U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

GEOTHERMAL TECHNOLOGIES PROGRAM

2011 Peer Review Report

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Geothermal Technologies Program
2011 Peer Review Report

June 2011

Cover photo: Geysers Geothermal Power Plant, Calpine

Geothermal Technologies Program

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Executive Summary

On June 6-10, 2011, the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technologies Program (GTP or the Program) conducted its annual program peer review at the Bethesda North Marriott Hotel and Conference Center located in Bethesda, MD. In accordance with the EERE Peer Review Guide, the review provides an independent, expert evaluation of the strategic goals and direction of the program and is a forum for feedback and recommendations on future program planning. The purpose of the review was to evaluate DOE-funded projects for their contribution to the mission and goals of the Program and to assess progress made against stated objectives. Principal Investigators (PI) from over 140 projects, representing a total DOE investment of over $350 million, came together to disseminate information, progress, and results. In addition to the formal review, this event was an excellent opportunity for the geothermal community—both funded researchers and stakeholders—to share ideas and solutions about the challenges facing the geothermal industry.

The GTP develops innovative geothermal energy technologies to find, access, and use the nation's geothermal resources. Through research, development, and demonstration efforts that emphasize the advancement of Enhanced Geothermal Systems (EGS), GTP is working to provide the United States with an abundant, clean, renewable baseload energy source. GTP works in partnership with industry, academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. GTP's activities build on the technical research base that has been developed over the last four decades. This technical base will provide information and understanding necessary to create new and more efficient and reliable technologies and to enable the U.S. geothermal industry to compete for baseload electricity generation.

The 2011 Geothermal Technologies Program Peer Review Meeting was organized into the following tracks with associated sessions:

- Track 1 - Systems Analysis, Resources Assessment, Data System Development and Population; Power Conversion Technology; Stimulation/Fracture Prediction Modeling
- Track 2 - Enhanced Geothermal System Demonstrations; Seismicity and Reservoir Fracture Characterization; Specialized Materials and Geopolymer Sealing Materials
- Track 3 - High Temp Tools, Sensors, Systems; Drilling Systems
- Track 4 - Low-Temperature, Co-Production, Geopressured Demonstration; Reservoir Exploration, Characterization and Modeling; Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions
- Track 5 - Innovative Exploration Technology; Tracers and Tracer Interpretation

Each track was comprised of a grouping of individual projects with similar technical themes/objectives; these groupings are referred to as peer review sessions. Each project was reviewed by a minimum three expert reviewers whom provided both numeric evaluations and written comments. Reviewer comments were provided to the project PI for response. PI responses had no bearing on numerical scores but provided an additional platform for reviewers‘ assessments to be addressed and incorporated by the individual projects. The comprehensive collection of reviewer comments and PI responses can be found in this report in Appendix A and B.

Additionally, one overall chairperson, Dr. Allan Jelacic, was selected to oversee the entire peer review process. The chairperson provided oversight and guidance to ensure consistency, transparency, and independence throughout the review process. Key findings and recommendations of the peer reviewers and detailed project evaluations are provided in this 2011 Geothermal Technologies Program Peer Review Report.

Program Response

On June 6 to 10, 2011 the U.S. Department of Energy‘s (DOE) Geothermal Technologies Program (GTP or the Program) undertook a review of its board portfolio of analysis, research, development, and demonstration activities. This is an annual event designed to provide insightful and acute feedback to both the Program and to researchers, regarding the direction and results of this work. In total, 146 projects encompassing a DOE investment of over $350 million were evaluated by a group of over 100 reviewers. These reviewers were drawn from the geothermal community and from allied and associated fields which has cross-over technologies. The Program feels it is critical to engage a high quality, diverse and informed reviewer panel, to assess the fundamental science and technologies involved in the research and development (R&D) portfolio.

Many of the reviewed projects were initiated under the American Reinvestment and Recovery Act (ARRA) of 2009, with the balance resulting from periodic funding activities that target specific Program objectives. Total Program ARRA funding totaled $364 million. The ARRA projects had more than 12 months of progress as of the 2011 Peer Review, but are predominantly multi-year efforts; in this context the 2011 review is in part a status report on technical progress, management system effectiveness, and key challenges to date. Nearly all of the ARRA projects reviewed in 2011 will be reviewed again during the 2012 Peer Review, at which time there will be a more highly focused technical assessment.

The Annual Peer Review is not the only mechanism by which the Program gains rigorous, formal and documented evaluations of its activities. Large demonstration projects are separated into discrete phases separated by “stage gate” reviewers, and nearly all projects incorporate prescriptive “go/no-go” decision points. During a stage gate review, performance within a completed phase is documented by the principal investigator (PI) and reviewed by DOE and a team of independent experts, typically referred to as the Technical Monitoring Team (TMT). Stage gate reviews can result in various outcomes: the project can proceed with adjustments through the next phase; the project can be required to collect additional information or perform additional analysis before proceeding; or the project can be closed out. The results of the Annual Peer Review, in conjunction with regular project reviews and stage gate reviews, are evaluated to determine appropriate next steps for both technology areas and individual projects.

While the Peer Review has vital importance for individual projects, it also influences operational practices of the Program. For example, several reviewers commented that while program analytical efforts are well conducted, they require more actual test and operational data from industry for validation. The Program is addressing this need through the National Geothermal Data System (NGDS), which is designed to make all geothermal data more readily available, and the DOE Geothermal Data Repository, which will make all data generated through the Program available to the public.

The Peer Review should also be reflective of the Program‘s overarching strategy and priorities. Current strategic objectives include lowering the risk and cost of exploration and development of hydrothermal resources through advancement of new technologies, and identification and mapping of new prospects and play opportunities. Streamlining the regulatory process through first a Regulatory Roadmap, followed by collaborative multi-agency efforts to optimize this process, will benefit all stakeholders. The Program also sees Enhanced Geothermal Systems (EGS) validation at both a technical and commercial level, to be a critical goal.

As the Program moves forward, there are a number of themes and principles that will increasingly be a focus. The first of these is more attention to hard stage gates, and technically based go/no-go decision points. This will mean terminating non-performing projects. The second theme is more specific attention to the ability for new technologies and R&D to materially lower the risk and cost of geothermal exploration and development. Projects that have low potential to address this area will not move forward. Finally, combined with these principles, there will be increasing focus on annual, rather than multi-year funding, to more accurately reflect evolving Program and budgetary priorities.

The Program believes the Annual Program Review is a vital and important tool, and trust that both participants and all other stakeholders find it useful and effective. The Program looks forward to continued guidance and feedback as it strives to make this an even more effective tool in aiding to making geothermal energy a key part of the nation‘s energy solution.

1.0 Introduction to the Geothermal Technologies Program

The U.S. Department of Energy (DOE) Geothermal Technologies Program (GTP or the Program) develops innovative geothermal energy technologies to find, access, and economically use the nation's geothermal resources. Through research, development, and demonstration efforts that emphasize the advancement of Enhanced Geothermal Systems (EGS) and discovering of natural hydrothermal systems, the GTP is working to provide the United States with an abundant, clean, renewable baseload energy source. GTP works in partnership with industry, academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. clean energy supply. Geothermal energy production, a $1.5 billion a year industry, generates electricity or provides heat for direct applications including aquaculture, crop drying, and district heating, or for use in heat pumps to heat and cool buildings. The GTP conducts multi-year research and (R&D) on surface and subsurface opportunities for system cost reduction. EGS R&D priorities are focused on overcoming technology barriers that have the greatest potential to hinder the development of viable at acceptable cost, risk, and timeframes.

GTP's activities build on the technical research base that has been developed over decades. This technical base will provide information and understanding necessary to create new and more efficient and reliable technologies and to enable the U.S. geothermal industry to compete for baseload electricity generation. The funding history for the Geothermal Technologies Program is illustrated below in Figure 1.1.

GTP's R&D is currently (FY2011 and onward) organized around three areas:

- **Enhanced Geothermal Systems** – Demonstrate technical feasibility by 2020
- **Hydrothermal and Resource Confirmation** – Decrease the risk and cost of hydrothermal developments
- **Systems Analysis and Cross-Cutting** – provides direction, focus and analytical support for geothermal technology development and commercialization

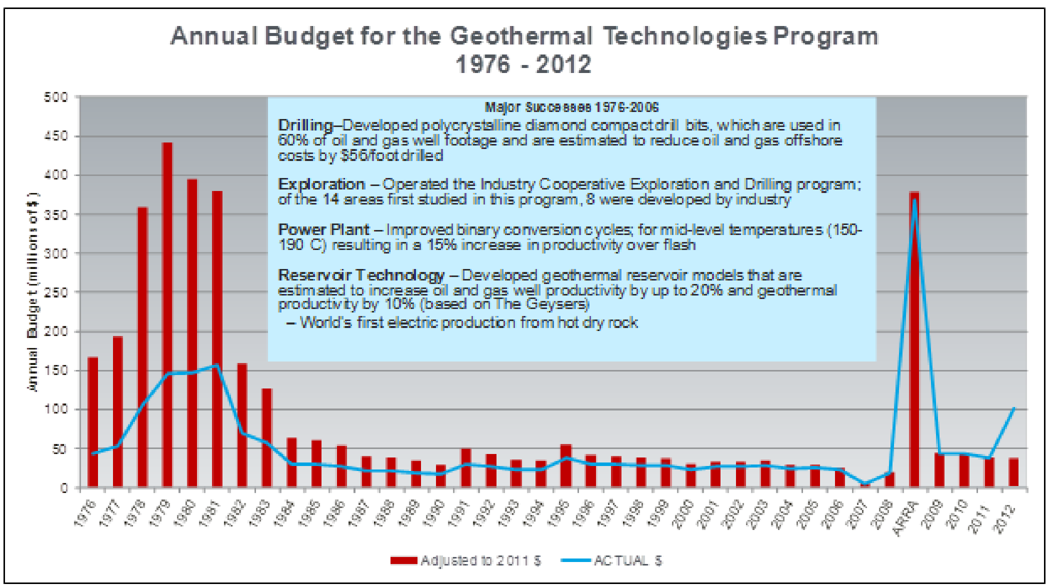


Figure 1.1. *Geothermal Technologies Program Funding History*

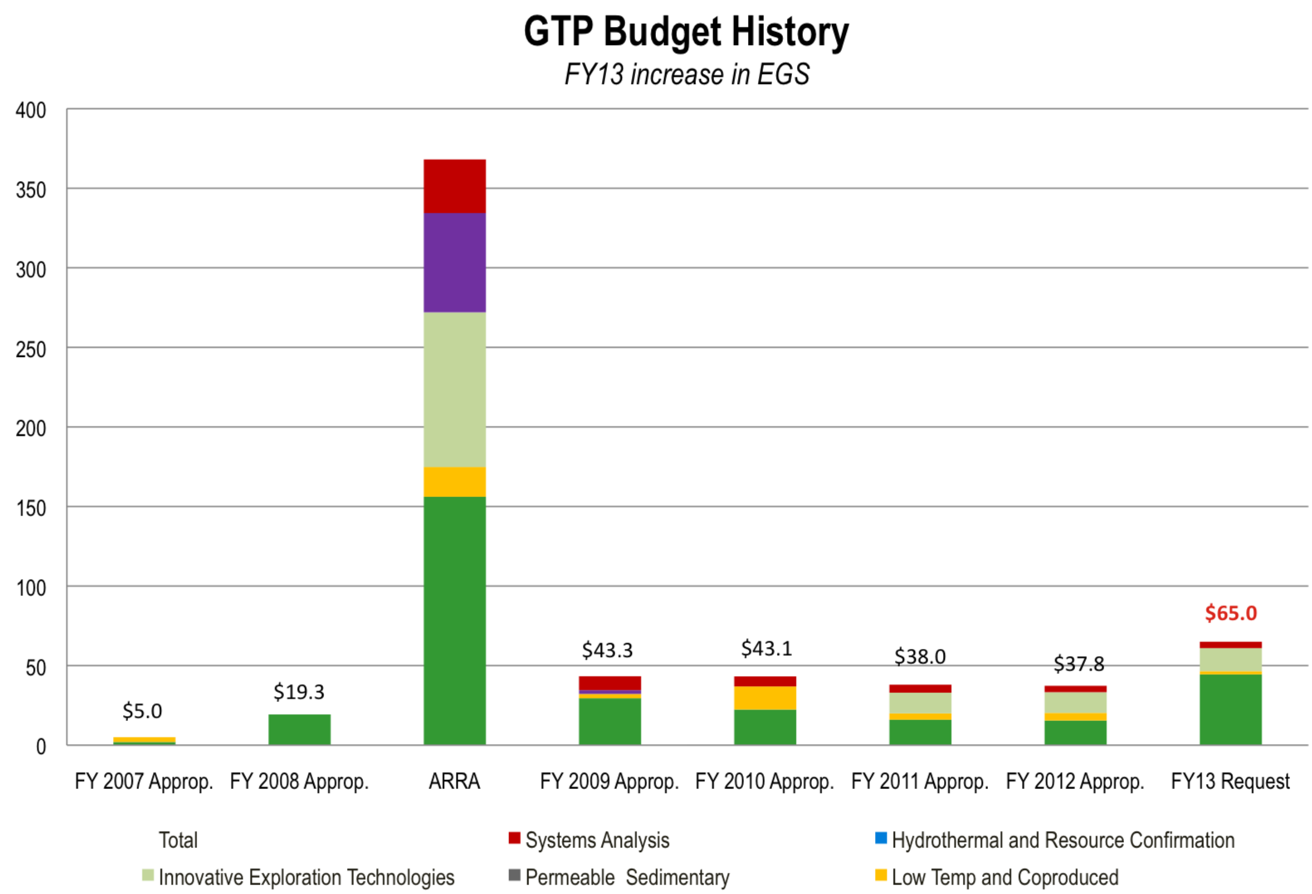


Figure 1.2. *Geothermal Technologies Program Budget History*

The GTP mission is to establish geothermal energy as a significant contributor to America's future electricity generation by partnering with industry, academia, and the national laboratories to discover new geothermal resources; research, develop, and demonstrate innovative technologies; and facilitate commercialization.

GTP's current goal is to reduce the cost of geothermal energy to be competitive with conventional sources of electricity and accelerate the development of geothermal resources.

To achieve this goal, the Program's strategy is to:

- Accelerate near-term hydrothermal growth by:
  - Lowering development and exploration risks and costs
  - Lowering levelized cost of electricity from blind hydrothermal systems (LCOE) to 6¢/kWh by 2020
  - Accelerating the development of 30 GWe of undiscovered hydrothermal resources
- Secure the future with EGS by:
  - Demonstrating the creation of a 5 MWe reservoir by 2015
  - Lowering the LCOE to 6¢/kWh by 2030

GTP has a total portfolio of more than 270 research, development, and demonstration projects being conducted (with very few exceptions) with academia, the national laboratories, and in cost-sharing partnerships with industry. The Program also supports some deployment activities designed to move advanced technologies into the geothermal industry and conducts a broad range of systems analyses that support and direct Program's activities and provide needed knowledge bases.

Note: At the time of the review, the Program was organized into three subprogram areas, Enhanced Geothermal Systems, Innovative Exploration Technologies, Low Temperature and Coproduced Resources. The Program has since been reorganized. The Program mission and objective remains the same but the subprogram goals at the time of the 2011 Peer Review were as follows:

- **Enhanced Geothermal Systems** – Demonstrate reservoir creation and sustainability in various geologic environments
- **Innovative Exploration Technologies** – Confirm 400 MWe of undiscovered hydrothermal by 2014 and lower the upfront exploration risk of blind hydrothermal systems
- **Low Temperature and Coproduced Resources** – Enable 3 GWe of added geothermal capacity for low temperature and coproduced resources by 2020

2.0 Geothermal Technologies Program Peer Review Process

Objective review and advice from peers—"peer review"—provides DOE managers, staff, and researchers with a powerful and effective tool for enhancing the management, relevance, effectiveness, and productivity of all Office of Energy Efficiency and Renewable Energy (EERE) research, development, demonstration, deployment, and supporting business management programs. The 2004 EERE Peer Review Guide[1] defines a peer review as:

> *A rigorous, formal, and documented evaluation process using objective criteria and qualified and independent reviewers to make a judgment of the technical/scientific/business merit, the actual or anticipated results, and the productivity and management effectiveness of programs and/or projects.*

This definition is drawn from the U. S. Department of Energy, the National Academy of Sciences (NAS), the White House Office of Management and Budget (OMB), the U.S. General Accounting Office (GAO), and other federal agencies and institutions. It clearly distinguishes in-progress peer review from other types of peer review, such as merit review to select winners of competitive solicitations or readiness (stage gate) reviews to determine when a technology is ready to move to the next phase of development, as well as from other management activities such as quarterly milestone reviews or budget reviews.

Peer reviews are one of the standard mechanisms for effective management of highly complex and/or technically challenging projects and programs and are widely used in industry, government, and academia. Experience has demonstrated that peer review is a powerful and effective tool for enhancing the relevance, effectiveness, and productivity of EERE research, development, demonstration, and deployment programs and business administration activities because it taps the experiences and insights of experts in the field.

Peer review is based on the premise that the people best qualified to judge a program or project are experts in that or related fields of knowledge. Seeking advice from experts is useful in all aspects of managing a program to add to the perspective and broaden the knowledge of a program manager. Peer review is essential in providing robust, documented feedback to EERE program planning. Peer review also provides management with independent confirmation of the effectiveness and impact of its programs. Knowledge about the quality and effectiveness of current projects and programs is essential in designing future programs and/or enhancing existing efforts.

A rigorous Peer Review was conducted as a five-day event from June 6 to10, 2011 at the Bethesda North Marriott Hotel and Conference Center located in Bethesda, MD. The purpose of the review was to evaluate DOE-funded projects for their contribution to the mission and goals of the Program, and to assess progress made against stated project objectives. PIs, representing a total DOE investment of over $350 million, came together to report progress and results. In addition to the formal review, this event was an excellent opportunity for the geothermal community, both funded researchers and stakeholders, to share ideas and solutions to address the challenges facing the geothermal industry.

The 2011Peer Review meeting was organized into five tracks with associated sessions and focused on the following geothermal technology areas:

- Systems Analysis, Resources Assessment, Data System Development and Population; Power Conversion Technology; and Stimulation/Fracture Prediction Modeling
- Enhanced Geothermal Systems Demonstrations; Seismicity and Reservoir Fracture Characterization; Specialized Materials and Geopolymer Sealing Materials
- High Temperature Tools, Sensors, Systems; Drilling Systems

[1] Peer Review Guide, Based on a Survey of Best Practices for In-Progress Peer Review, August 2004

- Low-Temperature, Co-Production, Geopressured Demonstration, Reservoir Exploration, Characterization and Modeling, Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
- Innovative Exploration Technology; Tracers and Tracer Interpretation

The objectives of the 2011 meeting were to review and evaluate the strategy and goals of the Geothermal Technologies Program; review and evaluate the progress and accomplishments of the Program's projects funded in FY2008 through FY2010; and foster information exchange among the national laboratories, industry, and academic institutions conducting research and development on behalf of the Program. GTP managers, staff, and researchers will consider findings from the Peer Review when setting priorities, conducting operations, and improving projects.

This document represents the Peer Review Panel's observations and findings, the response from the Geothermal Technologies Program Manager to these findings, and the supporting meeting materials including an agenda and list of participants.

2.1 Scoring Methodology for Projects Reviewed in FY2011

A total of 146 projects in the Geothermal Technologies Program's portfolio were reviewed at the meeting. Approximately 100 reviewers participated in the peer review process, providing a total of 553 project evaluations (not every panel member reviewed every project within a given track). There were up to five concurrent sessions over the course of the Peer Review, each with three to five reviewers. In accordance with DOE EERE Peer Review Guide Section 6.0[2], the reviewer submitted both quantitative (i.e., numerical scores) and qualitative (i.e., narrative accounts) evaluations as part of their review of the materials and projects presented. The comments herein are the most direct reflection of reviewer's written evaluations, and where possible have been included verbatim.

Quantitative scores were based on the following four criteria:

- Relevance/Impact of Research
- Scientific/Technical Approach
- Accomplishments, Results, and Progress
- Project Management/Coordination

Reviewers were asked to provide numeric scores (on a scale of 1 to 4, with 4 being the highest) for each of the four criteria. A description of the numerical scoring is provided below:

[2] Peer Review Guide, Based on a Survey of Best Practices for In-Progress Peer Review, August 2004

Numerical Scoring Descriptions

4 – Outstanding

The project has made substantial progress and impact on the DOE Geothermal Technologies Program missions and goals. The project has demonstrated outstanding advancement in addressing knowledge gaps and barriers. The project has exceptional impact on factors in geothermal energy development.

3 – Good

The project has made notable progress and impact on the DOE Geothermal Technologies Program missions and goals. The project has demonstrated significant advancement in addressing knowledge gaps and barriers. The project has considerable impact on factors in geothermal energy development.

2 – Fair

The project has made modest progress and impact on the DOE Geothermal Technologies Program missions and goals. The project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate impact on factors in geothermal energy development.

1 – Poor

The project has made little or no progress and impact on the DOE Geothermal Technologies Program missions and goals. The project has demonstrated little to no advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has marginal impact on factors in geothermal energy development.

The criteria were weighted differently across the 13 geothermal technology areas that were included in the 2011 Peer Review Meeting. Table 2.1 below illustrates the weighting of each criterion for each technology area. Scoring weight varies by technology area due to an effort by the Program to emphasize an alignment of areas of importance with the nature of the work performed.

