Geothermal Insights III:
Visions and values for the future

This article was [originally published](#) September 19, 2017 on LinkedIn.

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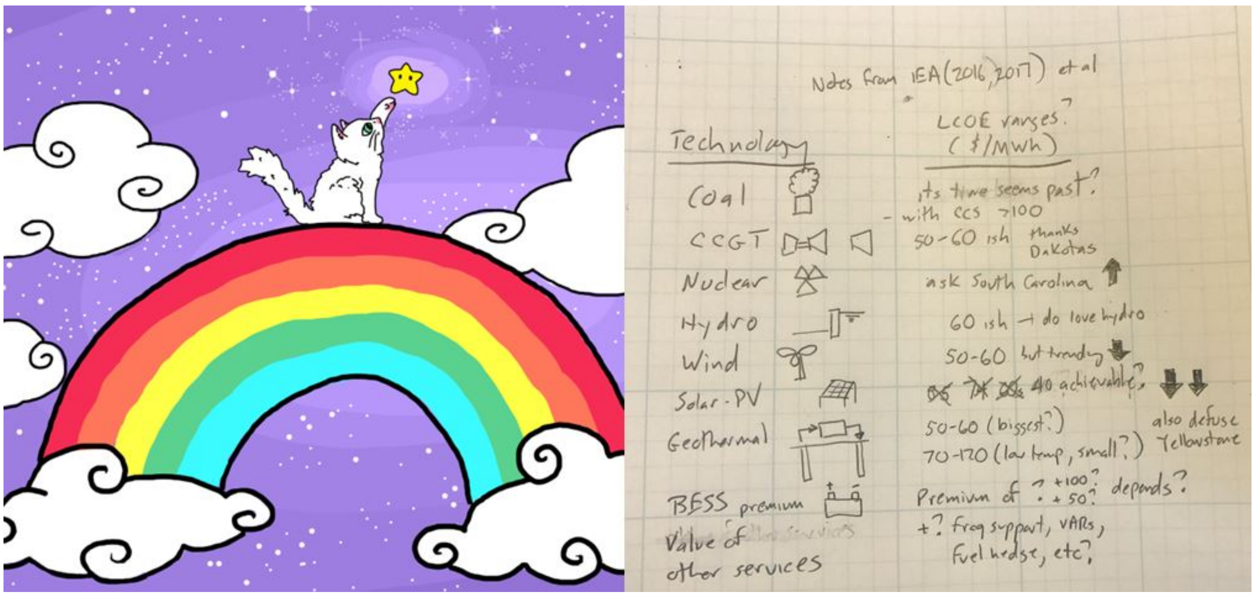


It's all kittens and rainbows until someone slogs through some numbers (Source: Sketchport)

This is the third in a three-part series discussing the trajectory of the geothermal industry: past, present and future. It is written from my perspective working at POWER Engineers, and draws on our company's history of engagements in the surface facility aspects of geothermal projects. It spans conceptual design and feasibility studies, detailed flash and binary plant design, monitoring of projects as an owner's engineer, and performing independent engineering for lenders.

The [first installment](#) was a retrospective: how have things changed from 1997 to 2017? What major trends are evident?

The [second installment](#) addressed the life of people engaged in this industry. What are geothermal projects like? Why do we enjoy this work?

This third installment is speculation about the future of the industry. How does geothermal stack up against other conventional or renewable power generation options? How can our industry continue to contribute and be competitive in the coming years?

After some disclaimers, we will step through current market conditions for baseload and intermittent generation types, reinforce the need for geothermal to effectively communicate their "full-spectrum" value propositions, and provide some speculation on the evolution of developments in different regions.

It's difficult to make predictions

…especially about the future. Better yet, predictions made in writing stand as enduring testaments, for months or years, to one's inability to make them accurately. The ones made here likely will be no different. Then again, being wrong a couple times a day before the second cup of tea should be commonplace; only people doing nothing make no false steps. So the objective here is not accuracy per se, but rather to help generate creative solutions to the constantly changing technical and market conditions in the general power industry.

