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Chuck Gentry
California Energy Commission
Sacramento, California
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RE: Comments: Geothermal Workshop

Dear Mr. Gentry:

Thank you to the CEC for the opportunity to provide comments and input to the CEC's geothermal research funding planning. Western GeoPower ("WGP") is developing a steam power plant at the Geysers, which is expected to come on-line in 2018, and as such has a particular interest in the ongoing discussions of flexible geothermal power plant operations and funding options for next-generation geothermal power development. WGP's parent company, U.S. Geothermal Inc. ("USGeo") also owns and operates three binary power plants in Idaho, Nevada, and Oregon. Understanding the cost structure and operating parameters of these plants can help better inform the discussion of flexible operations.

In this letter, there are five parts:

1) Summary of results and conclusions
2) Geothermal Power Plant Flexibility via Curtailment of Output
3) Geothermal Power Plant Flexibility via Output Increases
4) USGeo response to the CEC workshop panelist questions.
5) USGeo comments on information presented at the workshop.

Part 1: Summary of Key Points

The summary and conclusions reached in each Section are as follows:

Part 2: Flexibility Through Curtailment

Current discussion about geothermal flexibility focus on curtailment strategies, including AGC (Automatic Generation Control). Observations and conclusions about this strategy are:

1. Flexibility be achieved at most geothermal power plants at low additional capital cost.
2. The cost of a geothermal plant is ~95% fixed, and only ~5% variable. Therefore a curtailment would require at least 95% of the all-energy price of current PPAs just to provide an economic break-even proposition.
3. The break-even price for curtailment flexibility for most geothermal plants will be in the range of $59 to $86 per MWh of curtailment, but are as high as $95/MWh at USGeo's binary plants.
4. Curtailment of fossil plants can produce up to three times the generation reduction for the same

price as would be possible by curtailing USGeo's existing geothermal binary power plants.

5. Fossil plant curtailments eliminate the CO_2 emissions while there is essentially no grid emissions reductions when geothermal plant curtailments occur.
6. Physics and thermodynamics dictate that curtailments of geothermal plants inherently and universally decreases conversion efficiency, and therefore wastes geothermal energy.

Part 3: Flexibility Through Increased Generation

While flexibility curtailment will increase costs for ratepayers, flexibility through increased generation has the potential to lower costs. The CEC RFP could be broadened to solicit proposals for addressing the duck curve, and the baseload pond on which the duck is floating such as;

1. Methods to improve targeting of geothermal exploration and production wells.
2. Integrating geothermal with other technologies, including solar thermal, biomass, and gas.
3. The water/energy nexus around geothermal power plants.
    a. Economical methods to add water cooling to air-cooled plants for peak hours.
    b. Air cooling to water-cooled systems for water conservation and/or water production.

Part 4: Responses to the CEC panel discussion questions

1. Existing Plant Flexibility Research
    a. No further CEC funding of flexibility curtailments is warranted given the ongoing $6MM Geysers study and the Salton Sea not being suitable. The remaining curtailment potential is so small and the economic barrier so high that further CEC funded curtailment research is not a prudent investment for the ratepayer.
    b. We suggest an RPF for an independent assessment of the fixed/variable costs of geothermal power plants to understand the economics of flexibility curtailments.
2. Other research opportunities:
    a. The water/energy nexus.
3. Geothermal technologies with potential to succeed in California and CEC RFP requests:
    a. Integration of solar thermal and natural gas generation into geothermal plants.
    b. Mass adoption of geothermal heat pumps to reshape the load curve, reduce GHG emissions, and reduce ratepayer costs.
4. Opportunities for increased geothermal power, related to regulatory factors:
    a. Eliminate intermittent generation bias which overlooks integration costs, including CO_2 emissions and capacity costs for gas and storage, and required geothermal curtailments.
    b. Low cost natural gas generation with no cost adder for CO2 emissions.
    c. Uncertain market for geothermal power, which suppresses exploration investment.