Table 2.1 *Weighting of scoring criteria or metrics*

Technology Area	Relevance /Impact of Research	Scientific /Technical Approach	Accomplishments, Results, and Progress	Project Management /Coordination
Data Systems	15%	30%	30%	25%
Enhanced Geothermal Systems Demonstrations	20%	25%	40%	15%
High Temp Tools, Sensors, Systems, Drilling Systems	20%	30%	40%	10%
Innovative Exploration Technology	20%	25%	40%	15%
Low Temperature, Co-Production, Geopressured Demonstration	20%	25%	40%	15%
Power Conversion Technology	20%	30%	40%	10%
Reservoir Exploration, Characterization, and Modeling	20%	30%	40%	10%
Seismicity and Reservoir Fracture Characterization	20%	30%	40%	10%
Specialized Materials and Geopolymer Sealing Materials	20%	30%	40%	10%
Stimulation/Fracture Prediction Modeling	20%	30%	40%	10%
Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions	20%	30%	40%	10%
Systems Analysis, Resources Assessments,	20%	30%	25%	25%

Data System Development and Population				
Tracers and Tracer Interpretation	20%	30%	40%	10%

Reviews were conducted by different individual reviewers. For each project, an average score was calculated (from the combined scores of individual reviewers) for each of the four aforementioned criteria. These average scores were then weighted and combined to produce a final overall score for each project. In this manner, a project‘s final overall score can be meaningfully compared to that of another project. The following formula, where x = score and y = weight, was used to calculate the weighted, overall score:

Calculation:

{(x1*.y1) + (x2*.y2) + (x3*.y3) + (x4*.y4)}= total
{(4*.20) + (3 *.40) + (4*.15) + (4*.25)} = total
{(.8) + (1.20) + (.6) + (1)} = 3.6 total score

The ―total score” calculated using the formula above is averaged with the total score from all reviewers to produce the mean total score displayed in ―Average Project Score.” Scores and comments were submitted using laptops (provided on-site) to PeerNet, an online database, for real-time tracking of the review process.

3.0 Detailed Key Findings and Recommendations of the Peer Review Panel

Below are programmatic findings and recommendations that were compiled from the comprehensive collection of reviewer comments. In many tracks, independent reviewers provided similar comments, which are presented as one collective thought in this section. The comments presented below are focused towards the Program‘s technology areas and away from an individual project. All reviewer comments for an individual project were provided to that project‘s Principle Investigator for response. The comprehensive list of reviewer comments and PI responses can be found in Appendix A and B.

Systems Analysis, Resource Assessment, Data System Development and Population

- In general, the Program is currently conducting a robust analysis effort but needs to focus on defining a finite set of assumptions and obtaining the best estimates possible for those defined assumptions. Reviewers expressed some concerns that the Analysis Team may not comprise the appropriate individuals to achieve the goals set forth by the Program, particularly when it comes to addressing geothermal fracturing work.
- The Program should perform a thorough review of the redundant cost data to determine if there is enough data to validate analysis results and to find any inconsistencies.
- Projects in this technology area, particularly in the market and policy areas, are lacking hands-on input from industry. The Program should work to improve communication between these projects and industry, and should encourage PIs to review current work being conducted internationally.
- For future Funding Opportunity Announcements (FOA) or direct funding, the Program should consider requiring projects to have a project advisor from industry.
- Reviewers expressed some concerns regarding the Program‘s reliance on the Geothermal Electricity Technology Evaluation Model (GETEM) and the model‘s degree of robustness. The community seems to accept it, but reviewers feel the model needs formal validation because data systems analysts and users really need a sense for the quality of the data.
- Principal Investigators need to be encouraged to look at work conducted outside of the United States. A lot of work is being done internationally, which could be used to enhance project quality and learning.

Power Conversion

- The Program should ensure that some of the projects in the power conversion area are not ―reinventing the wheel.” Some reviewers expressed concerns that researchers may be looking at fluids that have been the market for awhile, and may be starting over rather than moving forward with new fluids and new analysis.
- The Program should focus additional efforts in the cost area for power conversion technologies. At this time there are zero Program efforts focused on costs.

Stimulation/Fracture Prediction Modeling

- The Program appears to be funding several redundant efforts in the fracture prediction modeling area. Reviewers expressed that some of these efforts may not be needed.
- The Program should require PIs to specify what the models can currently do and what the future plans are for improving upon current capabilities. Additionally, the Program should encourage more working group meetings which involve this group of PIs.

Enhanced Geothermal Systems Demonstrations

- The Program is funding numerous projects, with a wide range of maturity and level of effort, that are investigating several important issues in these technology areas. Project diversity is a major strength for this technology area, and reviewers feel the Newberry and Raft River projects have great potential.
- The variation in resource temperature and setting for these EGS projects is important because the diversity of settings will make results more robust.
- These projects are high risk and high reward. If successful, there is the potential for significant pay off, and it is possible that these projects will have implications for future economic and sustainable development strategies elsewhere.
- The Program needs to ensure better crossover between these projects and those developing tools.
- The Program should focus on the stress orientation and magnitude work and share the results more broadly with those PIs involved in these technology areas.
- A Phase 1 report should be prepared that addresses the following issues:
    - Explain the stimulation concept to be performed at site.
    - Communicate how this will be validated.
    - If the method was effective, explain the method and how it works.
    - Include a calculation on what should happen, and include alternative plans to account for surprises.

Seismicity and Reservoir Fracture Characterization

- In general, this technology area is performing highly relevant work to the Program. However, project execution issues may limit successes.
- Joint inversion for multiple geophysical datasets shows great promise, but it is not guaranteed that this will succeed beyond what could be done with a single geophysical technique alone. The issue of variable resolution in disparate datasets needs to be addressed.
- A combined geological-geomechanical approach to understand fracturing is a good start in meeting overall Geothermal Technologies Program objectives.
- This research addresses the core issues with regard to EGS monitoring. A successful project outcome would make a significant impact to the program. Monitoring and modeling fluid flow in the subsurface in an active EGS reservoir is key to successful application. Induced seismic events hold the key to understanding, tracking and controlling fracture creation; however, spatial coverage remains an inherent limitation.
- A combined geological-geomechanical approach to understand fracturing is a good start in meeting overall Program objectives.
- Waveform analysis may better identify faulting dynamics, thereby improving the understanding of geomechanical effects, which is one of the major goals of the project.

Specialized Materials and Geopolymer Sealing Materials

- Many of these projects address acute needs in the geothermal industry: zonal isolation and cementing. Further work in this area is recommended.
- The proprietary nature of many of these projects (i.e., not enough information provided) made it difficult to evaluate them thoroughly.
- The projects are in line with the objectives laid out for the broader mission and vision of the Program.

High Temperature Tools, Sensors, Systems, and Drilling Systems

- There are some near-term solutions that could potentially serve as stop-gaps or bridge solutions within this technology area. However, much of the implementation of these solutions is going to be market-driven. It would be helpful to know the thresholds where these technologies will be utilized, but it is nice to see that the research is occurring.

- Some projects have commercialization potential beyond the original scope of the research (e.g., geothermal needs). Some reviewers questioned whether or not the solutions are truly focusing on the needs of the geothermal industry.
- The Program should look at life-cycle costs. When targeting for 300ºC, with the result may be equipment that is over-designed based on industry need.
- Material science development projects are useful to the industry, though it is difficult to define their benefits.
- Some topics seem to be repeats of lessons learned from many years ago.
- The Program should consider developing a ―playground” for testing wells and/or house an example operating plant. The ―playground” could be called ―HADES” for ―Hot and Deep Energy Shop.”

Low Temperature, Co-Production, and Geopressured Demonstration

- A significant accomplishment to this Program area is the installation and commission of an actual power plant. This is directly contributing to the Program goals for installed capacity from this resource category.
- Reports on heat exchanger fouling, health of injection/production wells, efficiency of units, and other monitoring data can be seen as the real value of these projects. The Program needs to be committed to ensure such information is collected and widely disseminated.
- Data sharing was limited in some presentations due to ―Proprietary Information.” This impaired the ability to adequately assess the technical merits of these projects.

Reservoir Exploration, Characterization, and Modeling

- The Program should explore why different PIs are developing different codes. Some reviewers stated that PIs should be working together. Other reviewers noted that there will never be just one modeling code, but it may be possible to have one interface. If possible, the Program should convene a meeting with everyone in the modeling area a month prior to the next peer review to cross-compare similar problems.
- If the program continues to focus on TOUGHREACT, the simulator will have to be updated based on all the new experimental data that is quickly evolving and being produced.
- Computational resources should be taken into consideration; some codes need access to supercomputers to actually run, which may limit implementation.
- Within this portfolio some projects are intriguing and doing incremental work. They seem worthwhile and safe and are making decent progress. Other EGS projects were unclear on their objective and where they were going. These latter projects seem to be proving something already known.
- Industry is lacking focus on geostatistics.

Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions

- There are a lot of parallel activities in this technology area, and the Program should compile and consolidate the data for later use. Additionally, the Program needs to conduct more field applications and study the porosity and permeability effects of CO_2 in fracture networks. Currently, only porosity effects are being investigated in approximately nine projects and permeability effects appear to be ignored.
- The Program should have more CO_2 projects focused on investigating the effects of CO_2 and wet CO_2 on fracture networks.
- The Program should increase or encourage regular communication between the projects.
- The overall approach and strategy for these technology areas is fine, but the expertise is somewhat lacking (pure geologists are needed).
- Commercial developers need to weigh in and say whether or not the database has been sufficiently populated.
- The program is going to have to evolve beyond TOUGHREACT and be able to incorporate very different parameters that are emerging in this rapidly evolving field.

- The Program is currently obtaining a wide range of theoretical results and simulations. It would be useful to know what will be important and pertinent in field applications.

Innovative Exploration Technology

- Most of the projects in this technology area are doing good work. The Program should be aware that there is a big difference between the academic and industrial-led projects in this technology area.
- In many projects the innovative component is a combination of methods. However, sometimes these methods are all well established, well-studied, well-understood, and hence are not innovative. For example, putting multiple datasets together into one model does not seem like a very innovative approach.
- It may be useful to present a slide of Statement of Project Objectives (SOPO) tasks, and have the presenters explain where they currently are in terms of the project‘s objectives.

Tracers and Tracer Interpretation

- Regarding redundant work in this area, the Program should not reduce efforts to build the foundation of the knowledge base. However, it may be beneficial for the Program to ask for field test data from the PIs. Reviewers felt that many of the lab tests did not seem to come close to replicating the real world environment.
- The Program should explore the option to branch out from focusing on government laboratories and bring in a more diverse PI community.
- Tracer work in high temperature environments is a challenge. Starting with knowledge from work in low temperature and groundwater environments is encouraged.
- The Program should have better go/no-go decision points for some project, some that seem to lead to dead ends or to underwhelming results.
- It seems some projects are doing work that is putting the technology ahead of the science curve. Many of these projects are not ready to demonstrate. More constrained experiments are needed. Negative results are encouraged: if you‘re not getting negative results, you‘re not taking enough risks.

4.0 Project Scoring Evaluation Analysis and Results

As part of the 2011 U.S. DOE Geothermal Technologies Program Peer Review, 146 projects in 13 technology areas were reviewed by approximately 100 reviewers in this report. Analysis was performed based on project scores to determine if a correlation existed between the project scores and various project attributes. Project attributes considered for this analysis include total project funding, total project funding from the DOE, cost-share project funding, and the percentage of project completion based on schedule. These attributes were collected from the information given by the Principal Investigators in their presentation material. Correlation between project scores and project attributes (i.e., DOE/total project funding, completion of schedule, cost-share, etc.) could be either positive or negative. This could indicate that projects with a certain profile are perceived as performing better or it could show potential reviewer bias.

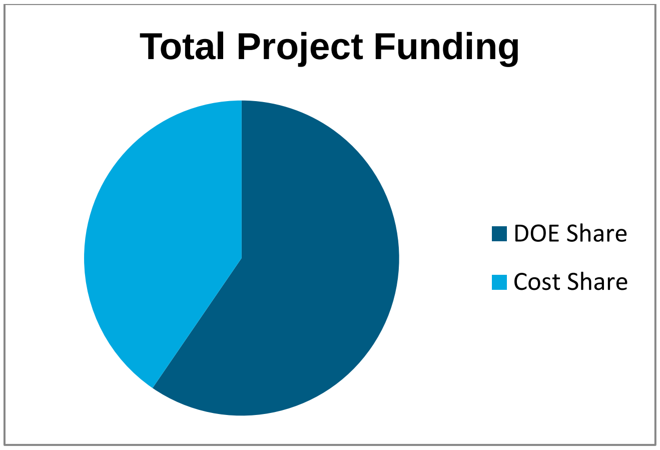


Figure 4.1. *Total Project Funding*

The budgetary attributes pertain to the entire project duration and are not indicative of or limited to project spending in the fiscal year of the Peer Review. The projects reviewed in 2011 totaled nearly $600 million in total project funding. As seen in Figure 4.1, approximately 60% of aggregate total project funding was provided by the DOE, while the remaining 40% consisted of cost-share funds.

Figure 4.2 is a scatter plot of project scores versus normalized total project funding. (The EGS demonstration projects were not included in this figure because their funding levels are significantly higher than the highest funded projects in any of the other 12 technology areas). From Figure 4.2, we see thatthere is no obvious correlation between the average project score of the project and the total funding for the project. DOE takes great care in reviewer selection and accurate project reporting, so it is not surprising that a correlation was not seen. While qualitative analysis of the trends in reviewer scores and comments is performed in the preparation of this report, this simple quantitative analysis further demonstrates the independent nature of the Peer Review process.

In addition to total project funding, similar analysis was performed on the project attributes of total project funding from DOE, cost-share project funding, and the percentage of project completion based on schedule. Again, clusters and wide distributions were seen with the scatter plots of the data for these attributes, indicating limited bias in reviews toward these project attributes. While this analysis does not reveal trends in project scoring, it does identify the low and high performing projects. This could be further examined to determine why peers considered certain projects successful or unsuccessful.

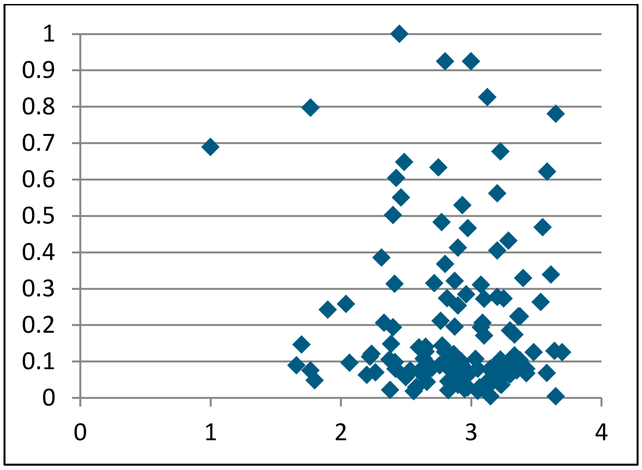


Figure 4.2. *Total Project Funding vs. Average Project Score (excludes EGS Demo projects)*

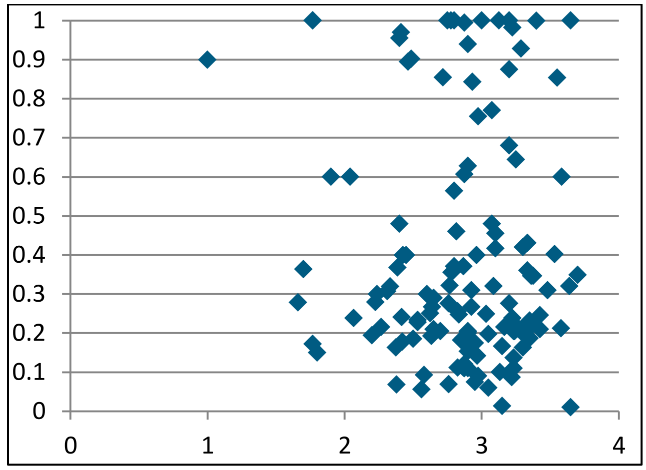


Figure 4.3. *DOE Project Funding vs. Average Project Score (excludes EGS Demo projects)*

Explanation of Figure 4.2 – 4.6:

The Y-axis is the ratio where the funding (whether total project, DOE-share, or cost-share) for each project is divided by the maximum amount. This gives the normalized value. For example, if the highest DOE funding was $5 million and the actual DOE funding for a particular project was $2.5 million, that project would show up as 0.5 on the Y-axis.

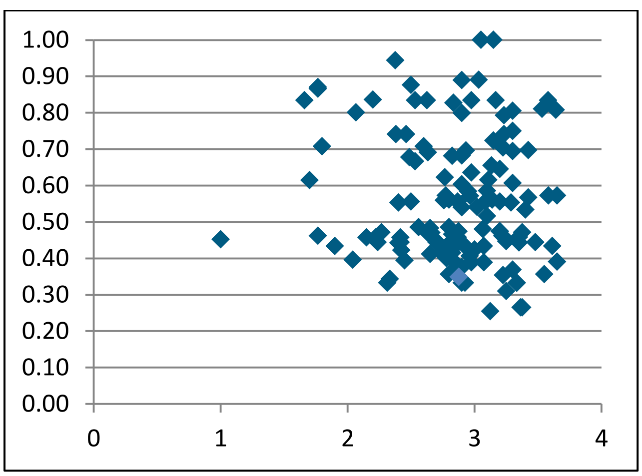


Figure 4.4. *Schedule Completion vs. Average Project Score*

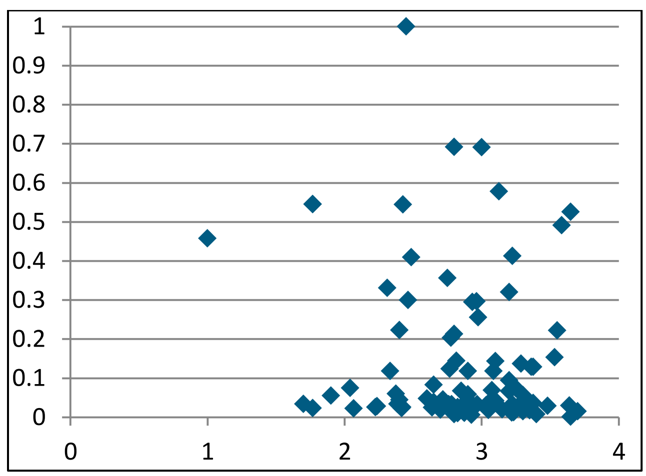


Figure 4.5. *Cost-Share Funding vs. Average Project Score (excludes EGS Demo projects)*

The following subsections describe the analysis of individual project scoring for each technology area included in the 2011 Peer Review. Also included in these subsections are callouts containing general or overview comments made by expert reviewers for each technology area. Detailed reviewer comments on individual projects are included in Appendix A, and PI responses to reviewer comments are included in Appendix B. PI responses had no effect on the final project score.

4.1 Data Systems Development and Population

The Program collects nationwide geothermal data, conducts analyses, and maintains this information in a National Geothermal Data System (NGDS) for widespread public use to reduce the upfront uncertainty and risk in geothermal development. DOE's research, development, and demonstration (RD&D) partners are required to submit data to the Geothermal Data Repository, a part of the NGDS. The NGDS will provide public access to geothermal data nodes across the country. In partnership with the American Association of State Geologists, geothermal data from all 50 states and Puerto Rico will also be publicly available and accessible through the NGDS. The NGDS is organized around the following strategy:

- **Systems Design, Development and Testing** – NGDS is being design and implemented as a distributed network of databases and data sites. The NGDS will provide both data from DOE sponsored RD&D and data from other geothermal-related entities.
- **Data Development, Collection and Maintenance** – Increase the capacity of the NGDS to accommodate new and legacy data. This will be accomplished through establishment of the DOE Geothermal Data Repository (GDR). This includes the acquisition of key data from DOE-funded geothermal RD&D projects and working with the U.S. Geological Survey to acquire and provide access to legacy data and data associated with the DOE-funded Geothermal Resource Assessment and Classification as well as other important new and legacy data. Another major strategy is to develop, collect, serve, and maintain geothermal-relevant data from state geologic survey-based providers.

Table 4.1 below provides a list of the Data Systems projects that were included in the 2011 Peer Review Meeting. The table includes the average total score per project, as well as the average score per project per metric.