The second hazard with attempts at soothsaying is that people may think the visions are too rosy or gloomy. To mitigate that, projections should at least have as a point of departure solid current data trends. Thus, we'll have to dive back into the past and present a bit to plot these trajectories.

State of LCOE

The first installment of this series talked a bit about levelized costs of electricity (LCOE) from geothermal, and how these have been drifting lower over the past decades. They are highly sensitive to site specifics, project size and financial intricacies, and currently may range from around 50 to over 100 $/MWh for new plants. Of this, perhaps some 15-30 $/MWh might be simply operations and maintenance costs, that even a fully paid-for facility would incur.

The costs of competing generation technologies such as wind and solar photovoltaics (PV) and their associated LCOEs, if in favorable locations, are changing so rapidly it is difficult to find and present information in the public domain that is not already a year or two old. Given the pace of current developments in those technologies, projections from 6-12 months ago may already be 10-20% out of date, which can be the difference between a feasible or infeasible project. However, there is a clear and impressive trend for solar PV and wind costs over the past few years that position them as formidable competitors to every power generation technology, including geothermal. Consider the following headlines over the past several years just in the PV market:

- 2014: Dubai Shatters Solar Price Records Worldwide – Lowest Ever! Developers bid as low as 60 $/MWh for a solar PV project in Dubai (Upadhyay 2014)
- 2015: Average Utility-Scale Solar Price in U.S. Falls to 5c/kWh [50 $/MWH] (Markham 2015)
- 2016: The Price of Solar is Declining to Unprecedented Lows (Fares 2016). The article describes installed costs falling by 12% in 2015, and PPAs coming in under 50 $/MWh.

The 2016 study, "Utility-scale solar: the path to high-value, cost-competitive projects" by SEPA shows LCOE as a function of capacity factors and panel prices with more conservative values than those shown above. Using data from that report, if you have a decently sunny, dry climate like we have in Idaho, with a capacity factor around 25-30%, and a project size comparable to a geothermal plant (say 20 MW), solar LCOEs within 60-70 $/MWh seem achievable, depending on panel prices.

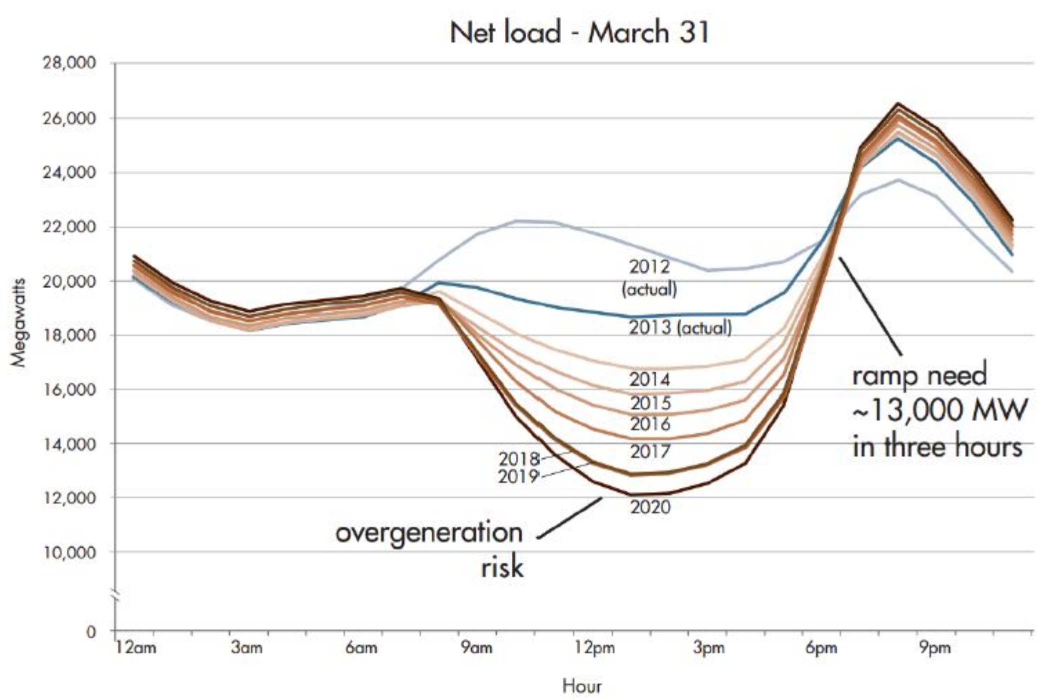
To be frank, surface facility capital costs of geothermal, while gradually declining, are not improving as dramatically as PV panel or wind turbine prices have over the past several years. The avenue for more profound improvements in geothermal LCOE probably lie more in advances in exploration and drilling (perhaps 30-50% of total project costs), via advances in the black arts of the geosciences. Barring dramatic breakthroughs however, it will be daunting to keep pace with solar and wind LCOEs, in areas favorable to those.