Part 5: Other Observations from the CEC workshop

1. Consequences of Calpine's success in achieving ISO-required 35% curtailment and fast ramping include;
    a. Inherent reduction of conversion efficiency (wasting of geothermal energy).
    b. Increased CO_2 emissions per MWh due to efficiency loss in the power plant.
2. The economics that made flexibility curtailments prudent at the Ormat plant in Hawaii do not exist in California;
    a. A small grid that could be regulated with a 16 MW plant.
    b. Dependence on oil at $100/bbl with no natural gas options.
3. Other observations on curtailment flexibility;
    a. Geothermal flexibility curtailment, even though technically feasible, is essentially pounding a round peg into a square hole.
    b. Operating strategies that increase CO_2 emissions and waste geothermal resource are

not in the public interest, especially since flexibility curtailment implementation at most geothermal power plants is uneconomical for the ratepayer.

c. Other grid technologies can provide flexibility curtailments at lower cost and lower overall grid emissions than from geothermal power plants.

Part 2: Flexibility Through Curtailment and/or AGC:

To-date, two ways have been discussed for a geothermal plant to have flexibility curtailments. Both take a typical baseload geothermal power plant, and then curtail it through either; 1) a straight reduction in generation, or 2) through a load-following automatic generation control (AGC).

USGeo wholeheartedly agrees that for the "right price" most geothermal power plants (other than the Salton Sea plants, per Cal-Energy), can be operated in such a way as to provide some, or even a large measure of flexibility. Second, USGeo also agrees with our colleagues at Ormat who have stated that the capital cost of a flexible geothermal power plant is no higher than the cost for a baseload plant. However, the most important element of the discussion that is missing so far is "What is that price that would be required to operate that baseload asset as a variable output power plant?" To answer that question, it is helpful to start with the classic dispatch concepts of fixed and variable costs.

A typical definition of fixed costs are those costs that do not change regardless of the output of the plant. The debt on the plant (i.e. the mortgage) is an obvious example of a fixed cost, because whether the plant is running at full load, or is shuttered and not staffed, the bank must be paid the same amount to avoid default. Plant personnel are another large fixed cost. The variable costs are those costs that change with the output of the plant. So for example, when a natural gas combined cycle combustion turbine plant ("CCCT") cuts its load by 1 MW, it saves the fuel required to generate that 1 MW. If the heat rate is 7MMBTU/hr, and the cost of natural gas is $4/MMBTU delivered, then the variable fuel cost is $28/MWh. Starting and stopping are also variable costs because of the wear and tear that they put on the equipment.

Plants that have significant variable cost components deliver the least expensive flexible operation cost. The cost components of a geothermal power plant are shown in Table 1 (next page).

The contract price for geothermal power might be as low as $65/MWh for existing geothermal power plants, but needs to be at least $90/MWh to build a new geothermal power plants (and typically higher than that for most binary power plants). Using the representative values for variable costs for geothermal power plants, the intrinsic cost savings **to the ratepayer** by reducing output is only $4 to $6 per MWh. However, the cost ADDER to the ratepayer by curtailing the plant is the fixed portion of the power price that would have otherwise been paid ($59 to $86 per MWh). So one can conclude that technically it is feasible to reduce the output of a geothermal power plant, but that the cost of doing so is very expensive and economically unattractive to the ratepayer compared to lower cost options, such as natural gas turbines.

The analysis above has one intrinsic assumption in it: that the generation that is curtailed for purposes of flexibility cannot be recovered later in the year. Whether this is true or not generally depends on whether the plant is in one of two resource categories; The Geysers, and everything else. The existing plants at the Geysers are a very special case because that is a very special geothermal reservoir. The Geysers is by far the largest of only three major steam reservoirs in the world, and produces over 40% of all US geothermal generation on an annual basis[i]. Things that are true about operating that reservoir and its multiple power plants are far different from anything else in the United States. As is noted in the GEA Report on Flexibility, plants at the Geysers were run in various modes to provide ancillary

services in the 1990s. The fact that they have not been run that way since then should raise questions about whether it is actually economical to do so, and in fact besides the issues raised here, the GEA report notes that the Geysers plants experienced added O&M expenses. However, there is already a CEC-funded study to investigate the potential of incorporating flexibility at the Geysers. [ii]

Table 1: Fixed and Variable Cost Components of Geothermal Power Plants

Item #	Cost Category	Fixed Costs ($/month)	Variable Cost ($/MWh)	
1	Debt Payment – Power Plant	Y(es)		Cap Cost = 3 to 4 $MM/MW
2	Debt Payment – Pipelines and Wells	Y		Cap Cost = 2 to 4 $MM/MW
3	Plant Staff	Y		With benefits = $1MM/yr
4	Corporate Overhead and Consultants (legal, technical, financial, audit, etc.)	Y		Not affected by reduced load
4	Periodic Turbine Overhauls	Y		Ditto
5	Trucks and Vehicles	Y		Ditto
6	Oils and chemicals, other than cooling tower	Y		Ditto
7	Royalty to Leaseholders		~ $3 - $5 per MWh	A percentage of the net generation delivered
8	Cooling tower chemicals	Most	~$1/MWh	Upper-end estimate of variable portion of CT chemical use
9	Stopping and restarting a binary power plant well pump		Y	Cost is not quantified, but most failures are related to starts, and a replacement is $300k, plus lost generation.

