The Economic Costs and Benefits of Geothermal Power

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Introduction

This paper examines current publically available research that assesses the economic costs and benefits of geothermal energy. GEA, as a matter of policy, does not utilize unpublished or proprietary information regarding power prices or bids. Utilizing published sources also ensures accuracy and fairness of the paper.

Also, it should be noted this paper is not intended to be a criticism of other sources of renewable energy technologies, which will certainly be an essential part of a diverse portfolio of electricity resources. However, this report is meant to be a frank and forward discussion on the costs of geothermal power and those costs and benefits relative to other technologies. To achieve this understanding, it's necessary to correct arguments that have misrepresented the costs of geothermal development.

An examination of recent studies published on the comparative costs of renewable technologies shows that geothermal power is an affordable renewable power resource. Its cost compares favorably with other technologies currently available according to three different analyses published in 2014.

When examining the costs of geothermal power, the most common resources available are analyses of the "levelized cost" of different technologies. This report looks at three recent reports, all published in 2014. The first is an analysis by U.S. Energy Information Agency, the second is the analysis by the

Bloomberg New Energy Finance and the last is a discussion on RPS costs and prices published by the California Public Utilities Commission.

All three of these reports reached the conclusion that geothermal power is fundamentally an economical choice for power. They each caution, however, that typically due to external or policy factors net prices may differ. The World Energy Council (WEC) and Bloomberg New Energy Finance (BNEF) note in their *World Energy Perspective* report, *"[Levelized Cost of Energy] demonstrate electricity generation costs only."*[1] LCOE's do not always represent or include all costs like costs of grid connection, balancing costs for integration of volatile and intermittent renewable energy resources, the costs of required back-up capacity based on conventional thermal plants, or occasional capacity shedding and other additional system costs the report notes.

LCOE's also exclude all subsidies and support mechanisms. According to WEC & BNEF, *"This facilitates a comparison of the total costs of each technology on an equal basis, but does not represent the net costs faced by developers in the market."*[2]

The difference between actual prices and levelized cost can be attributed to the additional market and system costs, as noted above, but also reflect contractual risks or liabilities, planning and permitting uncertainties, unexpected resource risks, actual versus planned project lead times, and other factors.

There are also substantial economic benefits to developing and producing power from geothermal resources that should be considered when examining the total cost. This paper also looks at some of the economic benefits of geothermal power based upon publicly available data. Geothermal power plants have numerous direct benefits including the tax revenues, induced investment they bring to the communities in which they operate, and new temporary and permanent jobs. While specific tax revenue figures are not published (reportedly to protect proprietary information), geothermal operators typically pay sales taxes, property taxes, mine taxes, business taxes, bonus bids, lease rental payments, royalties to federal, state and county governments, salaries and benefits to employees, and payments to a range of local vendors for products and services.

In the most recent year reported, 2013, $15 million was paid as royalties on federal leases which was distributed to federal, state and county governments. This revenue is one clear direct benefit of geothermal power production. In addition, geothermal production in western states may also involve state lands. For example, California state lands have generate over $4 million annually, and when leases involve school lands the revenues benefit the State Teachers' Retirement System (STRS).[3]

Another substantial positive impact on the local economy that can be estimated is the job creation that comes with geothermal power development. For every 100 MW of geothermal capacity 170 permanent jobs are created, and for new projects of the same capacity an additional 640 annual construction and manufacturing jobs are produced. Lastly, geothermal power can be engineered to provide both firm and flexible solutions to the changing U.S. power system, including, but not limited to, baseload, regulation, load following or energy imbalance, spinning reserve, non-spinning reserve, and replacement or supplemental reserve.[4]

Costs of Geothermal Power

Geothermal power is sometimes misconstrued to be an expensive source of electricity. While it is true geothermal power plants require a significant amount of start-up capital and some government assistance in the earliest phases of exploration, the overall capital costs and operating costs of geothermal power are significantly lower than many other technologies. When looking at the entire lifecycle of the plant, geothermal power is one of the most affordable and enduring technologies. Geothermal plants have no fuel costs, and minimal maintenance or ancillary costs. Once a plant is operating it can generate electricity for 30 years or longer if the field is engineered and maintained sustainably. This year the Geysers, one of the first geothermal fields in the world celebrated its 50th anniversary.