Large markets naturally attract big money, research and government support, and recognize significant economies of scale. According to a U.S. Solar Market Insight briefing from September 2017, the U.S. market installed 2,387 MW(dc) of PV in the second quarter of 2017 alone. Contrast this to the geothermal market in 2015, which marked a total capacity increase of 313 MW for the entire year, throughout the world (GEA, 2016).

The geothermal industry faces the fact that if we are competing for projects solely on a raw $/MWh basis without other considerations, then competition in regions where there are favorable wind and solar conditions is extremely fierce. We are seeing that currently in the southwestern U.S., where it is challenging (albeit not impossible) to obtain PPAs at rates suitable to make new geothermal projects feasible. Geothermal cannot rely on a blanket exemption from competing in the same market conditions that other options such as coal, natural gas, diesel or nuclear must face; one can bear witness to the slowdown in coal in the U.S. as one double-edged cautionary tale. We must adapt, and swiftly.

Baseload Power - Are We the Only Renewable Show in Town?

We see that geothermal is in a knife fight with other generation types just based on LCOE, and can still fare well at selected locations, today. But LCOE should not be the whole story, and geothermal advocates often point to the high capacity factors and relative insensitivities to diurnal or environmental variations that geothermal has, touting its baseload power capability. Does that deserve a premium? Well, it depends on the entities managing the power grid, and their plans for managing the integration of intermittent resources such as solar and wind with baseload/dispatchable resources such as hydro, fossil, biomass or geothermal. If the penetration of intermittent renewables is high, then the dispatchable resources must ramp up or down rapidly during periods such as dawn or dusk.



The infamous duck curve (NREL 2015)

Now intermittent renewables have yet another ally: battery energy storage systems (BESS). BESS costs are also changing so rapidly it is hard to keep pace with data, and their economics depend on the profile of the loads to be dealt with. However, we can consider a few data points from the recent past:

- Lazard (2015) provided an analysis of LCOE for storage types, and for BESS using lithium-ion batteries for peaker replacement, these were in the range of 321-658 $/MWh. That's a significant premium; so at the time, saying "well, just couple a BESS with solar and it is baseload" might not make it competitive with other true baseload generation types, including geothermal.
- Lazard then provided a 2016 update estimating the lithium-ion BESS peaker replacements LCOEs being in the range of 285-581 $/MWh. The intent here is not to focus on the absolute numbers, but just consider the estimated LCOE premium reduction - perhaps over 10% in one year.
- Those studies are still several years old, and we have seen how rapidly conditions change. So now take an update from the SEPA 2017 Utility Energy Storage Market Snapshot, showing projects where solar and BESS (note: with only several hours of storage) were coupled for PPA pricing ranging from <45 $/MWh in Arizona to 139 $/MWh in Hawaii.