In the "everything else" category, examining the actual performance history of USGeo's three operating power plants, gives an indication of the answer to the question of whether generation can be recovered later. Two of USGeo's plants, San Emidio in Nevada, and Neal Hot Springs in Oregon operate at full capacity around the clock, except when there are utility transmission outages, and scheduled or unscheduled maintenance. There is no ability to add generation in some hours, reduce generation in other hours, and net the same total delivered power over the course of any month or year. Therefore, any reduction in output from these plants for flexibility translates into lost revenue on an annual basis.

Regarding the economics of flexibility curtailments, the average PPA power price of the two plants is over $100/MWh, and the average royalty is about 4%. Therefore, the curtailment cost of reducing power from these two plants is at least $96/MWh. Furthermore, a 35% curtailment during flexibility events would net a delivery reduction of about 10 MW ($1,000/hr). With grid capacity in the western US of tens of thousands of MW in every hour, not only is it expensive, the effect of the curtailment is irrelevant to the grid.

By comparison, using the avoided fuel cost example for the CCCT, the same $1000/hr investment would result in flexibility response of over 30MW, or a three times larger response for the same ratepayer investment. Furthermore, the $CO_{2\text{-equiv}}$ emissions reductions from a geothermal power plant are essentially zero for binary plants, while 30 MW of CCCT reductions would be well over 15 tons per hour. So not only is the CCCT a better economic choice for curtailment, it also results in progress

toward California's CO_2 goals under AB-32 that cannot be matched by curtailing geothermal power plants.

In USGeo's operations, any curtailment for flexibility would result in essentially paying for lost generation at essentially 100% of the contract rate. So while there are minimal technical barriers, USGeo does not believe that it is in the best interest of the ratepayer to operate our plants, or possibly any geothermal power plant in this way.

One last important technical item that further works against geothermal plants for flexibility curtailments is that the above discussion assumes that conversion efficiency (defined here as the pounds of reservoir fluid required to generate one kWh of net power) is constant. This is not true at the Geyser and it is not true at any of USGeo's binary power plants. Reducing output from any power plant results in lower turbine inlet pressures. Lower turbine inlet pressure reduces efficiency. The physics are not worth going into in this letter, but it can be taken as a universal truth for all steam turbines and all binary turbines. Therefore, even for reservoirs that may be able to "bank" unproduced reservoir fluids for later withdrawal (such as possibly the Geysers), there will be a net generation loss that the plant owner will need to be compensated for. That net generation loss must ultimately be made up to the grid by a power plant with extra capacity, which is currently by definition and default, a fossil fueled plant. Therefore, even if bankable geothermal reservoir production is identified, using it for regular flexible operations will not only increase costs, but also increase CO_2 emissions over geothermal baseload operations.

To summarize the potential for geothermal baseload power plant curtailments for grid flexibility, it is:

1) Technically feasible.
2) Possible with essentially no change in the capital cost of the geothermal power plant.
3) Very expensive ($60 to >$90 per MWh) because of the very high fixed cost of the plant.
4) Results in lost geothermal generation under all scenarios for multiple reasons.
5) Increases CO_2 emissions of 0.5T/MWh or more compared to fossil fired power plant curtailment, and therefore runs counter to the goals of AB-32.
6) Irrelevant to grid stability from any one power plant, or even multiple power plants, with the possible exception of the Geysers field as a whole.
7) More expensive than alternatives, and therefore not in the financial interests of the ratepayer.

Based on these seven factors, USGeo recommends that the CEC modify its proposed RFP for research and study proposals to either exclude altogether curtailment-based strategies for geothermal power plant flexibility or alternatively, require that any curtailment research proposals demonstrate greater value to the ratepayer in terms of both CO_2 and cost than curtailments of fossil-fired resources. As is noted above, the Geysers are already being studied for flexibility curtailments under a CEC grant, and so allocation of further research dollars toward flexibility in existing Geysers plants is unlikely to yield incremental benefits to California's taxpayers.

