| Gridley Lake | 41.766 | -118.816 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Hawthorne | 38.513 | -118.657 | | 15 | B | 0.8 | 12 | $5,268 | $6,585 | $30.00 | $37.50 | 0.8 | $127.32 |
| Hazen (aka Patua Hot Springs) | 39.585 | -119.082 | | 25 | B | 0.8 | 20 | $4,862 | $6,078 | $25.00 | $31.25 | 0.8 | $111.23 |
| Hot Creek Ranch | 38.482 | -116.316 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Hot Creek Springs (aka Carlotti Ranch Springs) | 40.317 | -116.050 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Hot Pot | 40.925 | -117.113 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Hot Sulphur Springs (incl. East Independence prospect) | 41.468 | -116.152 | | 30 | B | 0.8 | 24 | $3,870 | $4,838 | $25.00 | $31.25 | 0.8 | $89.92 |
| Howard Hot Springs | 41.720 | -118.535 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Hyder Hot Springs | 40.012 | -117.740 | | 15 | B | 0.8 | 12 | $8,333 | $10,416 | $30.00 | $37.50 | 0.8 | $193.14 |
| Jackrabbit | 40.271 | -119.805 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jersey Hot Springs (aka Jersey Valley) | 40.186 | -117.473 | | 25 | B | 0.8 | 20 | $4,020 | $5,025 | $25.00 | $31.25 | 0.8 | $93.14 |
| Kyle Hot Springs (aka Granite Montain) | 40.414 | -117.886 | | 20 | B | 0.8 | 16 | $4,450 | $5,562 | $30.00 | $37.50 | 0.8 | $109.75 |
| Leach Hot Springs | 40.609 | -117.634 | | 20 | B | 0.8 | 16 | $8,072 | $10,091 | $30.00 | $37.50 | 0.8 | $187.54 |
| Lee Hot Springs | 39.212 | -118.745 | | 15 | B | 0.8 | 12 | $5,116 | $6,395 | $30.00 | $37.50 | 0.8 | $124.05 |
| Macfarlanes Bath House Spring | 41.049 | -118.710 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| McCoy | 39.832 | -117.478 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| McGee Mountain | 41.815 | -118.850 | | 15 | B | 0.8 | 12 | $4,073 | $5,091 | $30.00 | $37.50 | 0.8 | $101.66 |
| McGinness Hills | 39.346 | -116.919 | | 25 | B | 0.8 | 20 | $4,020 | $5,025 | $25.00 | $31.25 | 0.8 | $93.14 |
| New York Canyon | 40.060 | -118.000 | | 25 | B | 0.8 | 20 | $4,218 | $5,273 | $25.00 | $31.25 | 0.8 | $97.40 |
| North Valley (incl. Black Warrior & Fireball Ridge) | 39.891 | -119.181 | | 35 | B | 0.8 | 28 | $3,534 | $4,418 | $25.00 | $31.25 | 0.8 | $82.71 |
| Pearl Hot Springs | 37.824 | -117.498 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Pinto Hot Springs | 41.360 | -118.800 | | 20 | B | 0.8 | 16 | $3,709 | $4,637 | $30.00 | $37.50 | 0.8 | $93.85 |
| Pirouette Mountain | 39.510 | -118.160 | | 20 | B | 0.8 | 16 | $3,652 | $4,565 | $30.00 | $37.50 | 0.8 | $92.61 |
| Preston Springs | 38.911 | -115.062 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Pumpernickel Valley | 40.768 | -117.479 | | 20 | B | 0.8 | 16 | $5,111 | $6,389 | $30.00 | $37.50 | 0.8 | $123.95 |
| Pyramid Lake Indian Reservation (aka The Needles) | 39.986 | -119.505 | | 20 | B | 0.8 | 16 | $4,660 | $5,825 | $30.00 | $37.50 | 0.8 | $114.26 |
| Reese River (aka Shoshone) | 39.899 | -117.150 | | 15 | B | 0.8 | 12 | $3,834 | $4,793 | $30.00 | $37.50 | 0.8 | $96.53 |
| Rhodes Marsh | 38.290 | -118.059 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Rose Creek | 40.859 | -117.940 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Rye Patch (incl. Humboldt House) | 40.535 | -118.268 | | 40 | B | 0.8 | 32 | $4,524 | $5,655 | $25.00 | $31.25 | 0.8 | $103.97 |
| Salt Wells | 39.307 | -118.575 | 18 | 70 | B | 0.8 | 56 | $3,464 | $4,331 | $22.00 | $27.50 | 0.8 | $76.79 |
| Silver Peak | 37.780 | -117.633 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Smith Creek Valley | 39.289 | -117.557 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Soda Lake | 39.567 | -118.850 | 23 | 15 | B | 0.8 | 12 | $3,025 | $3,782 | $30.00 | $37.50 | 0.8 | $79.16 |
| Sou Hot Springs (aka Seven Devils Springs) | 40.090 | -117.733 | | 15 | B | 0.8 | 12 | $5,047 | $6,309 | $30.00 | $37.50 | 0.8 | $122.58 |
| Spencer (aka MacLeod's Hot Springs) | 39.344 | -116.870 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Steamboat Hot Springs | 39.368 | -119.771 | 144 | 15 | B | 0.8 | 12 | $3,200 | $4,000 | $30.00 | $37.50 | 0.8 | $82.92 |