Table 4.1 *Data Systems projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
National Geothermal Data System Architecture Design, Testing and Maintenance	Boise State University	Snyder, Walter	3.5	3.0	2.8	2.5	2.9
State Geological Survey Contributions to National Geothermal Data System Data Development, Collection and Maintenance	Arizona State Geological Survey	Allison, Lee	3.5	3.5	3.5	3.5	3.5
DOE Geothermal Data Repository	Boise State University	Snyder, Walter	3.5	3.0	2.5	3.0	2.9
Heat Flow Database Expansion for National Geothermal Data System Data Development, Collection and Maintenance	Southern Methodist University	Blackwell, David	3.8	3.8	3.5	3.5	3.6

The four Data Systems projects were scored by four reviewers. The final score for this technology was calculated using the weighting presented in Table 2.1. The final scores of the Data Systems technology area had an average, maximum, and minimum score of 3.2, 3.6, and 2.9 respectively. Figure 4.7 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

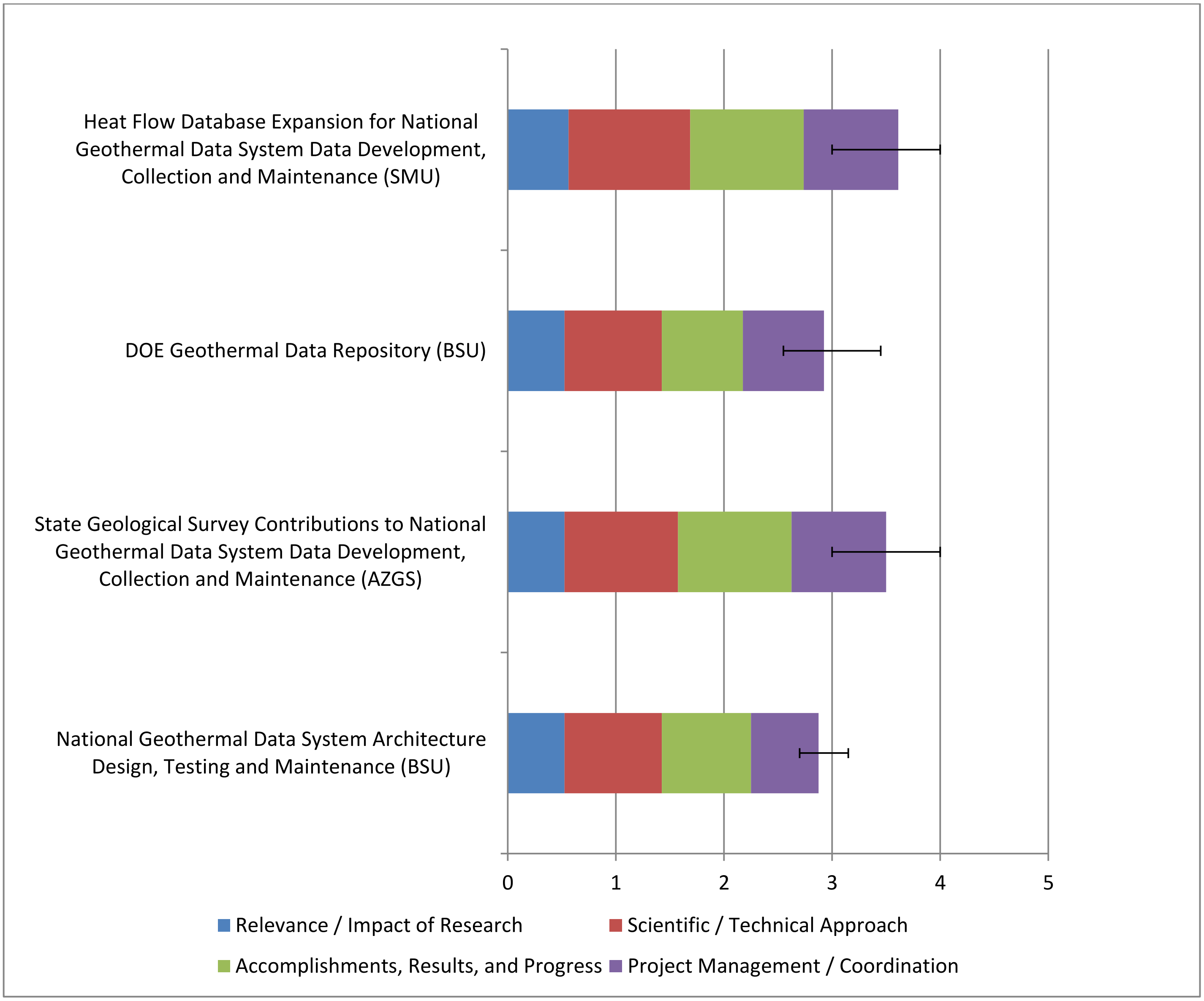


Figure 4.6. *Data Systems projects*

4.2 Enhanced Geothermal Systems (EGS) Demonstrations

The Program supports RD&D activities through academia, national laboratories, and industry partnerships that advance EGS technologies. EGS are engineered reservoirs created to produce energy from geothermal resources that are otherwise not economical due to a lack of water and/or permeability. EGS technology has the potential to unlock the vast amount of heat and energy located at depths accessible to current and future drilling technologies. This is a strategic domestic resource that can supply more than 100,000 MWe of clean baseload energy.

Key EGS activities are currently focused on:

- Demonstrating and validating currently available stimulation techniques, in a variety of geologic environments, that result in sustained production flow rates and heat extraction rates.
- Resolving key component R&D challenges related to extreme EGS environments.
- Optimizing reservoir flow rates and minimizing thermal drawdown to enable long-term, economical energy production.

Examples of EGS Technology Advancements Through R&D activities:

- Develop tools and models that better characterize fractures and fracture networks.
- Advance high temperature and high pressure tools, sensors and equipment.
- Gain public support through experience and better scientific understanding of induced seismicity.

Demonstrations Activities:

- Seven demonstration projects in Nevada, California, Oregon, Alaska, and Idaho
- Controlled hydraulic stimulation is underway at Desert Peak, NV (August 2011).

Figure 4.7. *Approach to EGS Technologies Development*

The Program invests in both near-hydrothermal field and greenfield EGS. The near-hydrothermal field EGS resource includes the areas around identified hydrothermal sites that lack sufficient permeability and/or in-situ fluids to be economically produced as conventional hydrothermal resources. Greenfield EGS is used to describe technology demonstration in geologic settings that have not been previously exploited as hydrothermal resources. Technologies of R&D solicitations have included: temperature-hardened submersible pumps; zonal isolation tools; smart tracers; high temperature, high pressure monitoring and logging tools; advanced seismic analysis for interpretation of fluid flow and induced seismicity; coupled models to predict reservoir development and performance; advanced mineral recovery from geothermal fluids; high temperature cements; directional drilling systems; measurement while drilling tools; well stimulation technologies; advanced fracture characterization technologies; and power conversion. While these technologies are vital to the success of EGS, they also apply to other types of geothermal power generation technologies (e.g., hydrothermal systems). Recent successes include improved reservoir models and the expansion of the suite of high temperature downhole tools available for geothermal energy applications.

"The stress orientation and magnitude work is critical to EGS. The GTP should focus on what other tools will allow for better data collection on this critical piece of the puzzle."

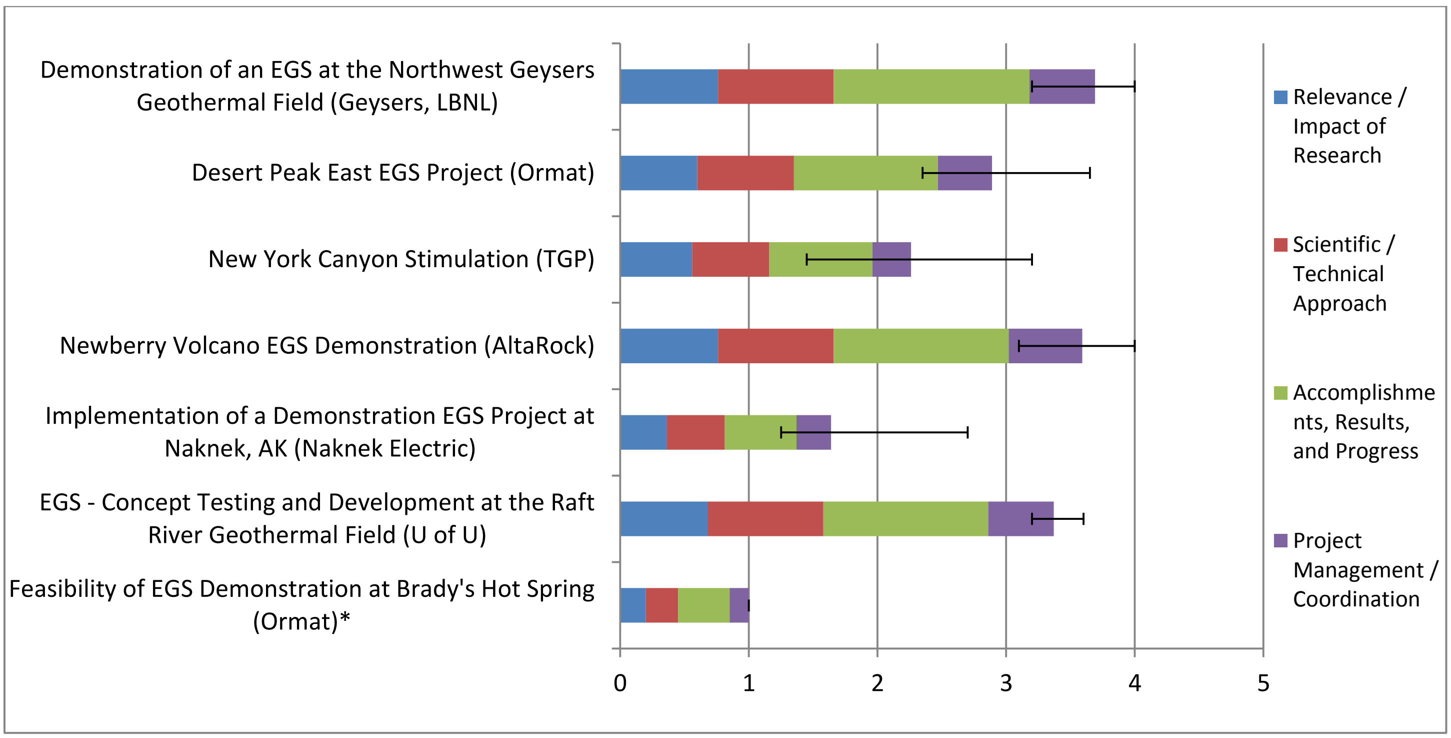
"There needs to be better cross-over between tools developed by projects in other technology areas and the demonstration projects."

Table 4.2 below provides a list of the EGS Demonstrations that were included in the 2011 Peer Review Meeting. The table includes the average total score, as well as the average score per project per criterion.

Table *4.2 EGS Demonstration projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Feasibility of EGS demonstration at Brady's Hot Spring	ORMAT	Drasko, Peter	1.0	1.0	1.0	1.0	1.0
Enhanced Geothermal Systems Concept Testing and Development at the Raft River Geothermal Field	University of Utah	Moore, Joseph	3.4	3.6	3.2	3.4	3.4
Implementation of a Demonstration EGS Project at Naknek, Alaska	Naknek Electric Association	Vukich, Donna	1.8	1.8	1.4	1.8	1.6
Newberry Volcano EGS Demonstration	AltaRock Energy, Inc.	Petty, Susan	3.8	3.6	3.4	3.8	3.6
New York Canyon Stimulation	TGP Development Company LLC	Raemy, Bernard	2.8	2.4	2.0	2.0	2.3
Desert Peak East EGS Project	ORMAT	Zemach, Ezra	3.0	3.0	2.8	2.8	2.9
Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Calpine - Geysers Power Company LLC	Walters, Mark	3.8	3.6	3.8	3.4	3.7

The seven projects reviewed were scored by five reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the EGS Demonstrations technology area had an average, maximum, and minimum score of 2.9, 3.7, and 1.0 respectively. Figure 4.9 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.



* This project was not presented for review

Figure 4.8. *EGS Demonstration projects*

4.3 High Temperature Tools, Sensors, Systems, Drilling Systems

The Recovery Act of 2009 allowed the Program to support research and development of high temperature tools, sensors, and drilling systems technology areas. High temperature tools and sensors are being designed to target specifications of 374°C and depths up to 10,000 m (supercritical reservoirs). In Drilling Systems technologies, increased rates of penetration (3x current rates of 10 ft/hr), reduce costs for drilling in hard rock environments, and 300°C tolerance with capabilities of reaching depths of up to 10,000 m are being developed. The Directional Drilling and Measurement-While-Drilling technologies focus on tool development to guide directional drilling operations and facilitate characterization of the rock mass/reservoir during drilling, including telemetry methods to transmit data to the surface and design and development of high performance bottom-hole assemblies.

"There seem to be some near-term solutions with some of these projects that could serve as stop-gaps or bridge solutions. However, much of the implementation of these solutions is going to be market-driven."

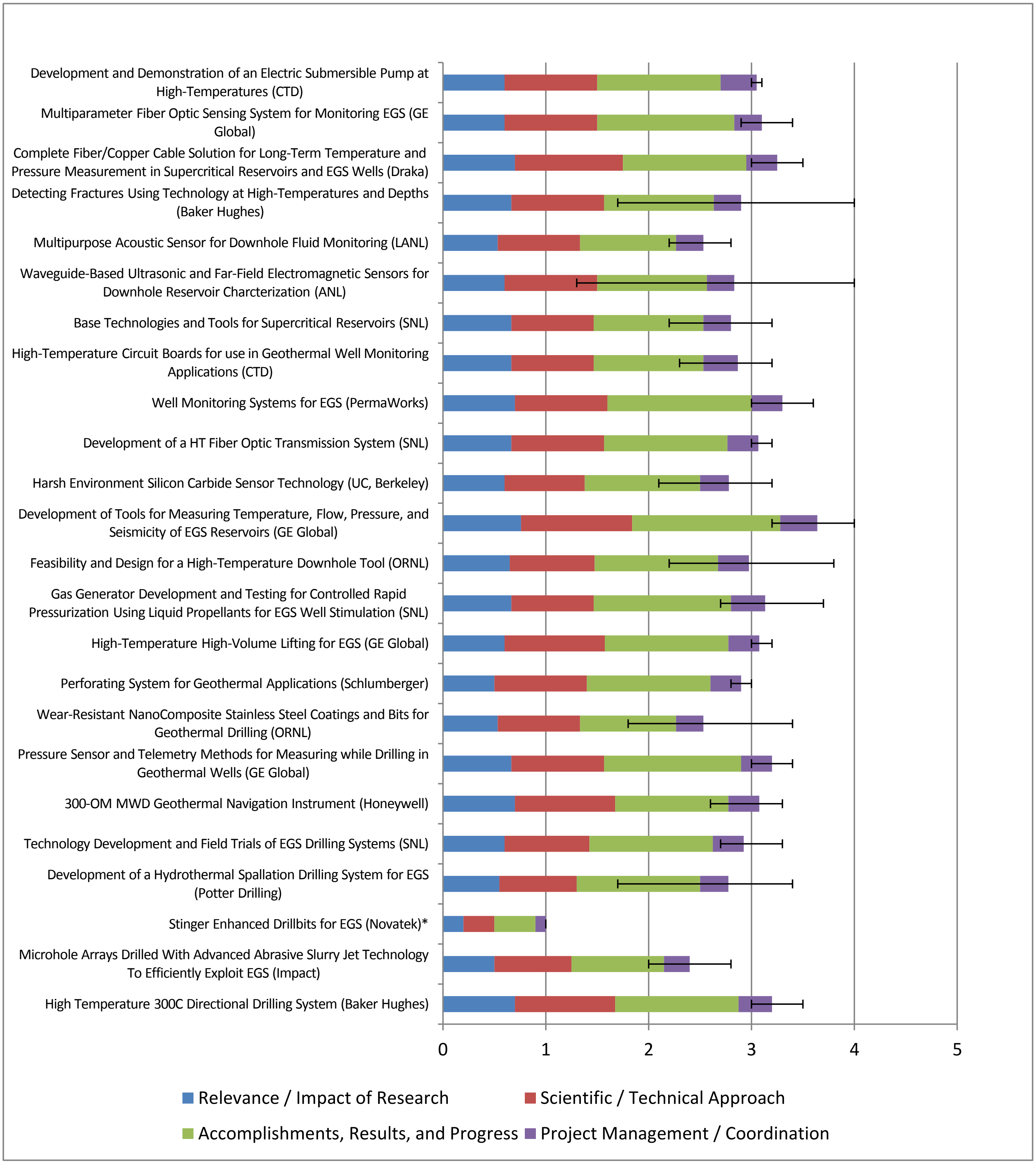
The Program continues to develop high temperature sensors and electronics, for both transient and permanent downhole applications, including tools for reservoir characterization and tracking reservoir evolution; real-time down-hole monitoring of temperature, pressure, fluid characteristics, and seismicity; tools for identification and tracking fluid flow paths, pre- and post-stimulation; and tools, techniques, and technologies for drilling/well completion. The Program is also enabling technologies for reservoir creation and sustainable operation including high temperature borehole packers and submersible pumps.

Table 4.3 below provides a list of the High Temperature Tools, Sensors, Systems, Drilling Systems projects that were included in the 2011 Peer Review. The table includes the total average scores, as well as the average score per project per criterion.

Table 4.3 *High Temperature Tools, Sensors, Systems, Drilling Systems projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments , Results, and Progress	Project Management/ Coordination	Average Total Score
High Temperature 300C Directional Drilling System, including drill bit, steerable motor, and drilling fluid, for Enhanced Geothermal Systems	Baker Hughes Oilfield Operations Inc.	Dick, Aaron	3.5	3.3	3.0	3.3	3.2
Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Impact Technologies, LLC	Oglesby, Kenneth	2.5	2.5	2.3	2.5	2.4
Roller cone and rotary drag drill bits with a novel cutting insert and a centralized jack/hammer are proposed for three fold increase in overall EGS drilling.	Novatek, Inc.	Hall, David	1.0	1.0	1.0	1.0	1.0
Development of a Hydrothermal Spallation Drilling System for EGS	Potter Drilling, Inc.	Potter, Jared	2.8	2.5	3.0	2.8	2.8
Technology Development and Field Trials of EGS Drilling Systems	Sandia National Laboratories	Raymond, David	3.0	2.8	3.0	3.0	2.9
Enhance And Deliver A High Temperature Directional Drilling Instrument For Geothermal MWD Tools	Honeywell International, Inc.	Anderson, Eric	3.5	3.3	2.8	3.0	3.1
Pressure Sensor and Telemetry Methods for Measurement while Drilling in Geothermal Wells	GE Global Research	Vert, Alexey	3.3	3.0	3.3	3.0	3.2
Resistant NanoComposite Stainless Steel Coatings and Bits for Geothermal Drilling	Oak Ridge National Laboratory	Peter, William	2.7	2.7	2.3	2.7	2.5
High Temperature Perforating System for Enhanced Geothermal Applications	Schlumberger Technology Group	Howard, Peter	2.5	3.0	3.0	3.0	2.9
High-Temperature High-Volume Lifting for Enhanced Geothermal Systems	GE Global Research	Turnquist, Norman	3.0	3.3	3.0	3.0	3.1
Gas generator development and testing for controlled rapid pressurization using liquid propellants for EGS well stimulation	Sandia National Laboratories	Grubelich, Mark	3.3	2.7	3.3	3.3	3.1
Feasibility and Design Studies for a High Temperature Downhole Tool	Oak Ridge National Laboratory	Akkurt, Hatice	3.3	2.8	3.0	3.0	3.0
300°C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems	GE Global Research	Vert, Alexey	3.8	3.6	3.6	3.6	3.6
Harsh Environment Silicon Carbide Sensor Technology for Geothermal Instrumentation	The Regents of the University of California	Pisano, Albert	3.0	2.6	2.8	2.8	2.8
Development of a High Temperature Fiber Optic Transmission System	Sandia National Laboratories	Henfling, Joe	3.3	3.0	3.0	3.0	3.1
Well Monitoring Systems for EGS	Perma Works	Normann, Randy	3.5	3.0	3.5	3.0	3.3
High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Composite Technology Development, Inc.	Hooker, Matthew	3.3	2.7	2.7	3.3	2.9
Base Technologies and Tools for Supercritical Reservoirs	Sandia National Laboratories	Henfling, Joe	3.3	2.7	2.7	2.7	2.8
Waveguide-Based Ultrasonic and Far-Field Electromagnetic Sensors for Downhole Reservoir Characterization	Argonne National Laboratory	Sheen, Shuh-Haw	3.0	3.0	2.7	2.7	2.8
Acoustic Sensor for Downhole Fluid	Los Alamos National Laboratory	Pantea, Christian	2.7	2.7	2.3	2.7	2.5
Geothermal Ultrasonic Fracture Imager	Baker Hughes Oilfield Operations Inc.	Patterson, Doug	3.3	3.0	2.7	2.7	2.9
Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Draka Cableteq USA, Inc.	Lowell, Mark	3.5	3.5	3.0	3.0	3.3
Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems	General Electric Company	Challener, William	3.0	3.0	3.3	2.7	3.1
High-Temperature Motor Windings for Downhole Pumps Used in Geothermal Energy	Composite Technology Development, Inc.	Hooker, Matthew	3.0	3.0	3.0	3.5	3.1

Overall, the High Temperature Tools, Sensors, Systems, Drilling Systems technology area had 24 project reviews performed. The 24 projects were scored by an average of 3.4 reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area The final scores of the High Temperature Tools, Sensors, Systems, Drilling Systems technology area had an average, maximum, and minimum score of 2.9, 3.6, and 1.0 respectively. The minimum score represents a project that did not present nor attend the 2011 Peer Review. Figure 4.10 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.



*This project was not presented for review

Figure 4.9. *High Temperature Tools, Sensors, Systems, Drilling Systems projects*

4.4 Innovative Exploration Technology

The Program is working with industry to develop exploration tools and methodologies to reduce the high upfront risk of confirming new hydrothermal resources. Best practices for geothermal exploration, which include geologic research, remote sensing, and both surface and downhole geochemistry and geophysical techniques and how they are used throughout the U.S, are being developed. These best practices will help establish technical and cost targets. The Innovative Exploration Technologies funded through the Recovery Act of 2009 has a goal of confirming 400 MWe of new geothermal resources.

Some specific technology areas requiring advancement are noninvasive geophysical techniques and improved data collection and interpretation of existing techniques; improved invasive measurement tools and techniques; geophysical airborne data gathering techniques; coupled geophysical inversion techniques; improved geochemical techniques for exploration and reservoir characterization; high resolution remote sensing data and reliable automated processing methods; stress/strain data mapping; multidisciplinary conceptual models; 3-D modeling software; identification of surface signals that identify deeper, hidden systems; and the creation of case study examples of geothermal systems in different geologic settings.

Table 4.4 below provides a list of the Innovative Exploration Technology projects that were included in the 2011 Peer Review Meeting. The table includes the average total project scores, as well as the average score per project per criterion.