Part 3: Flexibility Through Generation Increases:

This area of research hold much more promise for effective use of CEC taxpayer/ratepayer research funds than curtailment flexibility, and is one of several technical areas for which the CEC RFP should request proposals.

In the GEA report, a number of options are put forward for ancillary services that could be supplied by a geothermal plant designed or capable of baseload are presented. All of these options involve operating the plant in such a way that it either is not at full capacity, or it sheds load (MWh) when called on to do

so. All of these approaches and ancillary services are effectively Part 2 solutions, i.e. less generation from largely fixed cost assets. Flexibility through Generation Decreases, which have already been shown to not be in the economic nor to reduce CO_2 are not in the best interests of the ratepayer.

In order for the ratepayer to receive an attractive cost/benefit from ancillary services from geothermal plants, the geothermal power plants need to take advantage of the capacities it already has to <u>increase</u> generation and revenue, and in so doing lower the incremental cost of power and lower the emissions of CO_2 per MWh compared to the alternatives.

Furthermore, an RFP solicitation could ask for proposals to address specific areas of the duck curve. This may be one or more of following:

A) The 12,000 to 20,000 MW baseload "pond" on which the duck is floating. The CEC funding RFP could include requests for research proposals to lower the cost of baseload geothermal power and displace fossil fuel generation. Proposals in this area could include technologies and methods to
    a. Improve the targeting of geothermal exploration and production wells.
    b. Integrating or co-locating different power generation technologies, such as geothermal with PV, solar thermal, biomass, or natural gas.

B) The "neck" of the duck, which is the biggest problem and integration cost created by intermittent PV generation, must be addressed. The extraordinary ramp rate is currently the economic domain of pumped storage, and natural gas combustion. The totally unproven hope for the future, both technically and economically, is the emergence of a low cost breakthrough in storage technology.
    a. There is potential that integration of solar thermal and natural gas with both new and existing geothermal plants could help contribute to stabilize the grid during the neck each sunset, at lower CO_2 emissions and/or cost than current natural gas options.
    b. Since a large percentage of PV is on at least a 1-axis tracker, then it would be more economical to curtail PV in the morning and evening to flatten the required ramp rate than to take every potential kwh of power from PV and try to integrate it using geothermal, which is the quintessential baseload resource.

C) The water/energy nexus.
    a. There are numerous air-cooled geothermal plants. Integrating hybrid water cooling into the plant operation during peak hours can dramatically increase plant output instead of burning natural gas or adding to the duck curve problem by adding more PV.
    b. Where there are also water-cooled plants, the integration of air-cooling can address water conservation in California. Some potential examples of this are:
        i. At the Geysers, air cooling would result in greater injection and potentially greater future generation.
        ii. At the Salton Sea, additional water production would reduce the use of Colorado River water, which could then increase drinking water deliveries to coastal cities.
        iii. In other operations, it is conceivable that water derived from geothermal fluids could be used to supplement local surface water uses to agriculture.
    c. USGeo encourages the CEC to expand its RFP to include proposals to address the energy/water nexus in geothermal energy production.

<u>Part 4: USGeo's responses to the CEC questions asked of the panelists:</u>

1. *What are the main barriers and opportunities to operating geothermal power plants in flexible*

or load following mode? What are the main operational and maintenance cost drivers of geothermal power plants running in flexible or load following mode? What research and development activities should be conducted to address these barriers and cost drivers?

>>USGeo Response:

- The high fixed cost of geothermal power (95%) means that it is unlikely that flexibility curtailments will ever be economical for the ratepayer.
- The Geysers represents over 40% of total geothermal generation in the U.S. according to Calpine's presentation. But from the table presented, it is >55% of California's. Cal-Energy states that it is not practical to use its 340+ MW for "flexibility" curtailments. Using their figure of 90% availability, that means that the Cal Energy plants represent about 2,700 GWh/hr or 25% of California's production. Thus only 25% or less of California's geothermal energy baseload production could even be evaluated for curtailment flexibility after subtracting the Geysers and Cal-Energy's generation.
    - Further research beyond what the CEC is already sponsoring at the Geysers with Calpine will not be a fruitful use of research funds.
- The CEC, PUC, and ISO have focused on the technical issues of geothermal flexibility. But the industry economics of flexible operations, especially in regard to fixed/variable costs have not been documented to understand what the cost of flexibility curtailments might be.
    - The CEC could ask for proposals to investigate this question.