| Stillwater - Geothermal I & North Expansion | 39.530 | -118.546 | 47 | 25 | B | 0.8 | 20 | 4,020 | $5,025 | $25.00 | $31.25 | 0.8 | $93.14 |
| Sulphur Hot Springs (aka Ruby Valley) | 40.586 | -115.276 | | 15 | B | 0.8 | 12 | $4,800 | $6,000 | $30.00 | $37.50 | 0.8 | $117.27 |
| Teels Marsh | 38.194 | -118.300 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Tracy | 39.574 | -119.547 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Trego | 40.764 | -119.114 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Trinity Mountains | 40.000 | -118.990 | | 40 | B | 0.8 | 32 | $3,810 | $4,763 | $25.00 | $31.25 | 0.8 | $88.64 |
| Tungsten Mountain | 39.622 | -117.729 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Vigus Canyon | 39.596 | -116.887 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Wabuska | 39.164 | -119.178 | 2 | 10 | B | 0.8 | 8 | $6,962 | $8,703 | $30.00 | $37.50 | 0.8 | $163.71 |
| Walker Warm Springs | 38.414 | -118.989 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Warm Springs | 38.184 | -116.356 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Wedell Springs (aka Gabbs Valley) | 38.924 | -118.213 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Wells (aka Humboldt Wells) | 41.174 | -114.985 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Wilson Hot Springs (aka Barren Hills) | 38.806 | -119.177 | | 15 | B | 0.8 | 12 | $3,713 | $4,641 | $30.00 | $37.50 | 0.8 | $93.93 |
| **Oregon** | | | | | | | | | | | | | |
| Alvord Hot Springs | 42.544 | -118.533 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Borax Lake | 42.333 | -118.600 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Crump's Hot Springs | 42.226 | -119.881 | | 40 | B | 0.8 | 32 | $3,640 | $4,550 | $25.00 | $31.25 | 0.8 | $84.98 |
| Klamath Falls | 42.250 | -121.749 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Lakeview (includes Hot Lake area) | 42.193 | -120.348 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Mickey Hot Springs | 42.346 | -118.346 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Mt Hood (outside wilderness area) | 45.383 | -121.750 | | 50 | F | 0.9 | 45 | $3,800 | $4,222 | $25.00 | $27.78 | 0.9 | $67.19 |
| Mt Rose (near Roseburg, along I-5) | 43.236 | -123.322 | | 50 | F | 0.9 | 45 | $3,600 | $4,000 | $25.00 | $27.78 | 0.9 | $63.80 |
| Neal Hot Springs (incl. Vale) | 44.023 | -117.460 | | 30 | B | 0.8 | 24 | $3,870 | $4,838 | $25.00 | $31.25 | 0.8 | $89.92 |
| Newberry Caldera | 43.726 | -121.267 | | 200 | F | 0.9 | 180 | $3,600 | $4,000 | $25.00 | $27.78 | 0.9 | $63.80 |
| Summer Lake | 42.695 | -120.705 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Three Creeks Butte (15 mi NW of Bend) | 44.151 | -121.577 | | 20 | B | 0.8 | 16 | $4,320 | $5,400 | $30.00 | $37.50 | 0.8 | $106.97 |
| Three Sisters | 44.147 | -121.807 | | 50 | F | 0.9 | 45 | $3,800 | $4,222 | $25.00 | $27.78 | 0.9 | $67.19 |
| Trout Creek | 42.188 | -118.378 | | 10 | B | 0.8 | 8 | $5,400 | $6,750 | $30.00 | $37.50 | 0.8 | $130.16 |
| Warm Springs | 44.656 | -121.951 | | 50 | F | 0.9 | 45 | $3,600 | $4,000 | $25.00 | $27.78 | 0.9 | $63.80 |
| **Southern British Columbia** | | | | | | | | | | | | | |
| Harrison Hot Springs | 49.647 | -122.011 | | 20 | B | 0.8 | 16 | $4,680 | $5,850 | $30.00 | $37.50 | 0.8 | $114.70 |
| Kootenay | 49.937 | -116.995 | | 20 | B | 0.8 | 16 | $4,680 | $5,850 | $30.00 | $37.50 | 0.8 | $114.70 |
| Meager Creek / Pebble Creek | 50.918 | -123.774 | | 100 | F | 0.9 | 90 | $3,835 | $4,261 | $22.00 | $24.44 | 0.9 | $63.85 |
| Mt. Cayley | 50.396 | -123.707 | | 50 | F | 0.9 | 45 | $3,900 | $4,333 | $25.00 | $27.78 | 0.9 | $68.89 |
| Mt. Garibaldi | 49.882 | -123.237 | | 50 | F | 0.9 | 45 | $3,900 | $4,333 | $25.00 | $27.78 | 0.9 | $68.89 |
| Okanagan | 49.668 | -119.943 | | 20 | B | 0.8 | 16 | $4,680 | $5,850 | $30.00 | $37.50 | 0.8 | $114.70 |
| Upper Arrow | 50.454 | -117.906 | | 20 | B | 0.8 | 16 | $4,680 | $5,850 | $30.00 | $37.50 | 0.8 | $114.70 |