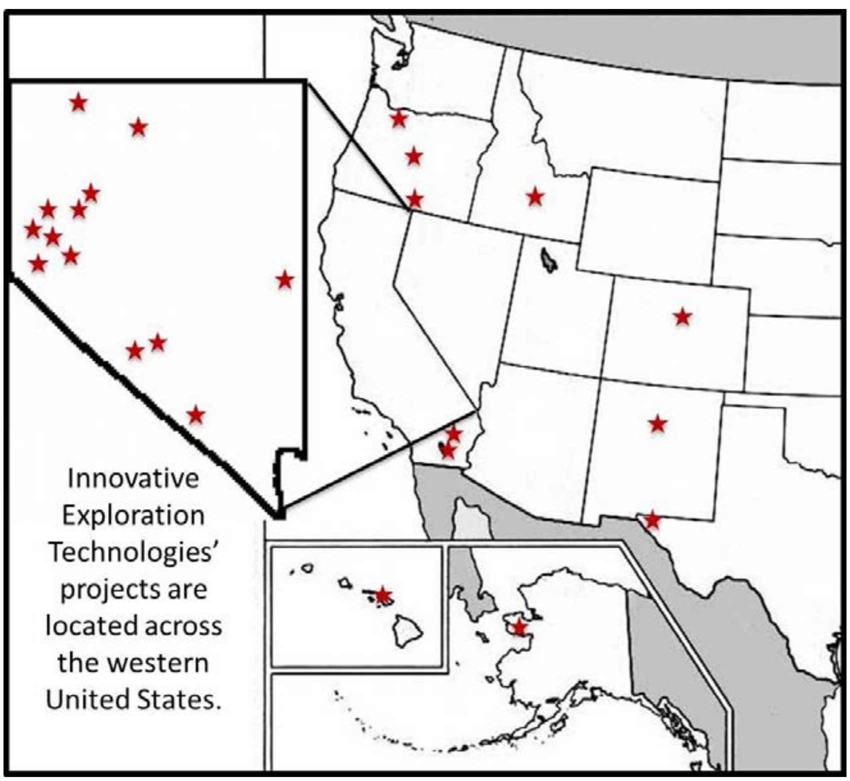


Figure 4.10. *Location of Innovative Exploration Technology Projects*

Table 4.4 *Innovative Exploration Technology projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Black Warrior: Sub-soil Gas and Fluid Inclusion Exploration and Slim Well Drilling	Newberry Geothermal Holdings, LLC	Casteel, John	3.7	2.3	1.7	2.3	2.3
Caldwell Ranch Exploration and Confirmation Project	Geysers Power Company, LLC	Walters, Mark	3.3	3.3	4.0	3.7	3.7
Innovative exploration techniques for geothermal assessment at Jemez Pueblo, New Mexico	Pueblo of Jemez	Kaufman, Greg	3.0	3.5	3.5	3.5	3.4
Detachment faulting and Geothermal Resources - An Innovative Integrated Geological and Geophysical Investigation in Fish Lake Valley, Nevada	University of Kansas Center for Research, Inc.	Stockli, Daniel	3.7	2.7	2.7	2.3	2.8
Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada	Geothermal Technical Partners, Inc.	Zehner, Rick	3.3	2.3	2.7	3.0	2.8
Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss	El Paso County	Lear, John	2.3	2.3	3.0	3.3	2.8
New River Geothermal Research Project, Imperial County, CA	Ram Power, Inc.	Johnson, Stuart	3.0	3.0	3.0	3.0	3.0
Away from the Range Front: Intra-basin Geothermal Exploration	GeoGlobal Energy LLC	Spinks, Karl	3.3	2.7	2.7	2.7	2.8
Merging high resolution geophysical and geochemical surveys to reduce exploration risk at Glass Buttes, Oregon	ORMAT Nevada, Inc.	Walsh, Patrick	3.3	3.3	3.0	3.3	3.2
Alum Innovative Exploration Project	Sierra Geothermal Power, Inc.	Ronne, Joel	2.0	2.0	1.7	1.3	1.8
Silver Peak Innovative Exploration Project	Sierra Geothermal Power, Inc.	Ronne, Joel	2.0	2.0	1.7	1.3	1.8
Validation of Innovative Exploration Techniques Pilgrim Hot Springs, Alaska	University of Alaska Fairbanks	Holdmann, Gwen	2.7	2.7	2.7	3.0	2.7
Blind Geothermal System Exploration in Active Volcanic Environments; Multi-phase Geophysical and Geochemical Surveys in Overt and Subtle Volcanic Systems, Hawaii and Maui	ORMAT Nevada, Inc.	Martini, Brigette	3.5	3.5	3.0	3.0	3.2
Use Remote Sensing Data (selected visible and infrared spectrums) to locate high temp ground anomalies in Colorado.Confirm heat flow potential w/ on-site temp surveys to drill deep resource wells	Flint Geothermal LLC	Robinson, F. Lee	2.7	2.3	2.3	2.3	2.4
Finding Large Aperature Fractures in Geothermal Resource Areas Using a Three-Component Long-Offset Surface Seismic Survey, PSInSAR and Structural Kinematic Analysis	U.S. Geothermal, Inc.	Teplow, William	3.0	2.8	3.0	3.3	3.0
Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA	ORMAT Nevada, Inc.	Matlick, Skip	2.5	2.5	2.5	2.3	2.5
A 3D-3C Reflection Seismic Survey and Data Integration to Identify the Seismic Response of Fractures and Permeable Zones over a Known Geothermal Resource: Soda Lake, Churchill County, Nevada	Magma Energy Corp.	Benoit, Dick	2.7	3.0	2.7	3.0	2.8
Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System (An Alternative to Grid-Drilling for Geothermal Exploration): McCoy, Churchill County, Nevada	Magma Energy Corp.	Benoit, Dick	2.8	2.3	2.5	2.5	2.5
Advanced Seismic Data Analysis Program ('Hot Pot Project') - Alytical Techniques of Coherency First Arrival Data Processing and Full Waveform Inversion Velocity Model and Validation by Drilling Wells	OSKI Energy LLC	Moore, Shuman	2.7	3.0	3.0	3.0	2.9
Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Pyramid Lake Paiute Tribe	Noel, Donna	2.5	2.3	2.3	3.0	2.4
Application of 2D VSP Imaging Technology to the Targeting of Exploration and Development Wells in a Basin and Range Geothermal System, Humboldt House-Rye Patch Geothermal Area, Pershing County, Nevada	Presco Energy, Inc.	Ellis, Richard	3.0	3.3	3.0	3.3	3.1
The Snake River Geothermal Drilling Project: Innovative Approaches to Geothermal Exploration	Utah State University	Shervais, John	3.3	3.3	3.3	3.5	3.3
We propose to explore and commercially develop blind (no surface evidence) convective hydrothermal systems associated with a young silicic pluton on the flanks of Newberry Volcano, Oregon.	Newberry Geothermal Holdings, LLC	Waibel, Albert	3.5	3.3	3.0	2.8	3.1
Crump Geyser: High Precision Geophysics & Detailed Structural Exploration and Slim Well Drilling	Newberry Geothermal Holdings, LLC	Casteel, John	3.3	3.0	3.0	3.3	3.1

Overall, the Innovative Exploration technology area had 24 project reviews performed. The 24 projects were scored by an average of 3.4 reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Innovative Exploration technology area had an average, maximum, and minimum score of 2.8, 3.7, and 1.8 respectively. Figure 4.11 shows each scoring metrics‘ weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

Figure 4.11. *Innovative Exploration Technology projects*

4.5 Low Temperature, Co-Production, Geopressured Demonstration

The Program works with industry and academia to develop and deploy new low temperature and co-production technologies that will help the geothermal community achieve widespread adoption of under-utilized, low temperature resources.

Low temperature geothermal energy is defined as heat obtained from geothermal fluid at temperatures of 300°F (150°C) or less. These resources are typically used in direct-use applications, such as district heating, greenhouses, fisheries, mineral recovery, and industrial process heating. However, some low temperature resources can be harnessed to generate electricity using binary cycle power system technology.

Approximately 25 billion barrels of co-produced hot water is produced each year from oil and gas operation in the United States. Historically this hot water has been an inconvenience and requires proper disposal; however, it is now being looked at as a resource to produce electricity for in-field use or to be sold to the grid. Co-produced geothermal resources have the potential to extend the economic life of oil and gas fields as well as engage the oil and gas sector in the geothermal market.

Projects funded by the Program in this technology area work toward a goal of achieving widespread production of low temperature power through demonstration of economic power generation from co-produced fluids, data collection and dissemination, and increased collaboration between government and industry. These efforts benefit from program-wide component research and development to drive down capital and operating costs through improved efficiencies in working fluids, cooling systems, heat exchangers, and other system components. The Energy Independence and Security Act (EISA) of 2007 provided the blueprint, and the Recovery Act of 2009 provided the financial support to initiate the low temperature portfolio.

Table 4.5 below provides a list of the Low Temperature, Co-Production, Geopressured Demonstration projects that were included in the 2011 Peer Review Meeting. The table includes the average total project scores, as well as the average score per project per criterion.

Table 4.5 *Low Temperature, Co-Production, Geopressured Demonstration projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Beowawe Bottoming Binary Project	Beowawe Power, LLC	McDonald, Dale	2.8	2.8	3.0	3.5	3.0
Dixie Valley Bottoming Binary Project	Terra-Gen Sierra Holdings, LLC	McDonald, Dale	2.5	2.3	2.3	3.3	2.5
Rural Cooperative Geothermal Development Electric and Agriculture	Surprise Valley Electrification Corporation	Silveria, Daniel	2.8	2.3	2.3	2.8	2.4
Low Temperature Geothermal at Klamath Falls	City of Klamath Falls	Brown, Brian	2.5	2.5	2.0	3.0	2.4
Novel Energy Conversion Equipment for Low Temperature Geothermal Resources	Johnson Controls, Inc.	Minor, Eric	3.0	2.5	2.3	3.5	2.7
Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas	Universal GeoPower LLC	Luchini, Chris	2.5	2.3	2.0	3.0	2.3
Electric Power Generation from Co-Produced Fluids from Oil and Gas Wells	University of North Dakota	Gosnold, William	3.3	3.5	3.5	3.0	3.4
Electric Power Generation from Low to Intermediate Temperature Resources	University of North Dakota	Gosnold, William	3.5	3.5	3.3	3.3	3.4
Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources	Oasys Water	McGinnis, Robert	3.3	2.8	2.8	2.8	2.9

Overall, the Low Temperature, Co-Production, Geopressured Demonstration technology area had nine project reviews performed. The nine projects were scored by an average of four reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores for this technology area had an average, maximum, and minimum score of 3.0, 3.4, and 2.3 respectively. Figure 4.12 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

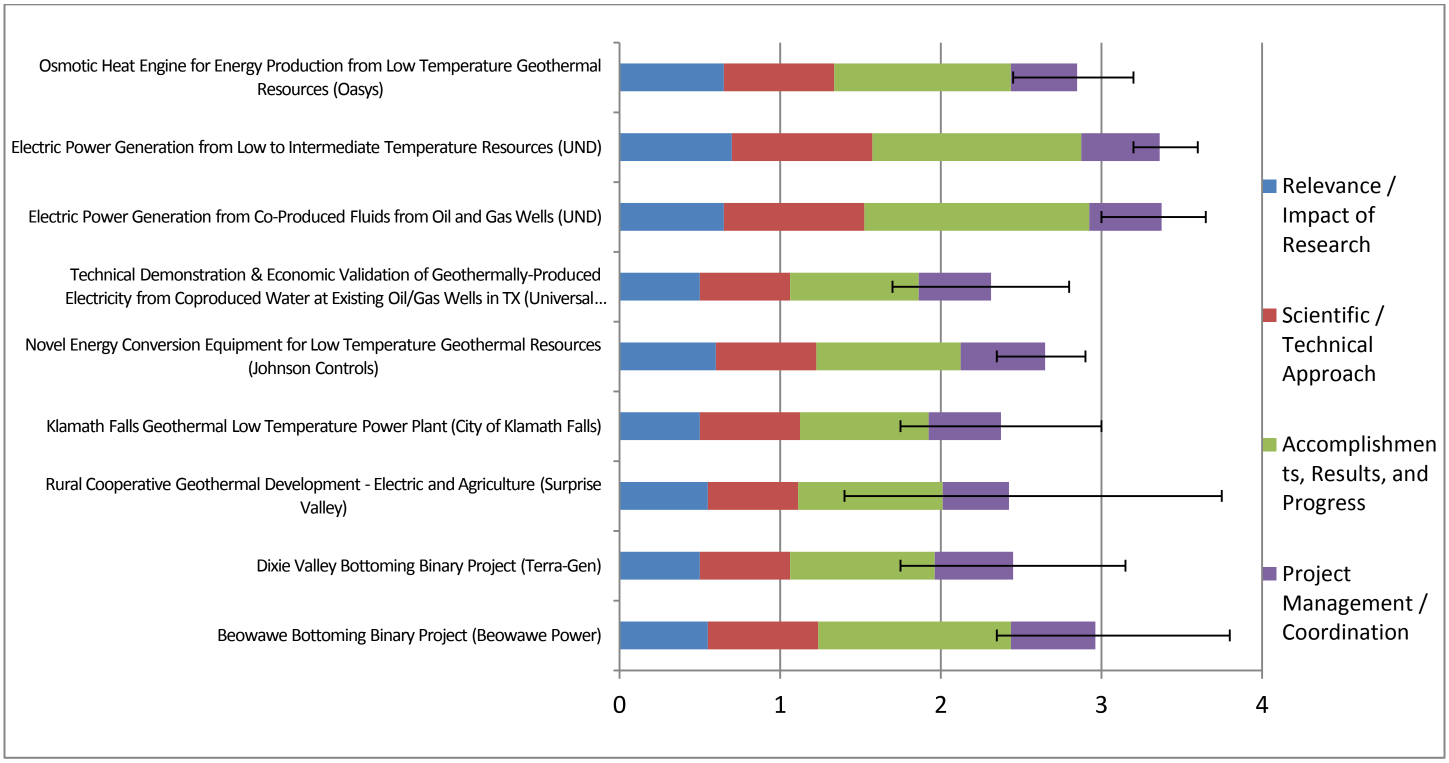


Figure 4.12. *Low Temperature, Co-Production, Geopressured Demonstration projects*

4.6 Power Conversion Technology

While much of the Program‘s R&D efforts for 2008 and 2009 focused on activities and funding on EGS, there continues to be a need to overcoming the challenges facing the continued expansion of electricity generation from hydrothermal resources. Many of the R&D activities for EGS will greatly benefit the existing hydrothermal power industry. Of particular application to all geothermal resources is the Program‘s R&D activity of advancing energy conversion technologies. The Program‗s efforts are directed to the development of more efficient power conversion systems that maximize the power generated for sale.

"More focus and efforts are required in the cost area. Currently, there are zero efforts focused on costs."

Table 4.6 below provides a list of the Power Conversion projects that were included in the 2011 Peer Review meeting. The table includes the average total project scores, as well as the average score per project per metric.

Table 4.6 *Power Conversion projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
High Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	GE Global Research	Klockow, Helge	2.0	2.0	1.7	2.3	1.9
Tailored Working Fluids for Enhanced Binary Geothermal Power Plants	United Technologies Research Center	Mahmoud, Ahmad	2.3	1.7	1.3	2.0	1.7
Working Fluids and their Effect on Geothermal Turbines	Oak Ridge National Laboratory	Sabau, Adrian	2.7	2.0	2.0	2.7	2.2
Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems	Pacific Northwest National Laboratory	McGrail, Peter	2.7	3.0	2.0	2.7	2.5
Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Argonne National Laboratory	Jody, Bassam	3.7	3.7	3.0	3.0	3.3
Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources	Energent Corporation	Hays, Lance	3.3	3.7	3.7	3.0	3.5
Optimization of hybrid-water/air-cooled condenser in an enhanced turbine geothermal ORC system	United Technologies Research Center	Wu, Hailing	2.0	2.0	2.0	2.7	2.1
Hybrid and Advanced Air Cooling	National Renewable Energy Laboratory	Bharathan, Desikan	2.3	2.0	2.3	2.7	2.3
Air-Cooled Condensers in Next-Generation Conversion Systems	Idaho National Laboratory	Mines, Greg	2.3	2.7	2.7	3.0	2.6

Overall, the Power Conversion technology area had nine project reviews performed. The nine projects were scored by an average of three reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Power Conversion technology area had an average, maximum, and minimum score of 2.5, 3.5, and 1.7 respectively. Figure 4.13 shows each scoring metrics‘ weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

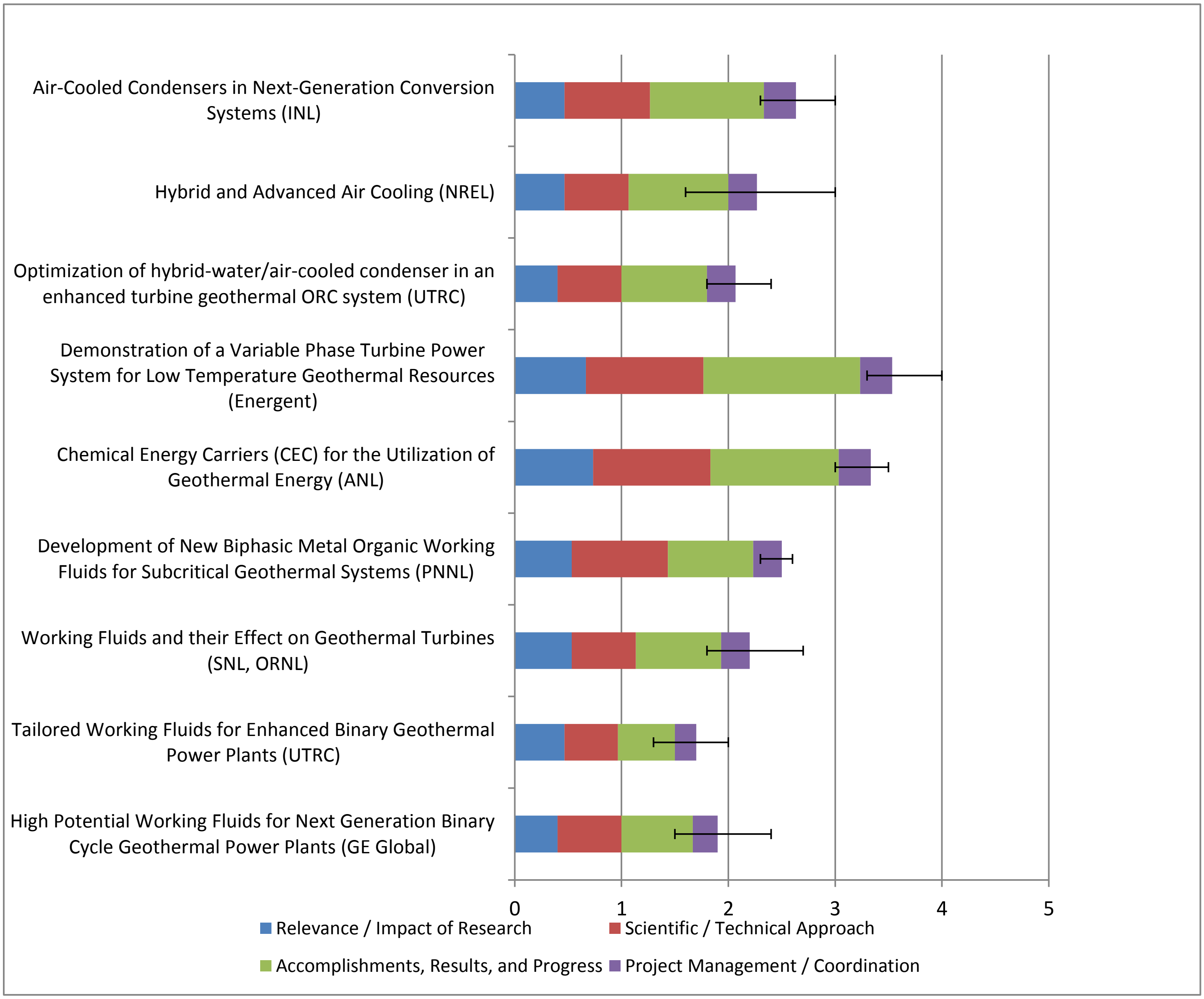


Figure 4.13. *Power Conversion projects*

4.7 Reservoir Exploration, Characterization and Modeling

Through various efforts that were reviewed in the Reservoir Exploration, Characterization and Modeling sessions, the Program aims to improve subsurface imaging, reservoir characterization by geophysical methods, and imaging of fluid containing fractures, as well as to develop modeling capabilities that couple Thermal-Hydraulic-Mechanical-Chemical (THMC) processes.

Within the Reservoir Exploration, Characterization and Modeling technology area, activities are focused on:

- Identifying geologic environments that are favorable to creating EGS.
- Identifying the most cost-effective geophysical methods and how they are applied for identifying undiscovered geothermal resources.
- Improving fracture and flow imaging using electrical resistivity.
- Developing joint geophysical inversion techniques.
- Developing a reservoir-scale fully coupled THMC models.

"Each project in this technology area is looking at different problems. Stronger communication between Principal Investigators may be critical to success for these projects."

Table 4.7 below provides a list of the Reservoir Exploration, Characterization and Modeling projects that were included in the 2011 Peer Review Meeting. The table includes the average total project scores, as well as the average score per project per metric.