2. *What other operational issues are limiting the success of geothermal power plants and what research and development activities should be conducted to address these issues?*

>>USGeo Response:

- Water use can both shape generation characteristics and contribute to California's overall water balance, as described in the question above.
    - Money for water/energy nexus demonstration projects in the 2016 RFP.

3. *What specific geothermal generation technologies or enabling technologies have significant potential to succeed in the California market and why? What further research and development is needed, if any, to accelerate the market adoption of these technologies or strategies?*

>>USGeo Response:

- Integration of solar thermal and natural gas generation into new and existing geothermal power plants.
    - Money for demonstration projects in the 2016 RFP for projects can show cost and/or CO_2 benefits compared to conventional applications of the technologies separately.
- Geothermal heat pumps would be highly effective at reshaping the duck curve. It is likely that the effect on peak demand (the neck and head of the duck) and the "pond" of 11-20 GW on which the duck floats would all be positively impacted by widespread adoption of GSHP. The transformation of heating load from CO_2-emitting natural gas to ever-increasingly low-CO_2 electricity would further the efforts of California to reduce GHG emissions and by reducing the disparity between summer and winter demand, reduce the cost of electricity as well.
    - The 2016 RFP should ask for proposals using smart meters and other data to evaluate the change in electrical demand on both hourly and seasonal basis by the conversion of >100,000 homes to geothermal heat pump systems.

4. *What is the current potential or opportunities for expanding power generation from geothermal and boosting its role in meeting California's renewable energy goals? What are the main barriers preventing more geothermal power from being added to the grid in California?*

>>USGeo Response:

- The greatest regulatory failure in California which impedes geothermal development is the

use of lowest cost per kwh evaluation criteria for new power contracts, especially PV, that fails to include the full integration costs, including geothermal curtailments, gas peakers, and battery storage capital and replacement costs, and the CO_2 emissions that occur when natural gas is used to integrate PV and wind.

  - Taking all of these factors into account would levelize the playing field, and not force the ratepayer to incur large and invisible costs for intermittent resources.

- Low cost natural gas, with no credit to geothermal for zero to low CO_2 generation or risk compensated natural gas price forecasting.
  - The lack of a deemed value for CO_2 gives fossil fuel systems a major economic advantage over geothermal power.
- Unstable power purchase market for new geothermal power that suppresses the willingness of investors to explore for and prove new geothermal reservoir capacity.

<u>Part 5: USGeo Comments on a few of the slides presented in the CEC workshop:</u>

1. <u>Calpine curtailment history and options</u>. Figure 3-1 shows Calpine's example 205/675 = 30% curtailment. Although not discussed, reduced steam flow inherently increases the pouunds of steam per kWh of delivered power. In short, flexibility both decreased the efficiency of the power plant and increases CO_2 emissions per delivered MWh. Figure 3-2 describes the options for reaching a given curtailment level. Note the "Y" portion means dumping the steam straight into the condenser, without either banking the steam, or getting any beneficial use from it. This technique, if required, will produce the largest CO_2 increase and wasting of California's geothermal energy. Asking/requiring the geothermal industry to reduce geothermal conversion efficiency to help with grid regulation on a recurring, non-emergency basis is not only wasteful, but is bad public policy. This is especially true when the same 200MW curtailment from fossil resources would result in a decrease of CO_2 emissions of between about 80 and 200 tons per hour.[iii]

Fig 3-1 Calpine ISO curtailment

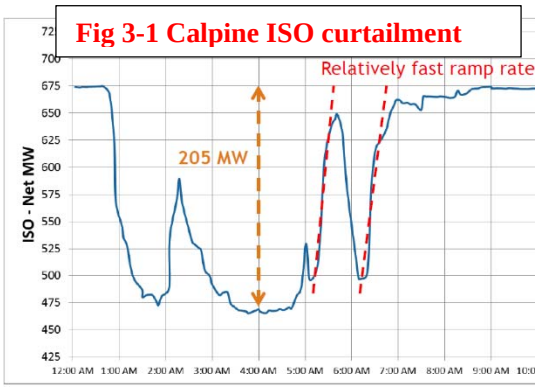
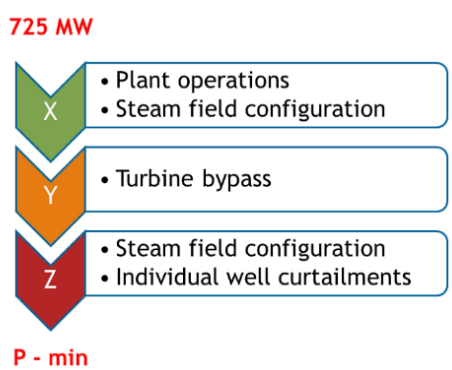
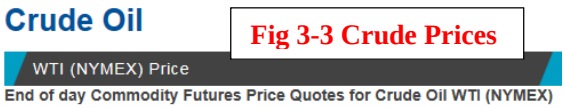