At present it appears the LCOE of baseload geothemal can still be less than the LCOE of a (solar+BESS), if there is appropriate value put on baseload power. Just from a technical perspective, one might prefer a market where appropriate pricing signals allowed consumers to shift demand, or dispatch generation types to conserve fuels, rather than cycle a BESS and incur the modest charge/discharge losses and degradation. However, it appears that BESS costs are falling swiftly, and geothermal may or may not be always able to count on a permanent persistent competitive advantage by playing the "baseload" trump card, again in regions where wind and solar are very competitive. We have to find the markets where this baseload value is recognized and quantified.

Another touted virtue of geothermal or other conventional plants with synchronous generators is that they can offer stability to the grid, through their mass inertia and the ability to provide reactive power of a synchronous generator. Well, guess what? Smarter inverters backed by a BESS are now able to provide reactive power and frequency support, reducing that competitive advantage. Can they do it as well, as inexpensively and reliably, over the life of the plant? I will not address that here, but that capability is another example of a differentiator that is slowly being eroded.

Bottom line is, the analysis and valuation of the potential benefits to the grid via baseload geothermal generation versus intermittent renewables and those coupled with BESS will need to be detailed and highlighted to the decision makers in most settings in order to draw out what those values are, and to evaluate whether geothermal still provides an enduring competitive advantage. To further the cause of geothermal, Colin Powell has some advice for us about Resource Parks.

Colin Powell and Resource Parks

Colin Powell is a respected U.S. military and political figure (moderate like Eisenhower; which seems like a fading virtue today) that had several principles regarding intelligent deliberations to take in a conflict, collected into a "doctrine" by journalists. There are a set of these steps, but an underlying theme of the overall doctrine was that one should exhaust every avenue and use every tool available at one's disposal to achieve an objective. Geothermal is in a tough scrap now. We see that the period where it took little effort to defend and promote geothermal as the lowest $/MWh renewable electrical generation alternative may be drawing to a close. In order to advance these projects in the future, one will need to take a full-spectrum approach in promoting and harnessing every value stream that makes sense into the design of the facilities.

This strategy applied to geothermal is best exemplified by Albertsson and Jonsson (2010). They suggest viewing a geothermal project as a Resource Park that contributes "integrated usages of a variety of subjective and objective resources of different natures." Iceland provides great examples of the integration of these principles, and it's a pity value-added features such as those described in the next section have seen slower penetration into the U.S. market, given that we have such excellent historical precedents such as hundred year old district heating and pioneering binary systems in Idaho and the cogeneration facilities at the Geo-Heat Center in Oregon, to name just a few. That kind of momentum needs to be reestablished.

For our industry such consideration of wider contributions a geothermal project can provide can no longer be a question of "feeling good". Rather, we in development must better quantify these benefits and harness every available tool to increase the chances of competing with other generation sources. What are some of these values?

Geothermal Values

Let's pan out from the narrow vision of a geothermal project as an electrical power generation facility competing just on that basis with other electrical generation types. Wind turbine or PV panels produce electricity and little else, including few jobs after construction. As mentioned in the second installment of this series however, a geothermal plant is essentially a liquids, gas, and solids processing facility that, oh by the way, can produce electric power. If we seek to offer the maximum benefit from the project across those various dimensions, a selected description of only a few of these other values that other generation types may not provide might be as follows.

Liquids - Thermal Power: Delivering hot water to nearby communities for district heating or industrial facilities for thermal-energy intensive processes. For some reason, this application seems systematically undervalued by policy makers despite (or due to) its simplicity, considering its effectiveness. Consider a low-temperature geothermal project in a region where heating is otherwise provided via coal or natural gas. Why provide low grade thermal energy from the highest grade source (fossil, often imported), rather than from the lower grade source (geothermal, indigenous)? Think of geothermal as "liberating" your fossil fuels for more appropriate usage (or non-importation). This is well exemplified by flexible cogeneration facilities such as those in Iceland and Bavaria. It may not be as easily transmittable but there is profit potential here; at some projects such as Nesjavellir, the thermal power contributes over 20% to total revenue from a plant (Reykjavik Energy 2013). This thermal output can then be delivered for hundreds of years.