The total costs and values of geothermal energy are not always understood, which can lead to a misrepresentation of the true value of geothermal energy to the power market. A negative feedback loop occurs where cost competitive geothermal projects cannot win contracts because they are not valued fairly in the marketplace. For example, due the current methodology for estimating Least-Cost Best Fit in California, Investor Owned Utilities (IOUs) are required to use a zero value for integration costs. The result estimate of cost is an inaccurate Net Market Value for geothermal power, making other electricity sources appear to be more competitive when in truth they are more expensive.

Calculating the integrations costs, and thus addressing the total consumer cost of different energy options, is a very complex task. Few studies have approached this issue until recently. A new study released in January 2014 modeled the complex interactions between California's generating resources and reached notable conclusions. It determined that higher levels of geothermal power in the state will result in consumer benefits.

The E3 report, Investigating a Higher Renewable Portfolio Standard in California, published January 2014, modeled different future power mixes for California's Renewable Portfolio Standards (RPS) and found that integration costs were a "primary driver" of increased costs. E3 also found that the scenario with the most diversity and most geothermal had the lowest overall cost. "*The lowest-cost 50% RPS portfolio modeled here is one with a diversity of renewable resource technologies*."[5] It is fair to assume that the E3 conclusion could be more reflective of the actual outcome of expanding geothermal power in California.

If geothermal power is so economical why are there not projects generating power across the western United States? High upfront cost, risk of exploratory drilling, uneven policies and subsidies, and flat demand often keep projects stranded in early stages of development. However, when companies can obtain power purchase agreements to move projects forward, the economics should be quite favorable according to the recent studies this paper examines.

The following sections summarize the costs of geothermal power according to a number of third party sources.

U.S. Energy Information Administration

As part of the Annual Energy Outlook the Energy Information Administration collects and maintains information on the costs of many energy technologies. Their forecast outputs levelized cost for all energy technologies. Despite concerns that the levelized cost estimations for the 2014 Annual Energy Outlook might be too low, geothermal power was estimated to be the cheapest source of energy of all energy types entering service in 2019.

The U.S. Energy Information Administration's wrote in their latest Levelized Cost Analysis *"Geothermal cost data is site-specific, and the relatively large positive value for that technology results because there may be individual sites that are very cost competitive, leading to new builds, but there is a limited amount of capacity available at that cost."* California contains many of these cost competitive sites at geothermal fields where there is already extensive geothermal knowledge such as the Salton Sea, the Geysers, Coso Field, Medicine Lake, East Mesa and others.

EIA also depicts geothermal power as the only generation technology that has a Levelized Avoided Cost of Electricity (LACE)[*] greater than Levelized Cost of Electricity (LCOE) for the current 2014 forecast.[6†] EIA says "*the average net differences are negative for all technologies except geothermal, reflecting the fact that on average, new capacity is not needed in 2019*." Geothermal is the only technology competitive in a system that has too much capacity or flat demand for new power plants. It's important to note EIA's analysis includes the transmission and integration costs imposed by intermittent technologies.

Bloomberg New Energy Finance & Business Council for Sustainable Energy

When discussing the costs of new sources of electricity it's important to understand the larger context in which geothermal power is competing. Bloomberg New Energy Finance notes new environmental policies, and thinner profit margins due to less expensive gas, have prompted the retirement of 13.9GW of coal plants since January 2011. A further 32.5GW have announced their intention to retire.[7] The massive wholesale retirement of coal plants removes gigawatts of reliable baseload capacity from the grid. Some baseload power sources needs to be swapped out for the retiring coal facilities. Geothermal power is an emissions free baseload power source that can replace this retiring coal in the west.

The 2014 edition of the Sustainable Energy in America Factbook – published by the Business Council for Sustainable Energy and Bloomberg New Energy Finance (BNEF), provides up-to-date information about energy efficiency, renewable energy and natural gas.

BNEF collected PPA data for 33 utility-scale solar projects located primarily in the desert Southwest, revealing pricing mostly in the $100–150/MWh range. These projects signed PPAs between late 2008 and mid-2011.

[*] "The avoided cost [LACE, Levelized Avoided Cost] is divided by average annual output of the project to develop the "levelized" avoided cost of electricity (LACE). The LACE value may then be compared with the LCOE value . . . to provide an indication of whether or not the project's value exceeds its cost. If multiple technologies are available to meet load, comparisons of each project's LACE to its LCOE may be used to determine which project provides the best net economic value."

[†] LCOE represents the per-kilowatthour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.