Table 4.7 *Reservoir Exploration, Characterization and Modeling projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling	Lawrence Berkeley National Laboratory	Newman, Gregory	3.3	3.3	2.5	2.8	2.9
Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-Dimensional Electrical Resistivity Structure	University of Utah	Wannamaker, Phillip	3.0	3.3	2.5	2.5	2.8
Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	Board of Regents NSHE on behalf of the University of Nevada Reno	Faulds, James	3.8	3.3	3.3	3.3	3.4
Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation	AltaRock Energy, Inc.	Iovenitti, Joe	3.3	2.5	2.5	2.5	2.7
Integrated Chemical Geothermometry System for Geothermal Exploration	Lawrence Berkeley National Laboratory	Spycher, Nicolas	3.3	2.8	3.0	3.0	3.0
Coupled Thermal-Hydrological-Mechanical-Chemical Model and Experiments for Optimization of Enhanced Geothermal System Development and Production	Lawrence Berkeley National Laboratory	Sonnenthal, Eric	3.3	3.5	3.5	3.3	3.4
Development of Advanced Thermal-Hydrological-Mechanical-Chemical (THMC) Modeling Capabilities for Enhanced Geothermal Systems	Colorado School of Mines	Wu, Yu-Shu	3.3	3.3	3.3	3.0	3.2
THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity	Pennsylvania State University	Elsworth, Derek	3.8	3.5	3.3	2.8	3.4
Modeling and Simulation of EGS Reservoir Thermal Performance	Sandia National Laboratories	Desilets, Darin	2.7	2.0	1.3	1.3	1.8
A New Analytic-Adaptive Model for EGS Assessment, Development and Management Support	Board of Regents NSHE on behalf of the University of Nevada Reno	Danko, George	3.0	2.8	2.8	3.0	2.8

Overall, the Reservoir Exploration, Characterization and Modeling technology area had 10 project reviews performed. The 10 projects were scored by an average of four reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Reservoir Exploration, Characterization and Modeling technology area had an average, maximum, and minimum score of 2.9, 3.4, and 1.8 respectively. Figure 4.14 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

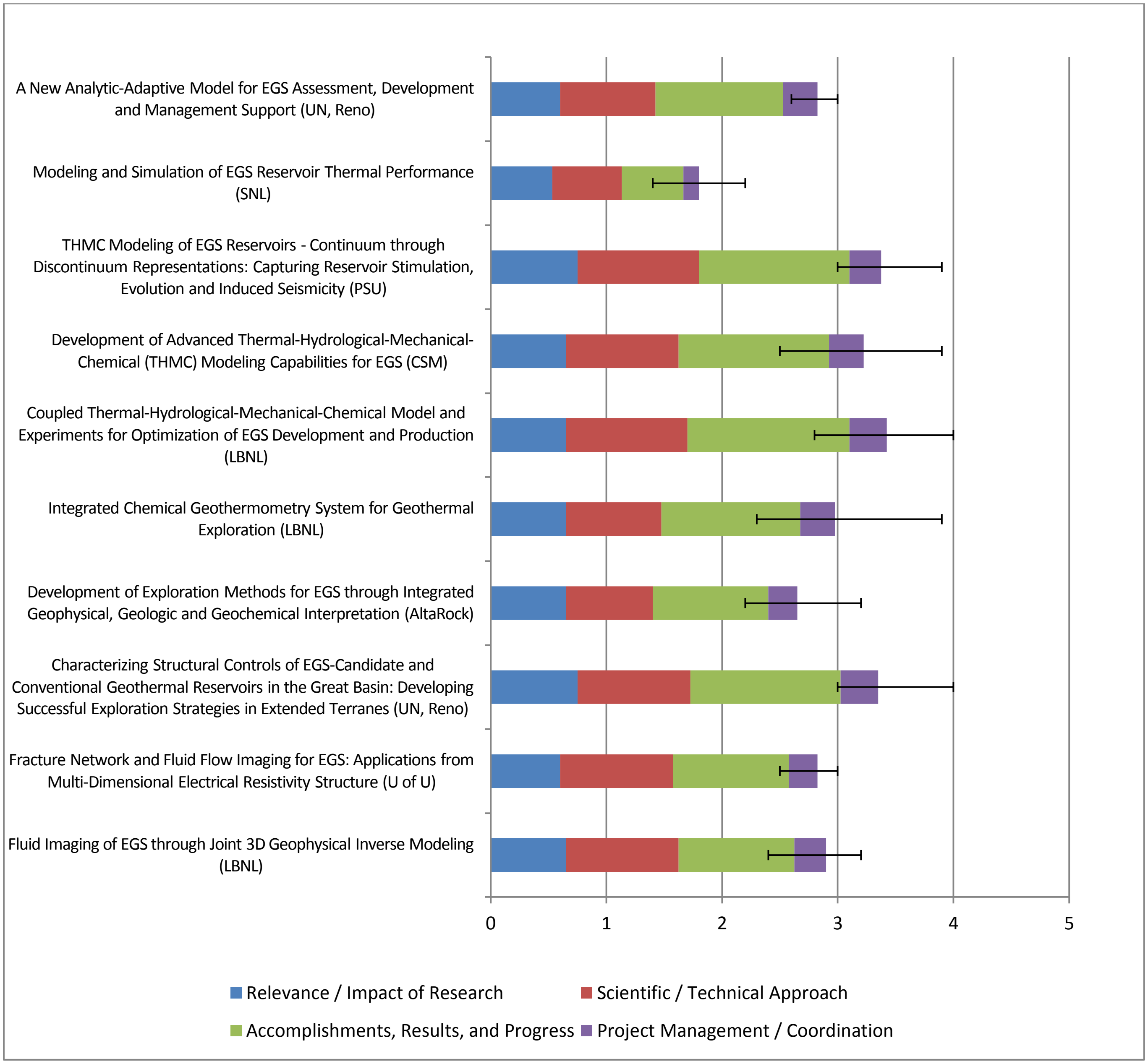


Figure 4.14. *Reservoir Exploration, Characterization and Modeling projects*

4.8 Seismicity and Reservoir Fracture Characterization

Reservoir stimulation (hydraulic, thermal, and/or chemical) is an essential step in creating an EGS. Seismic imagining, understanding and monitoring microearthquakes (MEQ), and fracture characterization are paramount R&D areas for EGS and have relevance to hydrothermal system as well.

Although hydraulic fracturing has been used for reservoir performance enhancements purposes for nearly 60 years in the petroleum sector, the distinct characteristics of geothermal systems make a direct application difficult. The current EGS conceptual model, which is built from field observations, is that permeability enhancement results from predominantly shear failure. The seismic energy released during reservoir stimulation provides the best means of locating and characterizing resulting fracture. The collection and interpretation of these seismic signals is thus crucial for creating an effective subsurface heat exchanger. EGS risk and hazard assessment will benefit greatly from better microearthquake predictions and simulation abilities currently under development.

Overall, the effects of mineral deposition on EGS reservoir performance is poorly understood and potentially significantly underestimated. Because EGS reservoirs have inherently low permeabilities, any mineralization that reduces fracture apertures and hydraulic conductivities can have a substantial effect on production and injection rates. This problem can affect EGS reservoirs where power is produced by either flash or binary cycle plants.

"The Program should encourage more working group meetings that involve the current Principal Investigators."

Comprehensive analysis and collection of experimental high resolution seismic, rock property, and hydrologic data are needed to identify mechanisms and thresholds/triggers of fracturing in different EGS candidate environments with different geologic and thermal settings. Knowing the processes and parameters that control induced shear fracturing will aid industry in optimizing reservoir stimulations.

The Program is developing surface and borehole seismic methodologies using both compressional and shear waves for characterizing fractures in EGS. Additionally, the Program is developing high resolution, microearthquake tools and methods suited to monitoring EGS-induced microearthquakes. The Program is also focused on developing joint geophysical imaging methodologies for geothermal site characterization and demonstrating their potential at three locations: Krafla volcano and associated geothermal fields in Northeastern Iceland, the Reykjanes-Hengill area in Southwestern Iceland that includes a number of producing geothermal facilities, and Coso Hot Springs in California.

Table 4.8 below provides a list of the Seismicity and Reservoir Fracture Characterization projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.8 *Seismicity and Reservoir Fracture Characterization projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems	Massachusetts Institute of Technology	Toksoz, Nafi	3.5	2.8	2.8	2.8	2.9
Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir	Massachusetts Institute of Technology	Fehler, Michael	3.7	3.7	2.0	3.3	3.0
Joint Inversion of Electrical and Seismic Data for Fracture Characterization and Imaging of Fluid Flow in Geothermal Systems	Colorado School of Mines	Batzle, Michael	3.5	3.0	3.0	3.5	3.2
Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks	The University of Texas at Austin	Hardage, Bob	2.3	2.0	2.3	2.8	2.2
Characterizing Fractures in Geysers Geothermal Field from Microseismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	University of Southern California	Aminzadeh, Fred	3.3	2.5	2.3	3.0	2.6
Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments (GEYSERS)	Texas Engineering Experiment Station	Ghassemi, Ahmad	3.3	3.5	3.3	3.0	3.3
Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions With Microearthquake Data for 3D Velocity Structure, Earthquake Locations, and Moment Tensors in Geothermal Reservoirs	William Lettis & Associates	O'Connell, Daniel	3.5	3.3	3.3	2.8	3.3
Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems	Array Information Technology	Gritto, Roland	3.5	3.5	3.3	3.0	3.4
Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Lawrence Livermore National Laboratory	Templeton, Dennise	2.3	2.3	2.7	2.7	2.5
Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in EGS Reservoirs	Los Alamos and National Energy Technology Laboratories	Huang, Lianjie	3.0	3.0	2.7	3.0	2.9
Joint Seismic-EM Inversion	Lawrence Berkeley National Laboratory	Newman, Gregory	3.3	2.5	3.0	2.8	2.9
Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems	Lawrence Berkeley National Laboratory	Majer, E. L.	4.0	3.5	3.8	3.5	3.7
Distributed Thermal Pertubation Sensing	Lawrence Berkeley National Laboratory	Freifeld, Barry	3.3	3.0	2.8	3.0	3.0

Overall, the Seismicity and Reservoir Fracture Characterization technology area had 13 project reviews performed. The 13 projects were scored by an average of 3.8 reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Seismicity and Reservoir Fracture Characterization technology area had an average, maximum, and minimum score of 3.0, 3.7, and 2.2 respectively. Figure 4.15 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

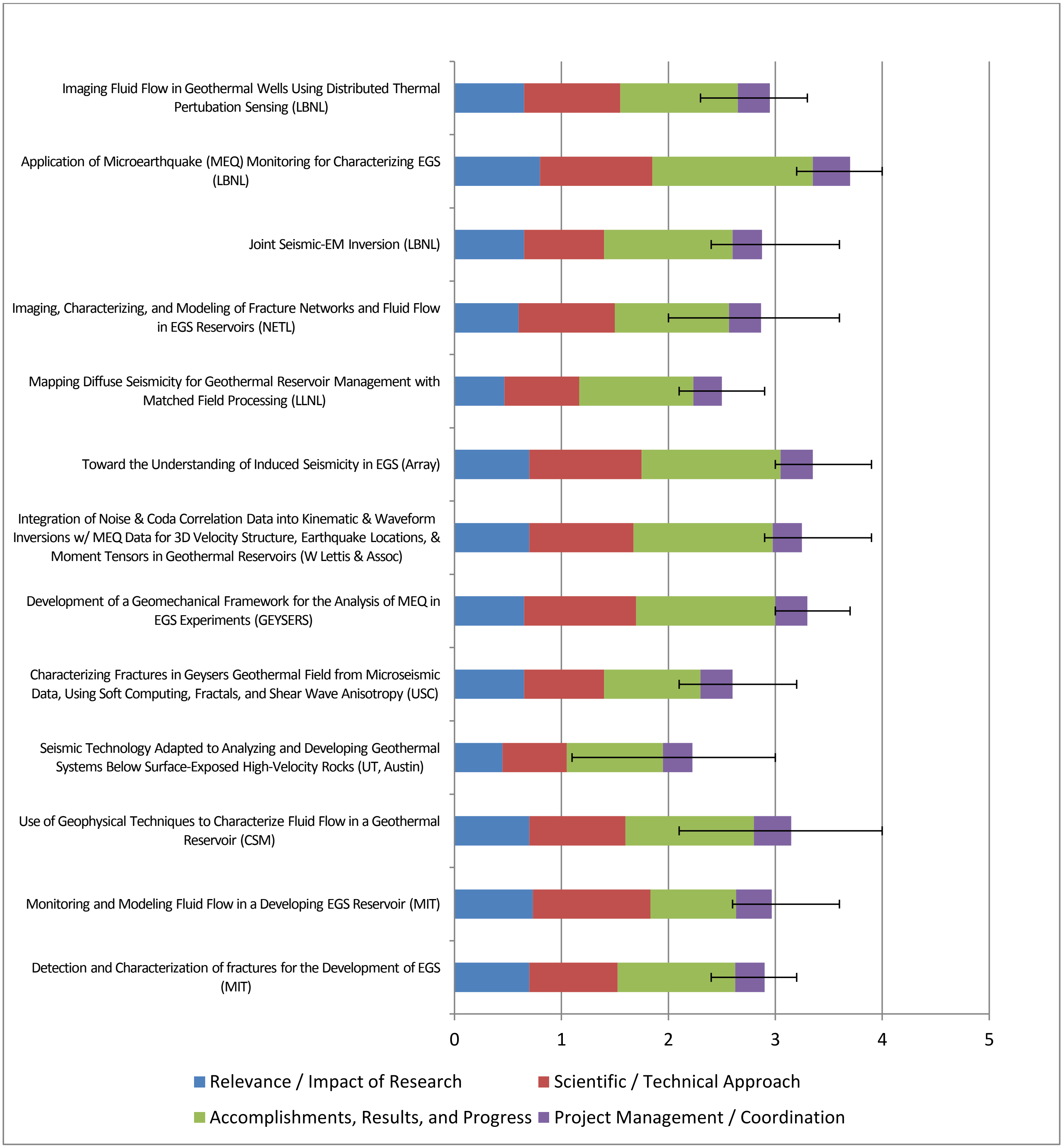


Figure 4.15. *Seismicity and Reservoir Fracture Characterization projects*

4.9 Specialized Materials and Geopolymer Sealing Materials

The Program is developing and characterizing field-applicable geopolymer sealing materials in the laboratory and transferring this developed material technology to geothermal drilling service companies who collaborate for field validation tests. One factor in reducing cost and trouble in geothermal drilling is the alleviation of the lost circulation problem brought about by the flow of drilling mud into natural fractures and fractures created during the drilling operation. To deal with this problem, lost circulation zones must be sealed or plugged by appropriate materials, which may require later self-degradation to reopen flow paths.

"Only one well cement project was considered under the latest round of DOE funding (ARRA). A substantial portion of funding in geothermal development is for cement."

This technology area contains the Program's work in high temperature fluid flow diverting technologies. These projects target both materials for stimulation (e.g., packers) and materials to manage fluid flow during long-term operations. The ability to isolate zones for multi-staged stimulation treatments holds promise for creating a high performing EGS reservoir. Multi-staged stimulations could produce large heat exchange areas within a large volume of reservoir rock. This increases access to reservoir heat and may prevent the development of a dominant flow path that thermally short-circuits the system. Without adequate fluid flow diversion technologies, the wellbore zone with the highest hydraulic conductivity will accept the majority of injected fluids. That zone may be continually stimulated without the ability to divert fluids to other regions of the wellbore with lower permeability.

For large scale EGS, fluid management during normal operations will be important for both cost and reservoir management reasons. Water lost to regions inaccessible to production wells will have an operational cost as fluid levels will have to be maintained by makeup water. If a region of the reservoir becomes thermally depleted prematurely, compared to the desired life of the project, materials can be injected to reduce the permeability of those cooled fractures. This will divert fluid to other fractures that have not been thermally depleted.

Table 4.9 below provides a list of the Specialized Materials and Geopolymer Sealing Materials projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.9 *Specialized Materials and Geopolymer Sealing Materials projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Geopolymer Sealing Materials	Brookhaven National Laboratory	Butcher, Thomas	3.0	2.8	3.0	3.0	3.0
High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells	Composite Technology Development, Inc.	Fabian, Paul	3.0	2.8	2.8	2.8	2.9
Temporary Bridging Agents for Use in Drilling and Completion of Engineered Geothermal Systems	CSI Technologies, LLC	Watters, Larry	3.3	2.8	2.7	3.2	2.9
Development of an Improved Cement for Geothermal Wells	Trabits Group, LLC	Trabits, George	3.5	3.5	3.2	3.2	3.3
Evaluation of Thermal Spray Coatings as Pressure Seals	Sandia National Laboratories	Henfling, Joe	3.3	3.2	2.8	3.0	3.1
Technologies for extracting valuable metals and compounds from geothermal fluids	Simbol Mining Corp.	Harrison, Stephen	3.7	3.7	3.5	3.5	3.6

Overall, the Specialized Materials and Geopolymer Sealing Materials technology area had six project reviews performed. The six projects were scored by an average of six reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Specialized Materials and Geopolymer Sealing Materials technology area had an average, maximum, and minimum score of 3.1, 3.6, and 2.9 respectively. Figure 4.16

shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

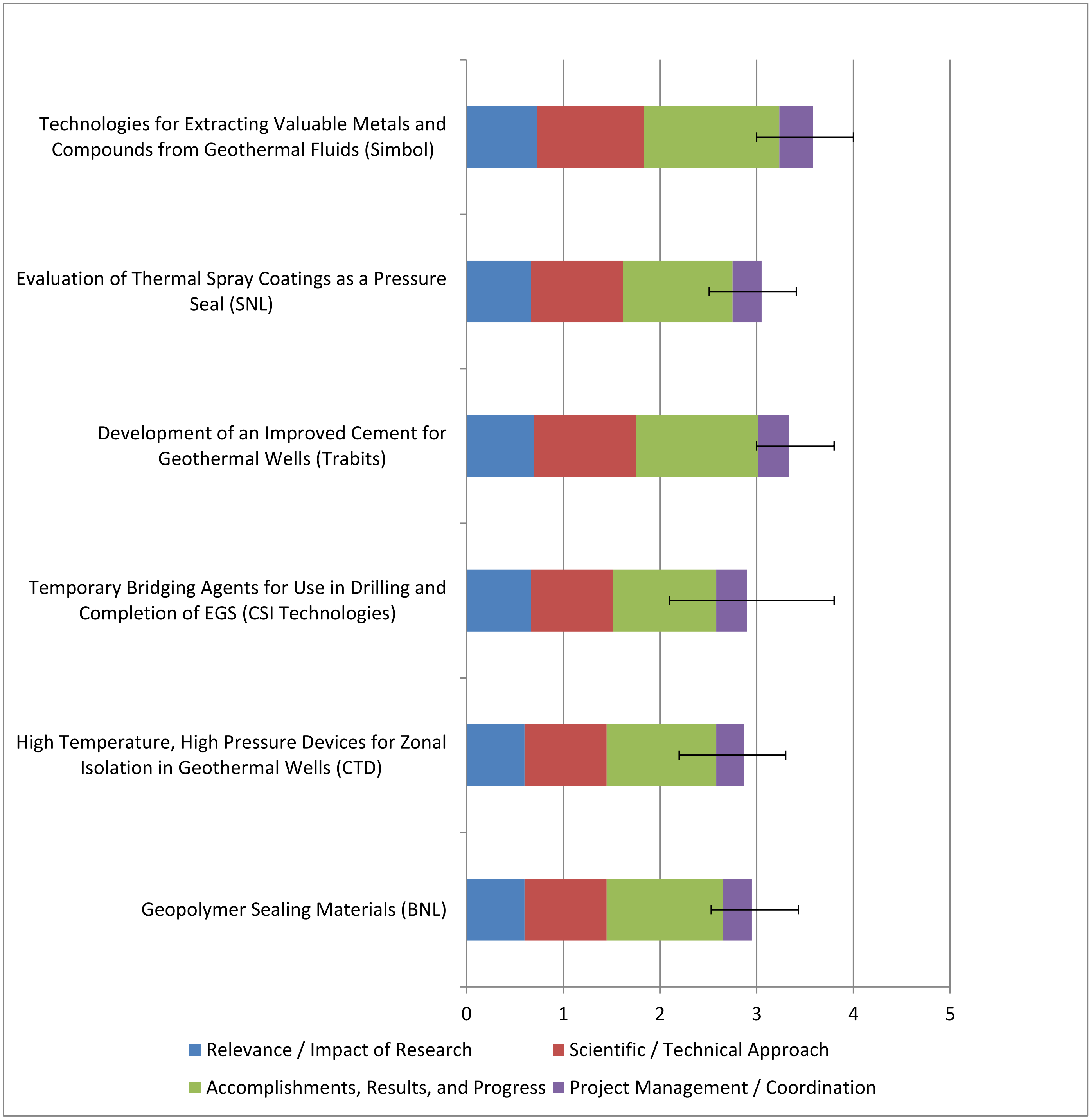


Figure 4.16. *Specialized Materials and Geopolymer Sealing Materials projects*

4.10 Stimulation/Fracture Prediction Modeling

The objectives of the Program's predictive modeling efforts are to assess the productive capacity and longevity of a geothermal system and to design the creation and exploitation of the reservoir, such as determining the number and location of production and injection wells, and anticipating future needs for makeup wells. For both the initial native state of the geothermal system, and in response to alternative exploitation scenarios that may be considered, predictive modeling of geothermal systems primarily involves fluid and heat flow modeling. However, prediction of rock response to enhancement activities is of particular importance for EGS.

Geothermal energy utilization can give rise to microseismic activity. Thus, modeling capabilities are needed to predict such activity from perturbations induced by stimulation, production, and injection operations, and to delineate operational conditions that would avoid generating unacceptably large and/or numerous earthquakes.

Within this technology area, an example of a funded activity is the development of a physics-based rock deformation and fracture propagation simulator by coupling a discrete element model for fracturing with a continuum multi-phase flow and heat transport model in order to predict the dynamics of fracture stimulation, fluid flow, rock deformation, and heat transport. The proposed model will have the ability to be validated, after stimulation, to geophysical and hydraulic monitoring data to verify results, improve targeting of production wells, and aid with operation optimization.