The Underworld - Plutonic thermal contributions to Turkey for over two millennia

Want to know more? Check out [Displaced Exergy: The Valuation of Thermal Power]

Liquids - Receiving and Delivering Water: The Geysers project in the U.S., facing a dire decline in reservoir fluids and pressure in the 1990s, developed a system that takes over 75,000 cubic meters per day of waste water from nearby communities and injects it into the reservoir. While much of the deserved attention on that project would be on its success in arresting reservoir decline, another factor to consider is how a project might add value by helping a community treat, dispose of, or otherwise process waste streams. In some settings a plant design can recover a stream of relatively clean condensed steam that could be used for other purposes where surface water is scarce.

Gases - Capture and Transformation: Depending on the cycle configuration, geothermal plants can have zero or some non-condensable gas emissions such as carbon dioxide, hydrogen sulfide, hydrogen, methane or others. These are generally minute compared to coal units on a ton per MWh basis. If there is a market opportunity, these gases can be partitioned, captured and transformed. Facilities in Iceland, Kenya, Turkey and New Zealand capture carbon dioxide for industrial or agricultural purposes. The Carbon Recycling International plant adjacent to the Svartsengi Resource Park in Iceland captures gases and uses low cost electricity to synthesize these into over five million liters of liquid fuel per year.

Solids Recovery or Processing: Solids from geothermal fluids can be mined for commercial or industrial applications, such as solid sulfur from the Geysers used for fertilizer, or silica and algaes grown using warm water with carbon dioxide enrichment, such as at the Blue Lagoon. Valuable metals such as zinc or lithium may be harvested from mineral-rich wells such as at the Salton Sea, although based on past projects this seems like a challenging technical feat.

General Capacity Harvesting via Colocation: A geothermal project has several other essential attributes - land, transmission and people. These can be "harvested" in creative commercial or technical ways.

One of the most obvious is that geothermal delivers an ongoing stream of revenue to the community via employment for operations and maintenance staff and local contractors; for better or worse, solar PV and wind employ fewer people during operations for the life of the plant. O&M costs should not be regarded as a "black hole" in LCOE but rather an investment stream that passes through to families in the community (as well as some returned via taxation).

Geothermal conserves land compared to other generation types; a geothermal project might deliver 20x the MWh annually per unit area compared to solar PV. A geothermal project is also a relatively secure facility with existing electrical interconnections and a knowledgeable operations staff. Space available at a project could be considered for colocation of other facilities, such as:

- hybrid solar-geothermal, such as Stillwater and Patua in the U.S.,
- hybrid biomass-geothermal, such as Honey Lake in the U.S. and Cornia 2 in Italy,
- thermal energy-intensive industrial facilities, BESS or other complementary uses.

Patua geothermal plant with 10 MW solar PV field (ThinkGeoEnergy 2017)

When one considers that land, permitting, and interconnection costs for stand-alone facilities might come to some 10-15% of project costs, then leveraging the values of a geothermal project via co-location can offer generous boosts to rates of return.

Visions by Region or Application

So how do we combine the rather sober outlook on $/MWh LCOEs and competition with the other promising value opportunities geothermal offers, over the next decade or so? Here are my projections:

1. Geothermal LCOE can still have a competitive advantage over solar and wind in various settings, but the advantage is narrowing, especially if there is no premium placed on baseload generation. While there will continue to be modest advances and reductions in costs in surface facility technologies as we have seen over the past decades, the most significant reductions in geothermal LCOE will come through improvements in exploration and drilling

technologies. Technologies developed through research projects such as FORGE or the IDDP will assist in that regard even for conventional hydrothermal projects.

2. Having said that, LCOE is not the whole story, and the approach to decision makers must not be simply "what is the cost," but rather "what are the values," in order for geothermal to stay competitive. Grid operators will need to develop more complex and realistic pricing and PPA structures. Engineers and developers will need to be prepared to illustrate and quantify these richer values of a project, and consider more "side hustles".