The price of solar is falling and extremely competitive with other energy technologies in many places, however these low costs are often due to government subsides. Bloomberg found in the same report, "*Intense competition for solar PPAs, along with declining system costs, has since caused solar rates to plummet. Solar PPAs for 2015-16 delivery are now being signed in the mid-to-high $60/MWh range. One project, First Solar's 59MW Macho Springs project, expected to be commissioned in 2014, signed a PPA for $57.90/MWh (it should be noted that this project benefits from New Mexico state tax incentives, which add another $28/MWh, on average, over the first 10 years of the project.)*"

The two monumental changes impacting how the US generates electricity, the retirement of a significant amount of baseload coal, and the addition of intermittent, clean, electricity sources, such as solar and wind raise concerns of some electricity market regulators about future grid reliability. The growing role of renewables potentially raises questions about the grid's vulnerability.

"*At sufficiently high levels of penetration, renewables create other challenges as well, including producing excess energy at some hours (such as during windy nights in Texas) and lower wholesale power prices, since these technologies tend to boast very low short-run marginal costs. Lower wholesale prices damage the economics for other sources of generation. Compensation for the reliability offered by firm sources – eg, via capacity payments – mitigates this effect somewhat.*"[8]

BNEF noted in its 2014 report that project capital costs for geothermal plants *"can vary significantly depending on site-specific characteristics."* For example, the specialty metals necessary to build a flash plant at the Salton Sea Geothermal Resource area to control the corrosive geothermal brines can be more expensive to build.

BNEF continues to say, *"large flash projects are usually – but not always – cheaper than binary projects. On a global basis, capex [capital expense] averaged about $2.65m/MW for flash and $5.18m/MW for binary projects over 2011-13. In the US, flash project capex has been higher in recent years (one project was built in 2012 at $8m/MW), but this may be due more to the specifics of the sites where flash projects are built, rather than due to the technology being fundamentally more expensive."*[9]

According to BNEF statistics, projects globally fall within a levelized cost range of $63-97/MWh. "*The LCOE for geothermal is often near the lower end of the spectrum when compared to other renewable technologies*". The economics of geothermal plants is greatly affected by resource characteristics such as temperature, flow rate, and depth, as well as drill rig availability and plant cost.

Lastly, flash plants costs continue to fall, owing largely to increased competition in the turbine and EPC supply markets. In 2012, steam turbine contracts (with turnkey EPC included) averaged $1.4–1.5m/MW; by comparison, before the global financial crisis, the all-in sum averaged $2m/MW. The turbine and generator account for about 25% of the cost, with the remaining 75% going to construction and the rest of the equipment – the cuts have been largely in this latter portion.[10]

California Public Utilities Commission's Analysis of Geothermal Costs

Section 910 requires the California Public Utilities Commission to provide an annual report to the Legislature on investor-owned utilities (IOUs) direct and indirect costs and costs avoided (savings) with the RPS program. Since most of the geothermal power in the U.S. is located in California, this report is a great indicator of the cost of geothermal power relative to other technologies. Also note, the past two years geothermal power has been a significant portion of California's utilities renewable resources. In 2012, the utilities' RPS portfolios (in dollar terms) were primarily comprised of wind (40 percent) and geothermal (30 percent) resources, followed by biomass (14 percent). In 2013, the large IOUs' RPS portfolios (in dollar terms) were primarily comprised of wind (41 percent) and geothermal (25 percent) resources, followed by solar PV (19 percent).[11]

Large IOU RPS Costs (cents per kWh) for 2013				
	PG&E	*SCE*	*SDG&E*	*Average*
Biogas	5.94	6.82	7.93	6.98
Biomass	9.73	-	9.25	9.67
Geothermal	7.19	6.75	Confidential	7.03
Small Hydro	8.72	8.91	5.30	8.66
Solar PV	15.18	11.90	10.39	13.96
Solar Thermal	14.23	13.48	-	13.52
Wind	8.40	9.77	6.10	8.68
UOG Small Hydro	4.60	12.38	-	5.71
UOG Solar PV	16.21	47.00	-	21.65

Source: Section 910, CPUC

Besides utility owned small hydro power plants geothermal power ranks second in lowest RPS costs on average in the state of California. Most technologies are a full cent per kWh more expensive in California's current system.