Fig 3-2: Calpine curtailment methods



2. Ormat flexibility experience. Ormat discussed that their power plant in Hawaii was contracted for by HELCO and now operates to provide several ancillary services. This is a credit to both HELCO and Ormat to address the unique requirements of a very small island grid. However, the needs and economics in Hawaii at that time are almost certainly not applicable to ratepayers and geothermal power plants in California. Hawaii is dependent on oil-fired generation. At the time of contract signing and power plant construction the cost of oil was between $80 and $110 per barrel. See Figure 3-3. This would result in reciprocating and turbine fuel costs of well-over $250 per MWh in Hawaii. Contrast this to the fuel cost calculated for California's natural gas ancillary services plants in Part 2, of about $28/MWh. What worked then for the Hawaiian grid and ratepayer, must be carefully analyzed for applicability and economic value for the California grid and ratepayer, and is likely to be rejected after such an analysis. Furthermore, the last point on the final Ormat slide (Figure 3-4) states that the contract is capacity and energy.[iv] In other words, even when the plant is curtailed for flexibility, the developer is being paid. This is a major deviation from the energy-only PPA commonly in use in California, which would deny the geothermal operator any payment during flexibility curtailments.

Fig 3-3 Crude Prices



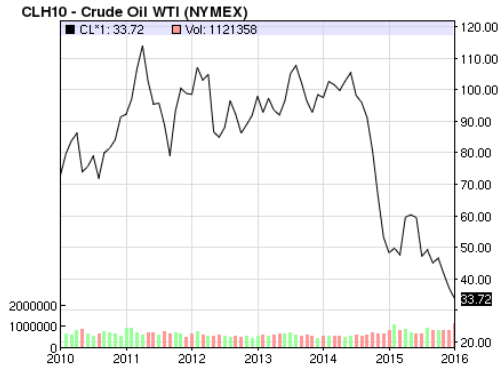


Fig 3-4: Ormat Hawaii Experience

- Puna Geothermal Venture, HI
  - 38 MW geothermal facility
  - Built in 1992, expanded in 2011
  - 16 MW of AGC control
  - Min. 2MW/min ramp rate
  - Quick pick up of 3 MW in 3 sec.
  - PPA with HELCO for energy & capacity

3. The overall purpose of the workshop, and focus of the presentations, were to discuss how baseload geothermal can be modified or operated as a variable output generation resource, and even more specifically for generation reduction and/or partial loading with respect to installed capacity. However, there is no value creation (for operators or ratepayers) by pounding round pegs into square holes. No one expects PV to deliver after sunset, or wind power when it's calm, or a coal plant to start and stop every day. Requiring each to operate in such a way would be very expensive for the ratepayer because there are more cost-effective technologies that can do each of these things. Geothermal power plants have both physical limitations, like those other technologies,

and economic limitations set by the intrinsic nature of the 95%/5% fixed/variable cost structure. California's ratepayers will be best served by efforts to make geothermal power lower cost in its baseload operations, not by asking it to do ancillary grid services that are more cost-effectively delivered by other generation technologies.

Respectfully,

Kevin Kitz (via e-mail)

Kevin Kitz, P.E.
VP - Project Development
U.S. Geothermal Inc.

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[i] Calpine presentation to CEC Workshop, 1/18/2016. Slide #3. 36.8% for Calpine, plus NCPA.
[ii] Firm and Flexible Power Services Available from Geothermal Facilities. Geothermal Energy Association Issue Brief. May 2015. Pages 1, 2 and 3.
[iii] Figures 3-1 and 3-2 are from the Calpine presentation material at the CEC Workshop.
[iv] Figure 3-4 is from the Ormat presentation material at the CEC Workshop.