Table 4.10 below provides a list of the Stimulation/Fracture Prediction Modeling projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.10 *Stimulation/Fracture Prediction Modeling projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs	Lawrence Livermore National Laboratory	Carrigan, Charles	3.3	3.0	2.7	2.7	2.9
Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity	Texas A&M University	Ghassemi, Ahmad	3.7	3.0	3.3	2.7	3.2
FRAC-STIM: A Physics-Based Fracture Stimulation, Reservoir Flow and Heat Transport Simulator	Idaho National Laboratory	Podgorney, Robert	3.0	3.7	3.0	2.7	3.2
Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.	Science Applications International Corporation	Pritchett, John	3.0	2.7	2.7	2.3	2.7
Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs	Texas A&M University	Ghassemi, Ahmad	3.0	3.5	3.5	2.5	3.3
Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems	Colorado School of Mines	Gutierrez, Marte	2.3	2.0	1.3	1.7	1.8

Overall, the Stimulation/Fracture Prediction Modeling technology area had six project reviews performed. The six projects were scored by an average of three reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Stimulation/Fracture Prediction Modeling technology area had an average, maximum, and minimum score of 2.8, 3.3, and 1.8 respectively. Figure 4.17 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

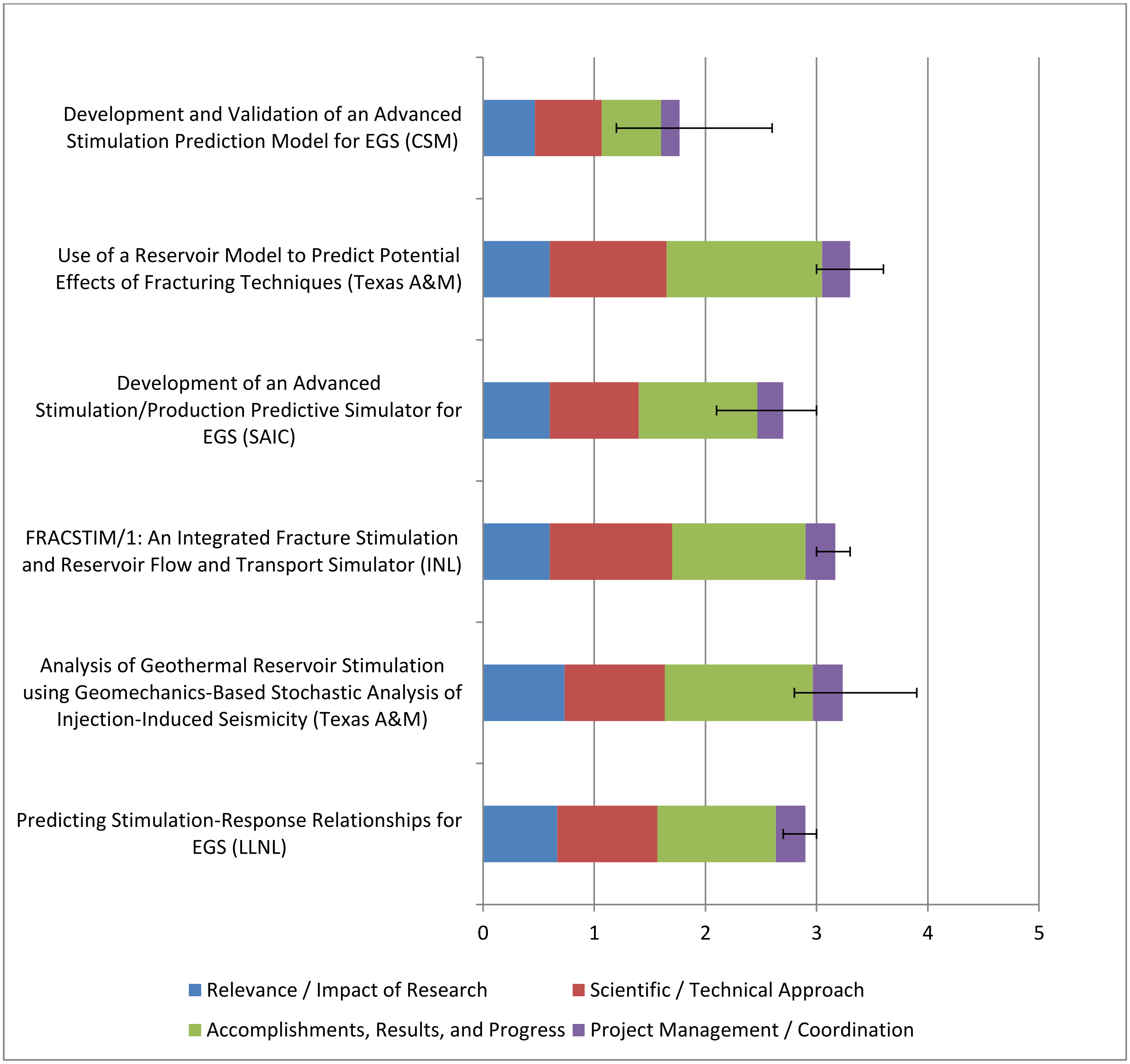


Figure 4.17. *Stimulation/Fracture Prediction Modeling projects*

4.11 Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions

The Program's Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions technology area has numerous activities that are currently focused on:

- Modifying an existing numerical simulator (TOUGH2) to allow coupling of experimentally observed chemical interactions between supercritical carbon dioxide (CO_2) and reservoir rocks with spatial and temporal variations in pore/fracture geometries and in associated permeability and flow fields.
- Elucidating comprehensively the carbonation reaction mechanisms between the supercritical carbon dioxide and reservoir rocks consisting of different mineralogical compositions in aqueous and non-aqueous environments, and to develop chemical modeling of CO_2-reservoir rock interactions.
- Assessing the geochemical impact of CO_2 on geothermal energy production by analyzing the geochemistry of existing geothermal fields with elevated natural CO_2, measuring realistic rock-water rates for geothermal systems using laboratory and field-based experiments, and developing reactive transport models using the field-based rates to simulate production scale impacts.
- Developing a CO_2 reactive-transport model that predicts mineral precipitation and dissolution reactions within an EGS reservoir as well as EGS surface facilities.
- Developing a new geochemical model capable of simulating an EGS-CO_2 reservoir both during the transition from water to scCO_2.
- Performing laboratory experiments to provide basic information on the performance of CO_2-based EGS and to enhance and calibrate modeling capabilities for such systems.
- Utilizing synchrotron X-ray measurements, to monitor all aspects of atomic to nanoscale structural changes resulting from chemical interactions of scCO_2-H_2O binary fluids with rocks under environments directly relevant to EGS.

"The effect of CO_2 in fracture networks needs to be studied."

Table 4.11 below provides a list of the Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.11 *Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Development of Chemical Model to Predict the Interactions between Supercritical Carbon Dioxide and Reservoir Rock in EGS reservoirs	University of Utah	Lu, Chuan	2.6	2.8	2.8	2.8	2.8
Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	Symx Technologies, Inc.	Petro, Miroslav	2.0	1.8	2.2	2.2	2.0
An Integrated Experimental and Numerical Study: Developing a Reaction Transport Model that Couples Chemical Reactions of Mineral Dissolution/Precipitation with Spatial and Temporal Flow Variations in CO2/Brine/Rock Systems	Regents of the University of Minnesota	Saar, Martin	3.4	3.6	3.4	3.6	3.5
Laboratory and Field Experimental Studies of CO2 as Heat Transmission	Lawrence Berkeley National Laboratory	Pruess, Karsten	2.4	2.6	2.6	2.8	2.6
Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid	Lawrence Berkeley National Laboratory	Pruess, Karsten	3.0	2.4	2.6	3.0	2.7
Synchrotron X-Ray Studies of Supercritical Carbon Dioxide/Reservoir Rock Interfaces	Argonne National Laboratory	You, Hoydoo	3.5	3.3	3.0	3.3	3.2
Carbonation Mechanisms of Reservoir Rock by Supercritical Dioxide	Brookhaven National Laboratory	Butcher, Thomas	2.4	2.4	2.4	2.2	2.4
Chemical Impact of Elevated CO2 on Geothermal Energy Production	Lawrence Berkeley National Laboratory	Carroll, Susan	3.2	3.4	3.2	3.0	3.3
Properties of CO2 Rich Pore Fluids and their Effect on Porosity Evolution in EGS Rocks	Oak Ridge National Laboratory	Anovitz, Lawrence	3.6	3.8	3.4	3.6	3.6

Overall, the Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions technology area had nine project reviews performed. The nine projects were scored by an average of five reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions technology area had an average, maximum, and minimum score of 2.9, 3.6, and 2.0 respectively. Figure 4.18 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

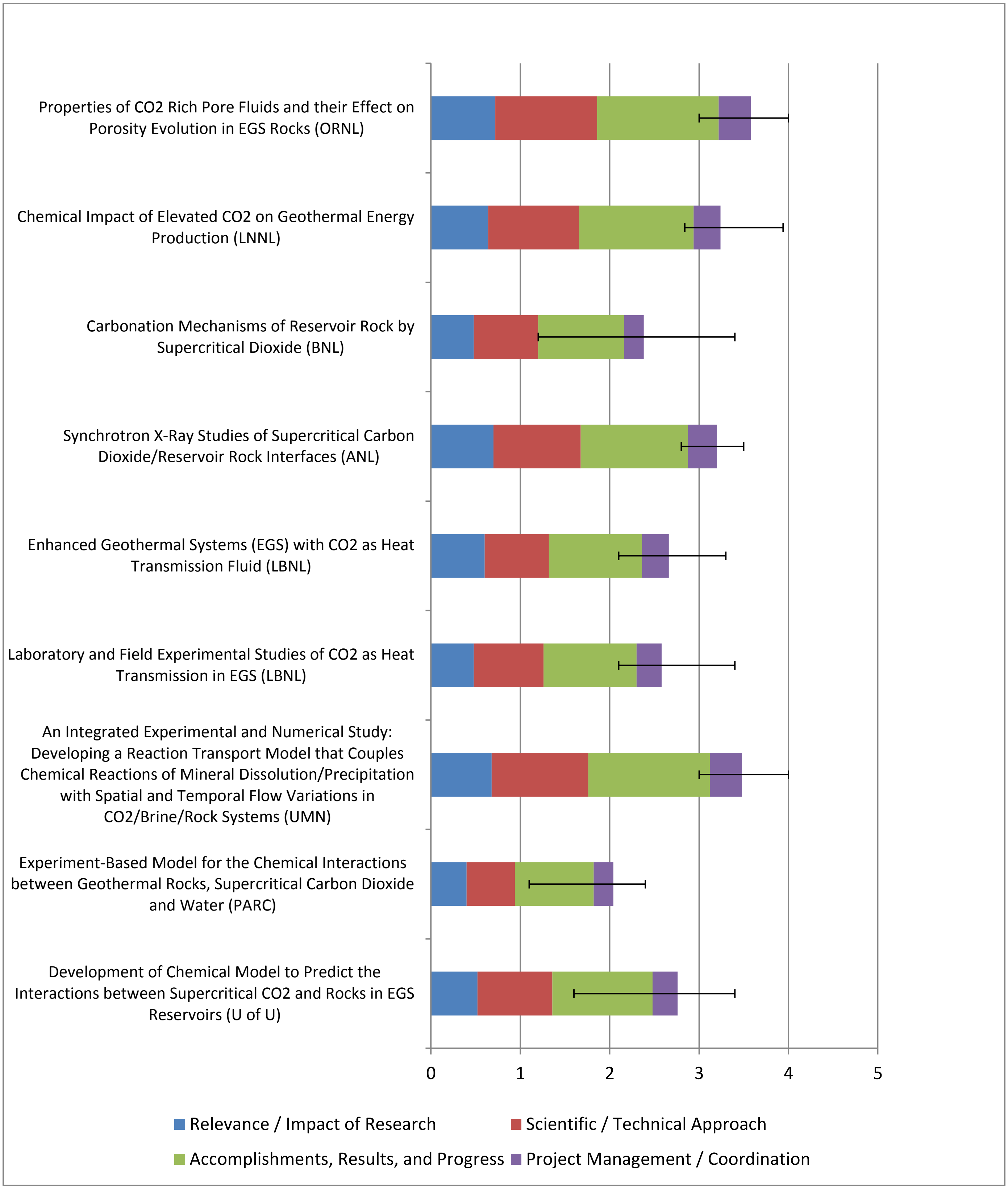


Figure 4.18. *Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions projects*

4.12 Systems Analysis and Resources Assessments

The Program's Systems Analysis and Resource Assessment efforts provide data and information tools to support geothermal RD&D and to inform decision-makers. Activities within this area also include environmental assessments and techno-economic modeling.

The Program is currently developing a supply curve and helping define the levelized cost of electricity for various geothermal resources, which will be used to model the market penetration potential of these resources, identify the most economical resources for development, and direct research to help reduce the cost of more expensive geothermal resources. Supply curves provide an assessment of the cost of developing geothermal resources based on resource assessments and current and future technologies. They also help characterize the supply of electricity generation potential from geothermal resources. The Program uses supply curve data to support portfolio development and market penetration models.

The Program and the U.S. Geological Survey (USGS) are developing a comprehensive geothermal resource assessment and classification system. In support of the DOE/USGS Interagency Agreement, the USGS is conducting a detailed geothermal resource assessment pertaining to:

- Conventional Geothermal Resource Characterization and Assessment
- Enhanced Geothermal Systems
- Geothermal Resources in Sedimentary Basins

Results from this assessment will be provided to the National Geothermal Data System.

"Now may be the time for the Program to perform a thorough review of the redundant cost data to determine if there is enough data and to find any inconsistencies."

Project feasibility and cost analysis is performed to determine the potential economic viability of geothermal energy production and helps to identify which technologies have the greatest cost reducing impact. Results from technology feasibility analysis efforts provide input to the Program's RD&D portfolio.

The economic competitiveness of a technology is assessed by evaluating its implementation costs for a given process compared to the costs incurred by current technology. These analyses are therefore useful in determining which projects have the highest potential for near-, mid-, and long-term success. Geothermal system components areas of interest include: exploration and confirmation, well construction and drilling, reservoir engineering, power conversion, geofluid purchase, leasing and permitting, and operations and maintenance.

Additionally, the Program is conducting analyses on the variability of water use in different geothermal power plants (cooling, field operations, etc.) to identify possible improvements and conservation efforts. Figure 4.19 illustrates the current the Program activities that are focused on techno-economic analysis, market, policy, regulatory analysis, and environmental analysis.

"The Program is currently conducting a robust analysis effort but needs to define a finite set of assumptions and obtain the best estimates possible for these."

The Program uses various modeling tools to assess geothermal technology and its environmental, economic, and energy benefits. The modeling tools the Program uses include, but are not limited to:

- **Geothermal Electricity Technology Evaluation Model (GETEM)**—GETEM is the cost and performance estimating tool used to predict levelized costs of electricity from either hydrothermal or enhanced geothermal systems. Updated by Idaho National Engineering Laboratory, a beta version of GETEM is available for download from the Program's website.
- **System Advisor Model (SAM)**— The Program is currently working with the National Renewable Energy Laboratory (NREL) to incorporate geothermal costs and information from GETEM into a user-friendly tool. The geothermal version of SAM will allow the user to input and receive information on geothermal systems and take advantage of SAM's various project financing options.
- **Jobs and Economic Development Model (JEDI)**—The geothermal JEDI module estimates the number of jobs and economic impacts in a local area that could be supported by a geothermal power generation project.

Techno-Economic Analysis

Projects Undergoing Peer Review

- Geothermal Supply Curves – Geopressured and Co-produced
    - *Current Focus* – updating undiscovered hydrothermal and enhanced geothermal systems
- Life-Cycle Costs of Baseline EGS
- Co-production Risk Assessment
- Decision Analysis for EGS
- Energy ROI for EGS
- GETEM Development
- Costs/Benefits of Geothermal Heat Pumps
- System Engineering Analysis

Market, Policy and Regulatory Analysis

Projects Undergoing Peer Review

- Guidebook to Geothermal Power Finance
- RE Project Financing Website
    - *Current Focus* – WebView
- RE Finance Tracking Initiative (REFTI)
    - *Current Focus* – Feed-in Tariffs, Incentivizing Geothermal Tool; Geothermal Business Models

Environmental Analysis

Projects Undergoing Peer Review

- Life-Cycle Assessment on Emissions, Water and Energy Use
- Water Resource Requirements for Geothermal Energy Production

Figure 4.19. *Techno-economic Analysis, Market, Policy & Regulatory Analysis, and Environmental Analysis Projects*

Table 4.12 below provides a list of the Systems Analysis, Resources Assessments, Data Systems Development and Population projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.12 *Systems Analysis, Resources Assessments, Data Systems Development and Population projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Systems Engineering Analysis	Sandia National Laboratories	Lowry, Thomas	3.3	3.0	3.3	3.3	3.2
Energy Returned on Investment of Engineered Geothermal Systems	Arthure Mansure	Mansure, Arthur	3.5	4.0	4.0	3.0	3.7
Analysis of Low-Temperature Utilization of Geothermal Resources	West Virginia University	Anderson, Brian	2.7	2.7	1.7	2.7	2.4
Co-Production Risk Assessment	National Renewable Energy Laboratory	Augustine, Chad	3.3	3.0	3.3	3.0	3.2
Market & Policy Analysis		Augustine, Chad	2.5	2.8	3.0	3.0	2.8
Decision Analysis for Enhanced Geothermal Systems	Massachusetts Institute of Technology	Einstein, Herbert	2.8	2.8	3.0	3.0	2.9
Geothermal Supply Curve Development		Augustine, Chad	3.3	2.5	3.0	3.0	2.9
National Geothermal Resource Assessment and Classification	U.S. Geological Survey	Williams, Colin	4.0	3.3	3.3	3.7	3.6
GETEM Development	Idaho National Laboratory	Mines, Greg	3.8	3.5	3.3	3.3	3.4
Life-cycle Analysis for Geothermal Power Systems	Argonne National Laboratory	Wang, Michael	3.7	3.3	3.0	3.0	3.2
Water Resource Requirements for Geothermal Energy Production	Argonne National Laboratory	Wang, Michael	3.7	3.0	3.0	3.0	3.1
Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems	ADI Analytics, LLC	Turaga, Uday	2.5	2.8	2.3	3.0	2.6
Baseline System Costs for 50.0 MW Enhanced Geothermal System	GEECO	Dunn, Paul	2.3	3.0	3.3	3.3	3.0
Economic Impact Analysis for EGS	Univesity of Utah	Gowda, Varun	3.0	3.0	2.8	2.8	2.9
Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment and The Potential Employment, Energy, and Environmental Impacts of Direct Use Applications	Bob Lawrence & Associates, Inc.	Battocletti, Elizabeth	2.5	2.3	2.0	2.3	2.2
National Geothermal Student Competition	National Renewable Energy Laboratory	Geiger, Jesse	3.0	3.2	3.0	3.2	3.1
National Geothermal Academy	University of Nevad Reno	Calvin, Wendy	3.3	2.7	3.7	3.7	3.3

Overall, the Systems Analysis, Resources Assessments, Data Systems Development and Population technology area had 16 project reviews performed. The 16 projects were scored by an average of 3.7 reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Systems Analysis, Resources Assessments, Data Systems Development and Population technology area had an average, maximum, and minimum score of 3.0, 3.7, and 2.2 respectively. Figure 4.20 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

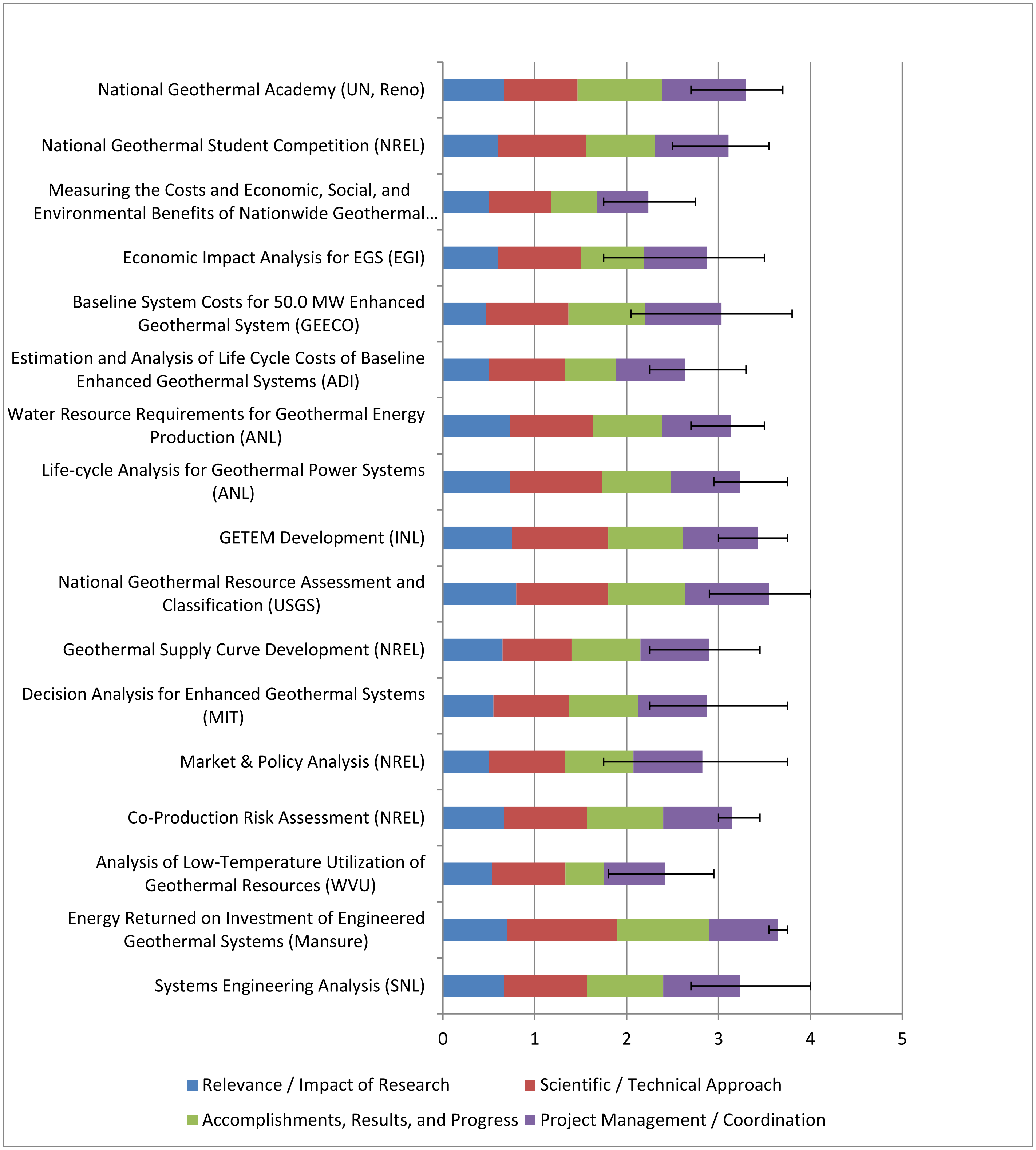


Figure 4.20. *Systems Analysis, Resources Assessments, Data Systems Development and Population projects*

4.13 Tracers and Tracer Interpretation

"Tracer work in high temperature environments is a large challenge. Starting with the knowledge from work in the low-temperature, groundwater environments is encouraged."

Tracers are important tools for reservoir characterization and can be divided generally into two groups: 1) chemically inert and 2) physicochemical reactive. Inert tracers are useful in providing information on the degree of well-to-well connectivity, tortuosity of the interwell pathway, and dispersive characteristics. Temperature sensitive, chemically reacting, or adsorbing and fluorescing tracers can provide additional insight into flow in fractured media, heat extraction efficiency along various flow paths, and fracture surface area. This information enhances the ability to construct reservoir models with predictive capabilities. Through quantitative analysis of multiple tracer and other hydrologic tests, information about the reservoir properties may also be obtained. Consequently, tracer interpretation technologies are critical to maximizing the benefit that geothermal tracers can provide.