Further CPUC support for this analysis would be The Padilla Report to the Legislature which was released after it was discovered that the IOU self-reported data presented in the 2003 - 2011 report had errors in how they compared technologies. When comparing "Average RPS Procurement Expenditures"[‡] in ($/kWh) using the report's adjusted generation weighted averages, the price of geothermal power ranged between 5.4 cents and 8.8 cents per kWh between 2003 and 2013. While over the same period the "Average Price of Contracts Approved"[§] ranged from 5.3 cents to 11.4 cents per kWh. [12]

For comparison from 2003 to 2013, the Average RPS Procurement Expenditures for Solar PV ranged from 6 cents to 18 cents per kWh and the Average Price of Contracts Approved ranged from 3.7 cents to 22 cents per kWh.

While RFOs were not awarded to geothermal plants in recent years, the current methodology used to evaluate bids in the RPS solicitation represents a market failure. According to CPUC's records of most recent renewable requests for offers (RFOs), including the 2012 RPS RFO and the renewable auction mechanism (RAM) 4, PG&E awarded 12 intermittent projects, SCE has awarded 11 intermittent, and SDG&E have awarded 6 intermittent projects (2 are bilateral negotiations), and all with no geothermal procured. Geothermal power won zero contracts even though according to the U.S. Energy Information

[‡]"Average RPS Procurement Expenditures" is the total, weighted average payments made to renewable generators for that year.
[§]"Average Price of Contracts Approved" includes all CPUC approved contracts except contracts that were subsequently terminated. Specifically, it includes facilities that are operating or in development.

Agency (EIA), Bloomberg, and CPUC estimates geothermal plants to have one of the lowest levelized costs when compared to other energy technologies when some costs estimates don't even factor integration costs. Procurement is not resulting in the best mix of resources, and instead favors a higher mix of variable energy resources due to improper valuation of power attributes and lack of defined integration costs.

Another area of inconsistency in the Californian market is the valuation of technologies under the RAM program. The RAM program has substantially benefited renewable energy projects. However, in the future it will be absolutely necessary to level the playing field so base-load resources are fairly valued under the program. Baseload projects do not require costly integration services necessary of variable energy resources; however intermittent projects are disproportionately chosen by RAM structure.[13]

Economic Benefits of Geothermal Power

Despite the many environmental benefits associated with geothermal plants like the reduction of carbon emissions and environmental pollution, there are numerous direct economic benefits. About half of geothermal plants operate on public lands generating revenue for state, municipal and federal governments. Geothermal plants employ a vast diversity of workers from conception to completion. Lastly, they can be engineered to be a firm or flexible power source.

Royalties, Property Tax & Rent Revenues

Geothermal power has some direct, financial benefits that are not typical of other renewable technologies. Unlike wind and solar, geothermal plants pay federal and state royalties and significantly more property taxes, generating revenue in rural counties where these plants operate. Industrial solar is exempt from taxes and displacing tax bases in these communities. According to the Federal BLM, in 2013 they oversaw geothermal "*production 818 geothermal leases, with 59 geothermal leases in producing status, with a total capacity of 1,500 megawatts of geothermal energy on public lands. This amounts to over 40 percent of U.S. geothermal energy capacity and supplies the electrical needs of about 1.5 million homes.*"[14]

In addition geothermal resources are competitively lease. "*Competitive lease sales since 2007 have netted over $76 million in bonus bids for geothermal lease parcels in Colorado, Idaho, Oregon, Utah, Nevada, and California*."[15]

The Department of the Interior's Office of Natural Resources reports that geothermal power in 2013 produced about $15 million in royalties and rents in 2013 alone from federal lands used for geothermal production.[16] Also, state lands generate additional revenues from geothermal development. Most western states received grants of federal land when they became states. These land grants were given to the states to generate income for public education and other state programs. States are required by law to use school trust lands for those purposes. The California State Lands Commission reports in 2011 annual geothermal royalty revenues over $4 million and a cumulative total since 1972 of $188 million.[17]

Employment

Geothermal resources tend to be located in rural areas and require local workforce support. For example, of the staff employed directly by one company at the Geysers Geothermal Complex in California, 425 full-time and 225 part-time employees are residents of the local community.[18]

In addition, the geothermal industry provides about 1.7 jobs per MW of power production capacity for power plant operation and maintenance and other geothermal development like research, consulting, legal and government regulators.

Temporary jobs in the manufacturing and construction sectors are also created by geothermal power plants. A construction workforce of 3.1 jobs per MW installed (including well drilling) and manufacturing of power plant equipment involves 3.3 jobs per MW for developing both flash and binary plant power facilities.[19]

Lastly, geothermal power plants require a variety of jobs skills, training, and education. This list includes but is not limited to: welders; mechanics; pipe fitters; plumbers; machinists; electricians; carpenters; construction and drilling equipment operators; surveyors; architects and designers; geologists; hydrologists; electrical, mechanical, and structural engineers; HVAC technicians; food processing specialists; aquaculture and horticulture specialists; managers; attorneys; regulatory and environmental consultants; accountants; computer technicians; researchers; and government employees who all play an important role in bringing geothermal energy online.