## References

Black & Veatch (2008). RETI Phase 1A Final Report. April 2008. http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-F.PDF

Black & Veatch (2009). RETI Phase 1B Final Report. January 2009. http://www.energy.ca.gov/2008publications/RETI-1000-2008-003/RETI-1000-2008-003-F.PDF

California Geothermal Energy Collaborative (2006). California Geothermal Fields and Existing Power Plants. Map and table. http://ciee.ucop.edu/geothermal/documents/FinalGeothermalFactSheetAndMap.pdf

Fairbank, B. D., and R. I. Faulkner (1992). Geothermal resources of British Columbia. Geological Survey of Canada, Open File 2526. Map, scale 1:2,000,000.

Geothermal Energy Association (Access date: May 2009). Information-Power Plants. http://www.geo-energy.org/information/plants.asp

GeothermEx (2004). New geothermal site identification and quantification. Report prepared for the Public Interest Energy Research (PIER) program of the California Energy Commission, April 2004. http://www.energy.ca.gov/pier/project_reports/500-04-051.html.

Gutierrez-Negrin, L.C.A., and J. L. Quijano-Leon (2005). Update of geothermics in Mexico. World Geothermal Congress, Antalya, Turkey. Paper No. 0102.

Nevada RETAAC (2007). Governor Jim Gibbons' Renewable Energy Transmission Access Advisory Committee Phase I Report, 31 December 2007. http://gov.state.nv.us/RETAAC-I/FinalReport.htm.

Shevenell, L., C. Morris, and D Blackwell (2008). Update on near-term geothermal potential in Nevada. Geothermal Resources Council Bulletin, Vol. 37, No. 3, May/June 2008, pp. 29-32.

Western Governors' Association, 2006. Geothermal Task Force Report, Clean and Diversified Energy Initiative. Table A-5. http://www.westgov.org/wga/initiatives/cdeac/Geothermal-full.pdf.

Williams, C. F., M. J. Reed, R. H. Mariner, J. DeAngelo, S. P. Galanis, Jr. (2008). Assessment of moderate- and high-temperature geothermal resources of the United States. USGS Fact Sheet 2008-3082.