The Value of Geothermal Power for Integration of Intermittent Generation

Project Officer: Elisabet Metcalfe
Total Project Funding: $200k
May 12, 2015

This presentation does not contain any proprietary confidential, or otherwise restricted information.
Relevance/Impact of Research

Project objective

• Estimate additional revenues that geothermal plant operators could earn by providing flexibility (frequency regulation, load following, spinning reserve, and non-spinning reserve) to the system operator.
• Revenues from flexible operations in California estimated for the year 2020 under a system with 33% renewable energy.

Unique contributions

• The project utilizes unique stochastic weather and production simulation models developed at LLNL in previous externally-funded research efforts.
Scientific/Technical Approach

• General assessment of anticipated market conditions in California in year 2020 with 33% renewable generation
  – Gov. Brown recently announced goal of 50% by 2030
• Weather and renewable generator model of the western U.S. that provides an ensemble of 30 possible renewable generation profiles for each day of the year
• Stochastic grid optimization model that minimizes expected cost of operating system given the uncertain inputs
• Assumed new business models and contract structure allow geothermal generators to provide needed flexibility
• Geothermal dispatch logic to estimate additional revenues
California ISO’s “duck chart” shows drop in net load mid-day due to solar generation.
Energy Prices in CAISO, MISO and PJM in 2014
Hourly average energy prices will be volatile in 2020

CAISO
Energy Prices
Forecast 2020

Avg = $60/MWh
Total = $500k/MW-yr
Higher load following prices in 2020 reflect this volatility

**CAISO Load Following Up Prices Forecast 2020**

- Avg = $11/MW
- Total = $100k/MW

**CAISO Load Following Down Prices Forecast 2020**

- Avg = $4/MW
- Total = $30k/MW
Regulation price patterns reflect more short periods of higher prices

(a) CAISO
Regulation Up Prices
Forecast 2020

(b) CAISO
Regulation Down Prices
Forecast 2020

Avg = $14/MW
Total = $120k/MW

Avg = $5/MW
Total = $40k/MW
Production rates from normal and flexible operations – extended well life
Current geothermal PPAs have high, energy-only payments

<table>
<thead>
<tr>
<th>Plant</th>
<th>Price ($/MWh)</th>
<th>Escalation (%/yr)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORMAT – Campbell</td>
<td>99</td>
<td></td>
<td>~$800k/MW-yr</td>
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<tr>
<td>Cyrg Energy – New Mexico</td>
<td>98</td>
<td>2.75</td>
<td></td>
</tr>
<tr>
<td>Trans Alta-Mid American</td>
<td>70</td>
<td>1.5</td>
<td>~$600k/MW-yr</td>
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<tr>
<td>U.S. Geothermal-Nevada</td>
<td>90</td>
<td>1</td>
<td></td>
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<tr>
<td>ORMAT - Puna</td>
<td></td>
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<td>8 of 38 MW plant is flexible</td>
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No incentive to reduce MWh deliveries unless ancillary service prices exceed energy price.

Capacity credit of ~$100k/MW-yr?
Accomplishments, Results and Progress

- Accomplishments/Progress to date.
  - Unique representation of uncertainty and variability in renewable generation and how grid operators would manage it using stochastic optimization methods

<table>
<thead>
<tr>
<th>Original Planned Milestone/Technical Accomplishment</th>
<th>Actual Milestone/Technical Accomplishment</th>
<th>Date Completed</th>
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<tbody>
<tr>
<td>Estimation of annual revenues from baseload operations during a typical year. Assessment of geothermal generator capability to provide regulation services. Estimation of additional revenues that could be earned by providing regulation services.</td>
<td>Same</td>
<td>Q2 FY14</td>
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## Accomplishments, Results and Progress

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<tr>
<td>Assessment of geothermal generator capability to provide load following services. Estimation of additional revenues that could be earned by providing load following services. Memo and presentation to DOE documenting results of tasks 1 and 2.</td>
<td>Same</td>
<td>Q3 FY14</td>
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<td>Evaluation of geothermal reservoir management with dynamic characterization.</td>
<td>Same</td>
<td>Q4 FY14</td>
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<td>Economic analysis and final report</td>
<td>Same</td>
<td>Q1 FY15</td>
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<tr>
<td>Present results at Stanford Workshop</td>
<td>Same</td>
<td>Q2 FY15</td>
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Future Directions

- Project completed in January 2015
- Additional modeling and analysis would be needed to examine proposed higher renewable generation targets for California (50%) and other western states, or examination of other markets such as the island of Hawaii.

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<th>Milestone or Go/No-Go</th>
<th>Status &amp; Expected Completion Date</th>
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Summary

- Expect increased level and volatility of energy and ancillary service prices
- Current geothermal contracts not configured to respond
- Flexible contracts could provide access to other revenue streams
- Financial penalties for deferral of energy revenues
Publications