Interpretation of tracer data is difficult and subjective, which can lead differing interpretations of a given set of tracer data. Tracers, whether they are conservative or smart tracers, only directly contact a fraction of the geothermal reservoir. Thus, interpretation of the data collected is always conducted with many unknown parameters. As DOE proceeds with the tracer and tracer analysis/interpretation technology area in the future, the goal will be to develop new technologies and data interpretation methods that reduce the number of unknown variables and yield data that is essential to characterizing the geothermal reservoir, as any heat exchanger would normally be characterized.

The Program is developing multidimensional geothermal tracer systems that possess potential to facilitate the usage and efficiency of hydrothermal geothermal developments. The Program is attempting to develop and demonstrate a new class of tracers that offer great promise for use in characterizing fracture networks in EGS reservoirs. The Program is also providing integrated tracer and tracer interpretation tools to facilitate quantitative characterization of temperature distributions and surface area available for heat transfer.

"Many of these projects are not ready to demonstrate. More constrained experiments are needed."

Finally, the Program is designing and analyzing laboratory and field experiments that would identify tracers with sorption properties favorable for EGS applications, apply reversibly sorbing tracers to determine the fracture-matrix interface area available for heat transfer, and explore the feasibility of obtaining fracture-matrix interface area from non-isothermal, single-well injection-withdrawal (SWIW) tests.

Table 4.13 below provides a list of the Tracers and Tracer Interpretation projects that were included in the 2011 Peer Review Meeting. The table includes the overall average project scores, as well as the average score per project per metric.

Table 4.13 *Tracers and Tracer Interpretation projects*

Project Title	Organization	Principal Investigator	Relevance/ Impact of Research	Scientific/ Technical Approach	Accomplishments, Results, and Progress	Project Management/ Coordination	Average Total Score
Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics	Power Environmental and Energy Research Institute	Tang, Yongchun	2.4	2.4	2.4	2.3	2.2
Quantum Dot Tracers for Use in Engineered Geothermal Systems	University of Utah	Rose, Peter	2.4	2.6	2.4	2.0	2.4
Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Lawrence Berkeley National Laboratory	Kennedy, Mack	2.6	3.0	2.6	3.0	2.8
Tracer Methods for Characterizing Fracture Stimulation in Engineered	Lawrence Berkeley National Laboratory	Pruess, Karsten	2.6	2.8	2.4	2.4	2.6
Using Thermally-Degrading, Partitioning, and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Brookhaven, Pacific Northwest, and Los Alamos National Laboratories	Watson, Thomas	1.6	1.8	1.6	1.6	1.7
Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2 and Water-based Geothermal Reservoirs	Idaho National Laboratory	Plummer, Mitchell	2.8	2.8	2.5	2.5	2.6
Tracers and Tracer Interpretation: Verification of Geothermal Tracer Methods in Highly Constrained	California State University; Long Beach Foundation	Becker, Matthew	3.4	3.4	3.0	3.2	3.2

Overall, the Tracers and Tracer Interpretation technology area had seven project reviews performed. The seven projects were scored by an average of 4.9 reviewers. Refer to Table 2.1 for the weighting criteria used to determine the final scoring for this technology area. The final scores of the Tracers and Tracer Interpretation technology area had an average, maximum, and minimum score of 2.5, 3.2, and 1.7 respectively. Figure 4.21 shows each scoring metrics' weighted contribution to the average final score for each individual project in this technology area. The error bars represent the maximum and minimum final score for that project.

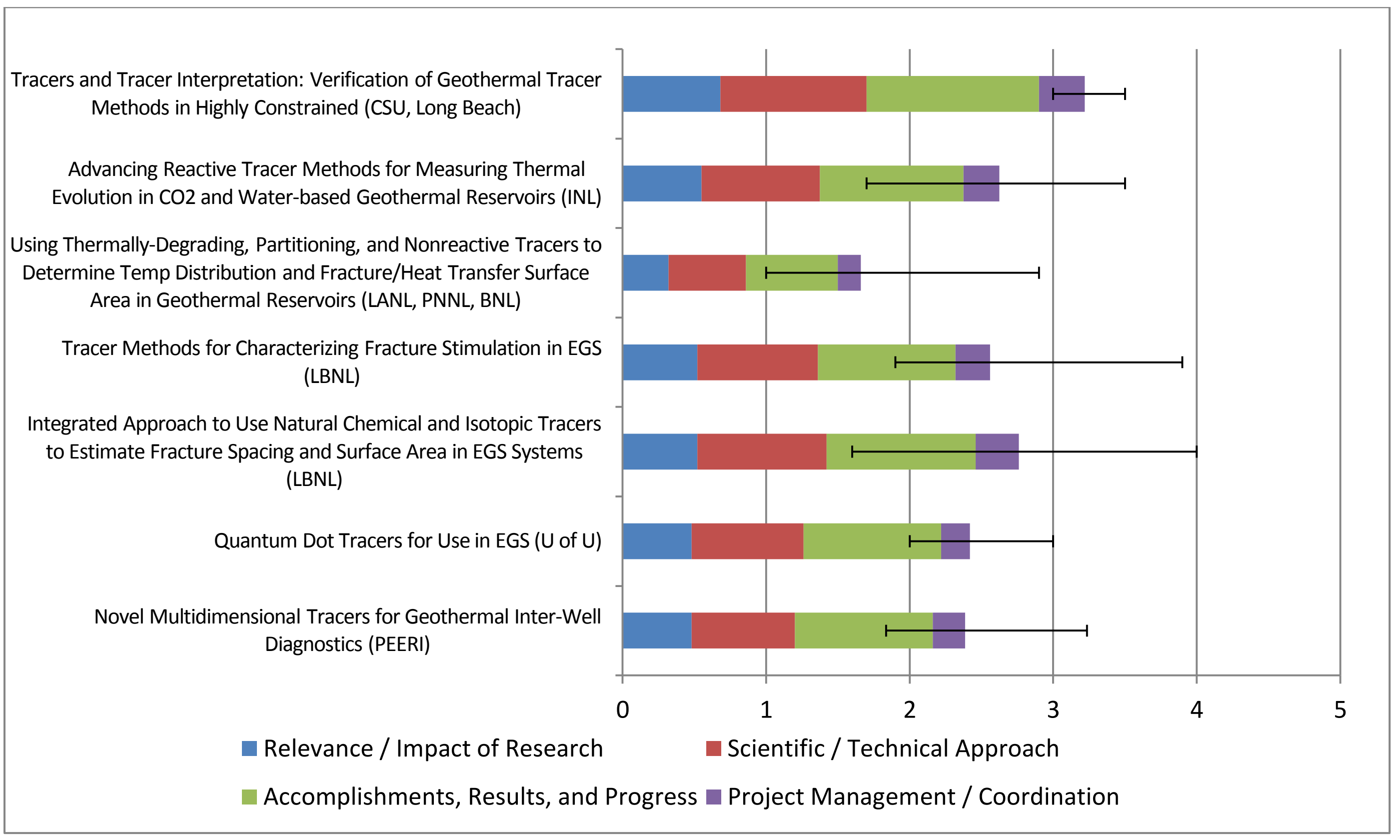


Figure 4.21. *Tracers and Tracer Interpretation projects*

Appendix A: Detailed Reviewer Comments

Data Systems

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0108
Presentation Title: National Geothermal Data System Architecture Design, Testing and Maintenance (BSU)
Investigator: Snyder, Walter (Boise State University)

Comments Regarding Relevance/Impact of Research

Reviewer 8:
This project is crucial to the advancement of geothermal as a component of the US energy picture. A consistent means to access comprehensive, relevant data is of great importance in reducing risks associated with geothermal development, and informing decision makers and investors at all levels. In establishing the integrating network and framework for access to and integration of geothermal data resources nationwide, this project is the key to success of all National Geothermal Data System (NGDS) related work.

Reviewer 27:
The project as presented has made excellent progress and will make, when completed, an important advancement in meeting DOE Program goals and objectives. It will have a significant impact on geothermal development.

Reviewer 2:
Accessible, trusted and usable data is at the core of realizing the Geothermal Technologies Program's goals.

Reviewer 17:
This project is needed in order to make the data from past research and technical data available to current and future researchers and early developers of systems.

Comments Regarding Scientific/Technical Approach

Reviewer 8:
It appears the project is back on track with regard to the approach. The reemphasis on the integrating framework, U.S. Geoscience Information Network (USGIN), should lead to a high likelihood of success. An agile technical approach should help with making adjustments as time progresses. However, the project should pay a bit more attention to the user view of NGDS. Ultimately, who will benefit from having all these data resources available through one environment, how would they use the system, and what value would they receive? It would have been useful to hear more about this and see evidence that the user view had been attended to.

Reviewer 27:
The approach taken by the PI to design, test and implement a "one size fits all" national database with four separate nodes at different locations with the ability to accept most resource data is rather remarkable. However, there are some items that will have to be addressed, such as coordinating and funding the efforts to perpetually store and maintain the NGDS at Boise State.

Reviewer 2:
Overall the architecture of a data catalog and library with well-defined WS access seems sound. Concerns: 1. There seems to be a lack of system architecture. From the presentation and discussion the primary focus has been on defining

individual data elements and not the higher level context or the relationships that allow for analysis and reporting on the data. 2. There was no mention of collaboration with data standards organizations like Data Management International (DAMA) or other open standards like the Universal Data Element Framework (UDEF) from The Open Group, which would allow for greater interoperability .

Reviewer 17:
The federated system approach is needed for this project.

Comments Regarding Accomplishments, Results and Progress
Reviewer 8:
The project is to be commended for the progress to date. It was useful to make a clear distinction between this project and the DOE geothermal data repository project. The new management structure should help with setting the stage for substantial progress. Establishment of the programmatic coordination group is very important to ensure that the various NGDS projects are working toward a common vision. It is also evident that significant progress has been made in establishing protocols and services via USGIN, and that the data partners are progressing in making their data resources available through NGDS.

Reviewer 27:
The PI has made significant efforts to accomplish the stated technical targets/goals. The results of the NGDS have already made some impact with other related research and data gathering efforts such as the Arizona Geological Survey (GS).

Reviewer 2:
The presentation lacked quality criteria to assess project accomplishment. It is unclear what still needs to be accomplished and with what priority.

Reviewer 17:
This project is in the early development phase. Defining the data architecture and the meta data are critical for success. How much involvement does this project have in defining and validating these designs?

Comments Regarding Project Management/Coordination
Reviewer 8:
Project appears to be run reasonably well. The new management structure should help in setting context and coordinating activities among all NGDS-related activities.

Reviewer 27:
The PI has made a fair use of DOE funds. At nearly $5.0 million dollars, it is a huge investment on a system that is not a repository but only the linking pipeline for a series of five nodes that operate independently, which in itself is not a negative, but does present the possibility of having five disjointed nodes that may have no continuity once DOE funding is extinguished.

Reviewer 2:
This project falls between fair and good. The reason being is that although the project reported progress on meeting objectives there is no mention of project management controls like gates, milestones, or risk management.

Reviewer 17:
Dollars are on schedule. The ability of the team to deliver the technical results may be at risk due to the appearance of depending only on locally available experts. More should be done to encourage future volunteers to participate in this effort.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 8:
This is definitely a worthy project that is relatively risky, due to the complexity of being a federated system of relatively diverse subsystems. It takes a lot of attention to bring a system like this to closure, and it takes a very robust infrastructure to support and sustain performance and function.

Reviewer 27:
This is a reasonable use of DOE funding; however, the amount of money being spent on this project is quite high.

Reviewer 2:
This is a critical project to the success of the Geothermal Technologies Program (GTP). The project seems to be making progress toward meeting award goals. From discussion, the project is creating necessary infrastructure using established protocols.

Reviewer 17:
This is a complex problem. Some of the other projects had teamed with external experts to provide the level of talent that was required to complete the project. The technical work seemed to be only addressed by local experts. This may be an issue when the delivery time approaches. The project is needed so that research and development dollars are spent on new work and not recreating information that has already been produced. Better access to past research and technical data is key.

Comments Regarding Strengths
Reviewer 8:

Reviewer 27:

Reviewer 2:
Strengths include: 1. Storage and retrieval of unstructured data. 2. Use of web services for data access and exchange.

Reviewer 17:
The federated approach will provide the most data access to users.

Comments Regarding Weaknesses
Reviewer 8:

Reviewer 27:

Reviewer 2:
As stated previously, there are two concerns: 1. There seems to be a lack of system architecture. From the presentation and discussion the primary focus has been on defining individual data elements and not the higher level context or the relationships that allow for analysis and reporting on the data. There was no mention of collaboration with data standards organizations like DAMA or other open standards like UDEF from The Open Group,which would allow for greater interoperability.

Reviewer 17:

The technical aspects of this project will determine its success. The presentation did not provide confidence that the design had the needed quality.

Suggestions for Improvement

Reviewer 8:

It is suggested that this project describe some typical user views of the system, e.g., who would use the system, how would they use it, what data would they access, and why would they use it (presumably because they get some value)?– It is also suggested that the project think a bit more of NGDS as the whole system, including at least the formally-recognized data nodes as subsystems. In that sense, NGDS does host data in one of the member data nodes/subsystems. It is important to keep the objective in mind and provide access to data resources that will reduce development risk and advance the state of geothermal science. It is important to not lose sight of that as the technical work of establishing the system is done.

Reviewer 27:

This project did not provide any discussion on prevention of cyber attacks, or protecting the integrity of the data collected.

Reviewer 2:

Without sufficient data governance there may come a time where the data becomes untrusted and therefore irrelevant. However, there was discussion around informal/word of mouth ratings. In anticipation of companies or the government spending millions on development projects it would seem appropriate to implement formal data governance and management. Insufficient information was presented to assess the rigor of the work elements, procedures and methods. It is recommended that data and system models be developed and presented for evaluation.

Reviewer 17:

It is suggested to include some technical slides about the architecture approach the project is using the next time this is presented for peer review.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0109
Presentation Title: State Geological Survey Contributions to National Geothermal Data System Data Development, Collection and Maintenance (AZGS)
Investigator: Allison, Lee (Arizona State Geological Survey)

Comments Regarding Relevance/Impact of Research

Reviewer 8:
This is a far reaching, ambitious project that has great potential to improve the overall knowledge base supporting the geothermal community. As a stand-alone system covering geothermal-relevant data from all 50 states plus a variety of other data providers, this is an impressive endeavor. Add to that its inclusion as one of several "nodes" in the National Geothermal Data System (NGDS) and it is even more impressive. It would be very helpful to outside observers, and potentially to the project itself, to document user views— possibly as use cases or user stories— that express relevant uses of the system, e.g., who would use the system, how would they use it, what data would they access, and ultimately, what value would they receive from using the system? Walking through a few of these scenarios in a demo setting would certainly help to "sell" the system to those who might be skeptics. This comment holds for all of the NGDS-related efforts.

Reviewer 27:
This project has definitely made a significant impact on DOE's mission and goals. The project has evolved exceptionally well and has addressed many difficulties in attempting to achieve its stated goals. The reviewer appreciates the fact that this project has recognized the value of obtaining data from the State of California's Division of Oil and Gas, and Geothermal Resources, and the California Energy Commission Geothermal Program.

Reviewer 2:
This project is an essential component to NGDS by providing source data and establishing reliable data collection methods.

Reviewer 17:
Potential thermal energy is not distributed uniformly across states. For political reasons the information may have some value, but it may only document that there may not be much geothermal energy available in most states.

Comments Regarding Scientific/Technical Approach

Reviewer 8:
The quality of the technical work, and the fact that the project stays responsive to suggestions from SAB, partners and the community at large, help ensure that this project will achieve its objectives. As an agile project with independent technical oversight by the SAB, the technical approach employs a reasonable level of rigor while avoiding the impedance inherent in some formal engineering methods. The annual cyclical process for incorporating new data appears well designed for its purpose.

Reviewer 27:
The approach taken by the PI and research team has been exceptional. They have taken on the enormous task to coordinate, expand and enhance the NGDS by populating a national network of state geological survey-based providers. The technical approach taken by the PI is remarkable, reasonable and logical.

Reviewer 2:
This projects utilizes industry standards and protocols, thereby reducing production costs.

Reviewer 17:
Predefining content models should allow for the collected data to be presented in a few usable structures. This will allow users to have much better data for project analysis.

Comments Regarding Accomplishments, Results and Progress
Reviewer 8:
Results are already extensive and impressive. Web services, content models and templates are well defined and published to data contributors. Standards and protocols have been defined and incorporated. Considerable amounts and types of data resources have been and continue to be added to the system. Many states are actively developing and contributing data. Three of four data hubs are active. In addition, the project has reached out internationally to ensure that when the time comes, international data resources can be made available.

Reviewer 27:
From what was presented it appears that the project is proceeding on schedule and within budget. The reported accomplishments, results and progress appear to be reasonable and within the scope of the project.

Reviewer 2:
Project has reported impressive accomplishments and the review would have scored outstanding; however, the presentation/project lacked quality measures and technical targets from which to evaluate.

Reviewer 17:
The accomplishments to date have materialized from the project management in both the capturing of state data and the technical planning. The bureaucratic delays that were involved in establishing state contracts may be made up by the outstanding project management.

Comments Regarding Project Management/Coordination
Reviewer 8:
No issues noted with project management, other than noted variations in invoicing resulting from the fiscal practices of the participating states. The project remains on track, overall.

Reviewer 27:
The project appears to be appropriately managed by the PI and research team. The PI provided an effective and wellprepared management strategy and deployment discussion. As presented, the project described the appropriate checks and controls.

Reviewer 2:
Despite delays in state subcontracts the project has provided sufficient corrective measures to bring project into alignment with end data targets.

Reviewer 17:
The rigor that was put into the planning for the involvement of most states was exceptional. The project may be able to make up a few months at the end because of the management effort.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 8:
This is a high value project providing access to myriad high value data sets from across all states. It is impressive in

scope and continues to have a high likelihood of success. Ultimately, the state geothermal data contributions will be integrated into the NGDS, producing even more value to the geothermal community as the state data is integrated with data from other NGDS nodes. Success in this project will significantly advance the U.S. geothermal scientific knowledge base.

Reviewer 27:
The overall impression of this project is positive and is worth the DOE financial investment. This project will provide geothermal developers, researchers and policy makers the appropriate information needed. This project is well thought out and designed with anticipated foresight. The PI has demonstrated the strength of the project team and flexibility to change course when necessary.

Reviewer 2:
The project made significant progress in identifying and populating metadata. In the last few months the digital resources have grown from ~4,000 records to ~12,000 records. The project is also making progress publishing WFS and WMS services.

Reviewer 17:
This is a strong, well-managed project. Commonality of the data will be achieved through the use of a limited number of content modules. This project is on track to be successful and finish on time.

Comments Regarding Strengths
Reviewer 8:

Reviewer 27:
The project is well organized and well presented. The strength of the project team is reflected in the quality of the work completed. The PI is working with many different organizations and all 50 states. The difficult and tedious task of incorporating legacy data has been addressed. The project is on schedule. The project has created 89 jobs.

Reviewer 2:
This project has demonstrated the following strengths: 1) ability to deliver useful products, 2) coordination among disparate providers, and 3) reuse of existing capabilities and standards to reduce production costs. Another notable strength is that the project is delivering usable product early which should allow for any corrections that are needed prior to the end of the funding cycle.

Reviewer 17:
The most visible strength was the outstanding project management.

Comments Regarding Weaknesses
Reviewer 8:

Reviewer 27:

Reviewer 2:
An observed weakness is the high cost of staff time devoted to finding, retrieving, and verifying information. To meet the intent of this goal the reviewer believes that users of the data and information also spend considerable resources in validating the information. Without formal data governance and management, users will be unable to realize a true

benefit.

Reviewer 17:
No weaknesses were noted.

Suggestions for Improvement
Reviewer 8:
Repeated from the first section: It would be very helpful to outside observers, and potentially to the project itself, to document user views—possibly as use cases or user stories—that express relevant uses of the system, e.g., who would use the system, how would they use it, what data would they access, and ultimately, what value would they receive from using the system? Walking through a few of these scenarios in a demo setting would certainly help to "sell" the system to those who might be skeptics. This comment holds for all of the NGDS-related efforts. As noted in the review discussion, provide capabilities that support users in understanding quality factors concerning the data they retrieve from the system. These could include clear provenance/pedigree metadata, crowd-sourced quality ratings, etc. Though having a "data quality czar" is impractical, reasonable indicators/clues of quality can still be supported.

Reviewer 27:
The reviewer recommends protection against cyber attacks and guarding the reliability of data.

Reviewer 2:
The reviewer offers the following suggestions: 1) it would seem appropriate that more rigor be applied to data quality for efforts in which companies or the government will be spending millions on development projects, and 2) once a data source is identified and passed through the Technical Data Development Cycle there is no follow up review for production data. This is probably not a problem for "data products" and "data sets"; however, "discrete" data sources may require QA after production.

Reviewer 17:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0110
Presentation Title: DOE Geothermal Data Repository (BSU)
Investigator: Snyder, Walter (Boise State University)

Comments Regarding Relevance/Impact of Research

Reviewer 8:
It is commendable for DOE to insist that funded projects contribute their data to the collection that will be hosted and managed using this data repository. New data from demonstration and research projects have the potential to significantly impact the understanding of the future position of geothermal energy in the nation's energy portfolio, and to impact decision makers in determining policy and investment for geothermal energy. However, it is unclear at this point whether the potential for this repository will be realized. Descriptions of scenarios demonstrating the value of this data collection would be helpful in providing a clearer understanding of the impact of this repository once established and operational.

Reviewer 27:
This project has made, and will make, a significant impact on meeting DOE's mission and goals. The project has evolved exceptionally well and has addressed many difficulties in attempting to achieve its stated goals.

Reviewer 2:
The Geothermal Data Repository's (GDR) focus on identifying and processing unstructured data so that it can be utilized by future geothermal projects extends the Geothermal Technologies Program (GTP) program dollars and resources.

Reviewer 17:
The goal of compiling historic documents and structured data for the geothermal research effort will be valuable for the community. The ―after the fact" capturing of data from research projects appears to be problematic because funds may have already been expended and the research work is done. The DOE data policy may need to require a data plan that uses standard structures (when possible) and that the data be delivered to the repository according to that plan. This may lead to sending data in as documents, which will greatly reduce the data availability benefits. Working with researchers to develop independent data models will be an ongoing task that extends long after this research project.