3. Where large quantities of clean, high capacity factor electricity are sorely needed, and extensive and energetic geothermal resources are available (e.g. Africa, Central America, Indonesia, Philippines, Turkey), then geothermal baseload electrical generation projects will continue to be added in sizeable 20-70+ MW increments. It is a bit puzzling that many of the existing flash plants in those regions do not already incorporate colocation of more "bottoming binary" plants that harvest additional energy from still-hot spent fluid, and advances in geochemistry assessments and mineral scale deposition prevention make this increasingly economical. Therefore, following large capacity additions, owners will apply a layered "Bob Ross Painting" technique, adding subsequent increments of value via retrofits to existing plants.

4. Where load growth is modest (or flat) and competition is fierce from other generation types, such as in Europe, New Zealand and the U.S., the most successful new projects will need to strive to creatively incorporate more value streams than simply electricity. In the "if you can't beat 'em, join 'em" philosophy, multiple generation types and grid services such as BESS will be co-mingled at geothermal sites. As electricity LCOEs in a country drop, energy-intensive industries should prosper, and if these have significant thermal demands, they may be well suited to be colocated at geothermal facilities.

5. For relatively high latitude regions with considerable thermal demands such as Alaska, Canada, China, Eastern Europe and Russia, district heating or flexible cogeneration facilities will be especially important to conserve other fuel sources for more valuable purposes. In some situations it might be argued that geothermal energy is "too valuable to be used to generate electricity."

6. Isolated areas or island nations with high imported fossil fuel and electricity costs may primarily see in the short term incremental capacity additions of wind or solar PV. This will continue up to the points where BESS and/or baseload geothermal will be needed for deeper renewable penetrations. If weather events continue to be so prevalent and severe as they have been here in late 2017, there may be increasing value placed on having a diverse set of generation types, versus a monoculture. Once electricity costs drop, these regions will be especially prime for electric vehicles to rapidly become more prevalent, and this will induce a feedback loop to spur additional load growth. Geothermal plants in this context might be regarded as island "fuel farms," even capable of providing liquid fuels for larger trucks, construction equipment or fishing vessels.

Summary

This series of articles has provided a retrospective of the progress of the geothermal industry in the past decades, described the appeal of the work, and offered a semi-quantitative view of current market forces, with projections of how geothermal projects can deliver positive contributions for decades to their communities. In a particular setting your numbers will differ from what I've outlined here, but hopefully these descriptions capture the broad strokes and major trends.

Ideally, all those engaged in renewable energy fields continue their strong efforts that have resulted in such great strides of late. As I tell many students in class or young engineers at talks, these past few years have been some of the most "energizing" when looking at the pace of change and positive developments, and the energy industries offer them and their societies a bright future.

About the Author

William Harvey, P.E. is a project engineer and a Ph.D. in Mechanical Engineering specializing in renewable energy projects, principally geothermal. His background includes design, commissioning and operating experience in mechanical, nuclear, chemical, and electrical power plant aspects. With POWER Engineers, he has served in all project phases for flash and binary geothermal plants, including projects commissioned in the Americas, Africa, Turkey and Asia. His roles span detailed design, owner’s engineering and independent engineering. Dr. Harvey has delivered training for industrial clients and organizations such as the Electric Power Research Institute, the Geothermal Resources Council, Kenya Electricity Generating Company, Costa Rica’s Instituto Costarricense de Electricidad, the Iceland School of Energy at Reykjavik University, and the International Finance Corporation, among many others. He writes and lectures extensively on geothermal and renewable energy topics. He tries to maintain a personal blog on semi-random engineering and renewable energy career topics at www.badgercrossroads.com. He is a contributing author for the textbook Geothermal Power Generation: Developments and Innovation (2016).

Please note that the opinions expressed in these posts are my own and not necessarily those of my employer.

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