Reliable Energy Source

As mentioned earlier in this paper, geothermal power can be engineered to provide both firm and flexible solutions to the changing U.S. power system, including, but not limited to, baseload, regulation, load following or energy imbalance, spinning reserve, non-spinning reserve, and replacement or supplemental reserve. It is well known that geothermal plants can operate 24 hours a day with a steady output, regardless of environmental conditions, and are not subject to the unpredictability and voltage swings that variable energy resources face and, hence, can fulfill the necessary role as a renewable baseload power source in the western United States. As aging baseload fossil fuel plants retire, geothermal plants can provide the electricity these plants have historically provided to the power system. Baseload technologies provide important attributes for grid stability including inertia, voltage control, capacity, and in geothermal power's case flexibility.

This combination of firm and flexible power capability positions geothermal energy as an ideal candidate to fill several roles historically performed by emission-heavy fossil fuels, such as baseload, regulation, load-following, and reserve functions. In addition to considerable environmental advantages over fossil fuels, geothermal plants generally lack the fuel costs of other baseload sources, or the ancillary and transmission costs associated with variable energy resources that often equate to the long-term stability in energy costs.[20]

And because of its baseload characteristics, every additional megawatt of geothermal power nay enable the installation of 3 to 5 megawatts of additional intermittent power like solar and wind on the grid.[21]

Often in the United States, where geothermal resources are found, the lack of development is not because of economic barriers (such as too-expensive technology), but it is instead a structural, political, or policy barrier that prevents development.

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[1] See World Energy Council and Bloomberg New Energy Finance's "*World Energy Perspective: Cost of Energy Technologies*" Page 5.
[2] *Ibid.* Page 7
[3] http://www.slc.ca.gov/division_pages/mrm/Program_Project_and_Updates/Geothermal%20Program/Geothermal%20PDFs/01%20-%20Geoth%20Program%20Factsheet.pdf
[4] See Geothermal Energy Association's "*The Values of Geothermal Energy*" by Benjamin Matek and Brian Schmidt
[5] See E3's report "*Investigating a Higher Renewable Portfolio Standard in California*"
[6] See Energy Information Administration's "*Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014*"
[7] See Bloomberg New Energy Finance and Business Council for Sustainable Energy's "*The Sustainable Energy in America Factbook.*"
[8] *Ibid.* Page 120
[9] *Ibid.* Page 53
[10] *Ibid.* Page 53-54
[11] See California Public Utility Commission's 2014 report "*Report to the Legislature in Compliance with Public Utilities Code Section 910*" and 2013 edition "*Report to the Legislature in Compliance with Public Utilities Code Section 910*"
[12] See California Public Utility Commission's 2014 report "*The Padilla Report to the Legislature the Costs of Renewables in Compliance with Senate Bill 836*" and the 2013 edition "*The Padilla Report to the Legislature the Costs of Renewable in Compliance with Senate Bill 836.*"
[13] See Ormat Technologies' "*Comments of Ormat Technologies, Inc. In Response to Administrative Law Judge's Ruling Requesting Comments on the Renewable Auction Mechanism*" from January 30th, 2014
[14] See Bureau of Land Management's "*Renewable Energy: Geothermal*" factsheet.
[15] *Ibid.* Page 1
[16] See Office of Natural Resources' "*Office of Natural Resources Revenue: Statistical Information*."
[17] http://www.slc.ca.gov/division_pages/mrm/Program_Project_and_Updates/Geothermal%20Program/Geothermal%20PDFs/02%20-%20Geoth%20Program%20Presentation.pdf
[18] See Geothermal Energy Association's "*Green Jobs through Geothermal Energy*" written by Dan Jennejohn.
[19] See Geothermal Resources Council Transactions "*Employment Involved in the US Geothermal Industry*" written by C. Nathanael Hance.
[20] See Aspen Environmental Group's "*The Value of Geothermal Energy Generation Attributes: Aspen Report to Ormat Technologies*" written by Carl Linvill, John Candelaria, and Catherine Elder.
[21] See North Bay Business Journal's article "*The Geysers powers SCP's 'Evergreen' option*" by Woody Hastings.