Comments Regarding Scientific/Technical Approach

Reviewer 8:
It is clear that the project has done considerable leg work to interact with contributors of the data through direct and group interactions in order to establish a well understood data submission process. The technical approach to this appears very solid. However, lacking in what was presented is a clear vision of how the system will ultimately be used. Once the data are submitted and characterized in the catalog, how will system users retrieve and apply the data to which they now have access? Some up front descriptions of a few typical usage scenarios—representing system requirements—would be immensely helpful in understanding the needs this system will meet. It appears that the requirements definition approach has some holes. There is a statement in the write-up indicating that "use case scenarios ...will be completed early in Phase II," -which seems very late for requirements development; the project is already about a third of the way to completion. This and other signals from the materials and the presentation indicate the system development approach could be improved.

Reviewer 27:
The approach taken by the PI in establishing and implementing a data repository and increasing capacity to accommodate new and legacy data is commendable. The architecture implemented to accomplish the stated objective is reasonable.

Reviewer 2:
The concept of the project is straightforward but the technical approach is inadequately described and not clearly laid out. In future reviews, the reviewer recommends the presentation include formal models that effectively describe the system.

Reviewer 17:
A defined technical approach was not described. The use case seems to say that we will do the ―right” thing for every data capture instance.

Comments Regarding Accomplishments, Results and Progress

Reviewer 8:
Results to date seem to be in line with the intent. It appears the data are being accommodated well as they flow in, and the system appears to be ready to catalog and manage them. Interfaces to integrate into the larger NGDS are underway and seem to be on track. The development of the various portals and other integration points are also in good shape. Treatment of data that are sensitive in some way is not entirely clear yet;this needs to be dealt with well and soon so that the data repository will be ready to receive these data.

Reviewer 27:
It appears that the accomplishments, results and progress made by the PI is on target. The project impact will reduce upfront costs and provide an invaluable source for further research and development of geothermal resources.

Reviewer 2:
The project has accomplishments reported; however, the presentation/project lacked quality measures and technical targets from which to evaluate.

Reviewer 17:
There were very few technical achievements claimed. The project management approach was flagged as a possible continuing issue with obtaining data. It is assumed that the ―team” members are independently paid so that there will be continual demands on their time.

Comments Regarding Project Management/Coordination

Reviewer 8:
Cost and schedule seem to be well managed. It is unclear that the results/performance are proceeding in line with the money and time spent. Better measures of performance linked to project objectives might provide a better understanding of project technical progress.

Reviewer 27:
As presented, it appears that the PI and research team have been responsible in the management of DOE funds and have made significant progress in accomplishing project tasks and within budget.

Reviewer 2:
The reviewer feels that this project should have rated between good and fair. The projected stated use of Agile methodology for software development, however, at the core of Agile software development, is the identification and management of risks. This project lacked adequate identification of risk and the methods employed to manage risk.

Reviewer 17:
The project management plan for this project seems to be dependent on cooperation among disinterested or not fully committed parties. There was not much of a description of the breadth of the V 1.0 data model. There is concern over how this model will support known and future research projects.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 8:
This is an important project with great potential to serve the DOE Geothermal Technologies Program and the geothermal community at large. It could benefit from a bit more rigor in software engineering practices.

Reviewer 27:
The reviewer's overall impression of this project is very favorable.

Reviewer 2:
This reviewer is concerned that there is possibly duplicative effort between the GDR and GDA (SMU, Siemens) projects.

Reviewer 17:
The data work needs to be the focus of this effort. How this system will be functional after the end of this project is a big issue.

Comments Regarding Strengths
Reviewer 8:
Good interactions with data contributors.

Reviewer 27:
The project is well organized. The PI is working with USGS, SMU, and DOE. The difficult and tedious task of incorporating legacy data has been addressed. Handling of proprietary data has been addressed. The interesting feature of the data submission process is the facility to upload data using templates. The project is on schedule. The project has created eight jobs.

Reviewer 2:
Project Strengths include: 1) use of Open Geospatial Consortium and ISO standards for interoperability, 2) simple data submission process, and 3)iIdentification and processing of legacy and at risk data.

Reviewer 17:

Comments Regarding Weaknesses
Reviewer 8:
There is a lack of clarity on the ultimate value to end users of the system.

Reviewer 27:

Reviewer 2:
The project is very focused on delivering product which might be at the expense of system engineering.

Reviewer 17:
Projects will be reviewed and ―then the best method is selected and the integration process starts."

Suggestions for Improvement
Reviewer 8:
Document use cases representing typical end uses of the system and the data it hosts. Clarify how sensitive data will be

treated. As part of the agile process (daily meetings, etc.) document well the significant design decisions that were made and the rationale for them. Establish measures of technical progress traced to project objectives.

Reviewer 27:
The PI should make provisions to protect the integrity of the data collected and prevent cyber attacks.

Reviewer 2:
Address duplicative activities with GDA (SMU, Siemens). Explore data warehouse and data mart architectures and use of COTS BI tools. Publish conceptual and logical data models to the project's Web portal.

Reviewer 17:
Capturing of legacy data appears to be better defined in the Geothermal Data Aggregation Project. Their approach may be beneficial to this project‘s requirements.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0111
Presentation Title: Heat Flow Database Expansion for National Geothermal Data System Data Development, Collection and Maintenance (SMU)
Investigator: Blackwell, David (Southern Methodist University)

Comments Regarding Relevance/Impact of Research

Reviewer 8:
The heat flow, well, and other data represented among the centers of excellence contributing to this project are crucial to the advancement of geothermal within the nation's renewable energy portfolio. Aggregating, linking and sharing these data will enable new studies and inform those making decisions about the future of geothermal energy. This will represent a core node in NGDS, making available some of the most important and relevant information to NGDS users.

Reviewer 27:
This project has made and will, make a significant impact on meeting DOE's mission and goals. The project has evolved exceptionally well and has addressed many difficulties in attempting to achieve its stated goals. The reviewer appreciates the fact that the PI has been working with the State of California's Division of Oil and Gas, and Geothermal Resources, to obtain the huge amount of data and incorporating that data into their heat flow database.

Reviewer 2:
The PI clearly presented justification for project alignment to the success of GTP. The project seems to be making progress to meeting award goals. From discussion, the project is creating necessary infrastructure focused on improving access and contextual relevance of geothermal data.

Reviewer 17:
Historic geothermal data can only be used for future benefit if it is properly cataloged and made available electronically. This project is framed to deliver on that need.

Comments Regarding Scientific/Technical Approach

Reviewer 8:
This project appears to be following a very solid software engineering approach, as well as well-founded scientific approaches for addressing data quality and correlation. Specifications for requirements and design are documented and managed. The system architecture seems well defined and efficient. Changes to specifications and end product appear to be managed well.

Reviewer 27:
The approach taken by the PI and research team has been exceptional. They have constructed a partial national database that is capable of aggregating numerous types of databases and libraries.

Reviewer 2:
The concept of the project is straightforward but the technical approach is inadequately described, and in future reviews, the reviewer recommends that the presentation include formal models and methods that were used to make architectural decisions.

Reviewer 17:
The PI has involved industry experts in assisting in the development of the process and procedures to best make this data available. The strength of the team was apparent throughout the presentation and documents.

Comments Regarding Accomplishments, Results and Progress

Reviewer 8:
Results to date are impressive. Large amounts of data have been incorporated, a prototype release has been demonstrated, software-supported de-duplication has been very successful, and integration with NGDS is underway.

Reviewer 27:
The accomplishments and preliminary results as presented by the PI indicate that the project has accomplished the stated goals so far. It is foreseeable that the results and outcomes of the project will have a significant impact on geothermal developments.

Reviewer 2:
The project has reported impressive accomplishments and appears to be meeting stated technical targets.

Reviewer 17:
Accomplishments are significant and they were well presented. The timelines go in enough detail to help convey the current status of the project.

Comments Regarding Project Management/Coordination

Reviewer 8:
There is clear evidence that this project is being managed well. Frequent communication with consortium members as well as with DOE help ensure the project stays on track. Communication with other NGDS-related projects helps reduce duplication of effort and facilitates coordination of design. The project has dealt with several significant changes, and even expanded its scope, without significant deviation from cost and schedule.

Reviewer 27:
Project management has been very good. Except for the high cost of the project, the PI has made the right decisions and has executed the project well. The PI has been creative and flexible enough to incorporate disparate data into one repository.

Reviewer 2:
In actuality this fell between the definition of fair and good. This reviewer is concerned that there is possibly duplicative effort between the GDR and GDA (SMU, Siemens) projects.

Reviewer 17:
The project management has been exceptional. Finding the right people for the team greatly improves the chances for a successful project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 8:
A high degree of transparency in this project helps provide assurance that the project is doing things right and doing them well. This is an impressive project with a high likelihood of success and ultimately will result in a highly-valued resource for the geothermal community.

Reviewer 27:
The reviewer's overall impression of this project is positive and feels that it is worth the DOE financial investment. This

project seemed to have been designed with anticipated foresight. The PI has demonstrated the strength of his project team and flexibility to change course when necessary to provide the needed results.

Reviewer 2:
The project, in partnership with industry, is creating necessary infrastructure with a focus on improving access and contextual relevance of geothermal data.

Reviewer 17:
The PI has put together a talented team and has managed it well. The realization that additional hours for project management were needed shows the attention being placed on achieving the project goals.

Comments Regarding Strengths
Reviewer 8:

Reviewer 27:
The reviewer thinks this is a strong project team with excellent communication between contributing partners.

Reviewer 2:
Strengths include: 1) a rich set of data to exercise system proof of concept, 2) defined methods to assess and address data quality, and 3) unstructured data Full Text Indexing of Data Products (unstructured data) and result grouping by NGDS metadata structure.

Reviewer 17:
The reviewer congratulates the PI on putting together a talented team.

Comments Regarding Weaknesses
Reviewer 8:

Reviewer 27:
A weakness is the high cost for implementing this type of project.

Reviewer 2:
Key services (Data Analytics, Full Text Search, etc.) may not be effectively utilized in other related data projects, and possibly duplicated by other projects.

Reviewer 17:
No weakness were noted.

Suggestions for Improvement
Reviewer 8:
The reviewer suggests: 1) identifying how these data can be used to feed and improve the quality of analysis and modeling being done by the DOE-funded geothermal systems analysis projects, 2) describing the means by which users can understand the quality of the data they are retrieving, and perhaps include this in documentation and/or on-line help.

Reviewer 27:
The reviewer suggests implementing measures to safeguard the integrity of the data from within and against cyber attacks.

Reviewer 2:
The reviewer suggests: 1) addressing duplicative activities with GDA SMU, 2) publishing conceptual and logical data

models to the project's Web portal, and 3) defining the life cycle and associated mortgage costs of data elements.

Reviewer 17:
Historic data comes in all levels of quality. During the discussions it was pointed out that questionable data may be better than no data. This will be a judgment call on the part of the involved data submitters, but it would be beneficial to users to have a flag on quality and possibly a comment section for future users of that data.

Enhanced Geothermal Systems (EGS)

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0400
Presentation Title: Feasibility of EGS demonstration at Brady's Hot Spring
Investigator: Drasko, Peter (ORMAT)

Comments Regarding Relevance/Impact of Research
Reviewer 3:

Reviewer 26:
No submission of information was made by the PI to DOE or PeerNet, nor was there a presentation given at the review meeting. In the absence of information, the project must be given a very low rating for this criterion.

Comments Regarding Scientific/Technical Approach
Reviewer 3:

Reviewer 26:
No submission of information was made by the PI to DOE or PeerNet, nor was there a presentation given at the review meeting. In the absence of information, the project must be given a very low rating for this criterion.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:

Reviewer 26:
No submission of information was made by the PI to DOE or PeerNet, nor was there a presentation given at the review meeting. In the absence of information, the project must be given a very low rating for this criterion.

Comments Regarding Project Management/Coordination
Reviewer 3:

Reviewer 26:
No submission of information was made by the PI to DOE or PeerNet, nor was there a presentation given at the review meeting. In the absence of information, the project must be given a very low rating for this criterion.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 3:
No show

Reviewer 26:
It is irresponsible of Ormat not to send a written submission of information for this project nor to make a presentation to the review committee at the designated meeting. Was there an excuse or apology offered to DOE or to the reviewers for this omission? None were mentioned at the review meeting. DOE should consider carefully the casual attitude and risk of non-performance by Ormat in awarding any future funding for this or other projects.

Comments Regarding Strengths
Reviewer 3:

Reviewer 26:
No information on which to base strengths.

Comments Regarding Weaknesses
Reviewer 3:

Reviewer 26:
Project management is incredibly weak and irresponsible to have ignored this opportunity for review.

Suggestions for Improvement
Reviewer 3:

Reviewer 26:
Participate fully with DOE once an award has been made.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0401
Presentation Title: Enhanced Geothermal Systems – Concept Testing and Development at the Raft River Geothermal Field
Investigator: Moore, Joseph (University of Utah)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
As a project based around a moderate temperature resource, this is an important part of the diversity of EGS targets being evaluated.

Reviewer 6:
This project will address several critical barriers to moderate temperature EGS, e.g., exploration/logging tools, flowrate improvement, connectivity, sustainability, seismicity, and staged thermal/hydraulic stimulation methods. However, it is weaker in addressing other barriers, e.g., stress/depth information, deeper drilling, high temperature tools, and pumps. This is a practical, well-conceived project with realistically achievable goals.

Reviewer 33:
This project will have an impact on the stimulation of unproductive areas of existing hydrothermal fields.

Reviewer 16:
This project has great probability of accomplishing the original project objectives. The project has made logical/timely progress, and there is no evidence of major faults close to the borehole.

Reviewer 26:
This is a well-conceived project that addresses DOE's goals of demonstrating the viability of enhanced geothermal systems in various geologic environments. It is unique among current EGS demonstration projects in that it addresses expansion of production from a known, moderate-temperature producing resource in a part of the field having limited permeability but a confirmed heat resource at moderate depth (280°F at ~5,000 feet in the target stimulation well). Such moderate-temperature resources are numerous throughout the West, both as stand-alone resources and on the margins of high-temperature systems. Success in this project would encourage developers to consider work at other resource sites of a similar nature and would generate technical and cost data of importance to them in making investment decisions. All data generated by this project will be publically available through the National Geothermal Data Repository.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
This project has demonstrated a very strong approach at this stage, using an appropriate diversity of techniques to characterize the geology of the site, an essential prerequisite to the next stages of the project.

Reviewer 6:
Phase 1 scientific methods were tested successfully; approach was sound.

Reviewer 33:
Excellent geoscientific work done in preparation for stimulation. Worthwhile introduction of ideas and expertise from the oil and gas industries.

Reviewer 16:

This project deals with dual phase stimulation with thermal preconditioning, a new concept; however, the awardee should do some modeling to optimize thermal shock (e.g. number of radial fractures created). Reviewer suggests taking one oriented core plug (if possible) to validate in-situ stress orientation. The reviewer found the project to have an interesting approach in using electromagnetism to attempt to determine the stimulated reservoir volume. PI is aware of recent technological developments.

Reviewer 26:
1. The technical approach appears to be sound. The project team is well experienced in geothermal energy. State-of-the-art geological, geochemical and geophysical data have been collected and interpreted, resulting in improvements to the reservoir model. These data will be of use as a baseline for comparison with post-stimulation data. Cooperation with Lawrence Berkeley National Laboratory (LBNL) has been instituted, and students are involved in several aspects of the project. 2. Innovation in this project involves the planned use of both thermal and hydraulic fracturing. Assessment of this combination in this environment will provide interesting information for application to other areas.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
Progress to date has been very sound and, with the exception of delays due to permitting issues, well on track. Reviewer suggests having stronger evidence of the potentially significant barrier to flow in the basement (the ―Narrows zone") given that this may impact significantly on the area of hydrology. Reviewer suggests more evaluation of the thermal cracking planned as early work in Phase 2.

Reviewer 6:
VSP was accomplished. There are no obvious fault targets from basement displacements. Chemistry produced interesting hydrological interpretation in terms of different source fluids that are poorly mixed. Petrography turned out to be perhaps less useful. Rock mechanics testing was limited by core availability, depth constraint, and core age (circa1980s). Integrated gravity/MT/VSP interpretation is still in progress; utility for targeting purposes in this setting is being tested. Pipeline is complete. Background MEQ is in place; few events have been recorded. Crucial stage of logging/ stimulation/ creation/ monitoring is yet to start.

Reviewer 33:
The project has accomplished its goals for the stage it is at in the process. No fracture modeling has been done yet.

Reviewer 16:
PI has a very good "handle" on the geology. Uncontrollable delays have affected the progress (e.g., access to funds, permits).

Reviewer 26:
1. The project is behind schedule because of permitting problems that are apparently not the fault of the project team. All permitted tasks that could be completed to this point in time have been completed, and the budget appears to be sufficient to complete the project as planned once permits are approved. 2. Geochemical studies have resulted in a new model of subsurface geothermal fluid flow for the area; a VSP seismic survey bears out a horizontal attitude of rocks and contacts and gives no indication of faulting in the vicinity of the planned stimulation; magnetotelluric and active-source EM surveys have helped to elucidate the subsurface resistivity structure—resurveying post stimulation will determine the utility of these methods for reservoir monitoring; mechanical tests on available rocks have been performed; an MEQ monitoring network has been installed and is operational; and a pipeline to bring water to the stimulation site has been completed.

Comments Regarding Project Management/Coordination
Reviewer 3:

No issues identified.

Reviewer 6:
Dealt with some frustrating delays with permitting exploration activities. Planning for Phase 2 appears sound. Coordination with other projects has been excellent. Data sharing is on track;assisted with metadata template development for NGDS. Phase 1 was relatively costly, presumably due to pipeline construction.

Reviewer 33:
A very diverse group of experts in a wide variety of fields has been assembled and they have coordinated with each other with very good results.

Reviewer 16:
The project has involved four students. There has been good coordination with several parties.

Reviewer 26:
1. This project appears to be well managed despite the fact that it is behind schedule. Future plans are well laid out and are ready to be executed when all permits are in hand. The project team is working well together. Decision points are appropriate. 2. Results to date have been published, and the project promises all data and results will be available in the National Geothermal Data Repository.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project has clear goals and has to date made good progress. A diversity of techniques has been used to characterize the site geology, and a strong case was articulated for the techniques used in this case. An appropriate range of further work is in prospect, including the use of mini-frac tests to inform stimulation plans.

Reviewer 6:
Overall, this is a good EGS demonstration project. Circulation success will be rapidly taken advantage of because of the existing 10 MW installation. Excellent collaboration between experienced researchers in a wide range of disciplines (geophysics, geology, geochemistry, tracers, logging, stimulation, etc.) providing tests of suitability of practical methods for EGS exploration tools. Coordination with other EGS projects allowing for knowledge transfer. Frustrating delays with permitting;significant parts of program involving stimulation, flow-testing, and interconnectivity improvement are yet to commence. Conceptual model of resource has improved, but progressive development of a numerical model has apparently not yet been addressed. Results of interest include observation that faults don‘t apparently offset target quartz monzonite basement significantly. VSP to 2,300 feet was successful with bridge plug, but deeper seismic knowledge is still lacking, and usefulness of the survey is not immediately obvious. Interpretation of 3D MT model is not very clear with regard to resource extent, but further work on integrating with gravity may prove productive in terms of target structures. Interesting hydrological interpretation of geochemical data regarding barrier structure needs independent verification. More work on in-situ stress conditions and explanation for quiet natural seismicity may be helpful. Mechanical testing of sedimentary core at 1606 meters depth appears to have been of limited usefulness. Construction of a pipeline was essential to conduct stimulation experiments, but in itself was an expensive component with no direct research benefit.

Reviewer 33:
This project is one of the strongest projects in the group, albeit at a relatively early stage of its implementation. The geoscientific work has been very extensive, and has been put to good use.

Reviewer 16:
Reviewer recommends that DOE help the project team overcome the delays. The success of this project will help in the EGS "cause".

Reviewer 26:
1. This is a strong and worthwhile project, being conducted by a strong team, but so far being held hostage by the permitting agencies involved. However, it is important to be able to develop and demonstrate EGS technologies in various geologic environments, and Raft River is an appropriate site for such work. Therefore, the project should be encouraged to move ahead at best speed despite permitting setbacks. 2. The material submitted for this review and the presentation at the meeting were both well done and very helpful.

Comments Regarding Strengths
Reviewer 3:
The use of diverse geophysical techniques to define the 3D geology of the area is a significant strength.

Reviewer 6:
See ―Overall" comment above.

Reviewer 33:
The geoscientific work was significantly more extensive than most. The introduction of expertise from the oil and gas industry has been very useful.

Reviewer 16:

Reviewer 26:
1. The project team is strong and the quality of the work completed to date is high—state of the art. 2. Future plans are well laid out. It will be interesting and informative to see the results of the innovative stimulation method proposed—two treatments with cold water to precondition the rock for a large hydraulic fracture stimulation. Will this idea prove to be worthwhile in this geologic environment? Project results should answer this question and perhaps establish this method as one to consider at other locations. 3. The site is well instrumented with MEQ equipment to locate seismic events and fractures that will result from the stimulation. Resurveying using electrical geophysics after the stimulation will help evaluate these methods for reservoir monitoring.

Comments Regarding Weaknesses
Reviewer 3:
Little weakness identified at this stage although caution should be exercised in not over-interpreting data sets such as MT and the geological significance of the water chemistry.

Reviewer 6:
See ―Overall" comment above.

Reviewer 33:
More extensive analysis of the stress state and likely fracture performance would have been useful.

Reviewer 16:

Reviewer 26:

No technical weaknesses are apparent.

Suggestions for Improvement
Reviewer 3:

Reviewer 6:
See ―Overall” comment above.

Reviewer 33:
Push ahead with fracture modeling.

Reviewer 16:
See ―Overall” comment above.

Reviewer 26:
1. Nothing was mentioned about public outreach for this project. The existing power plant has been well accepted in the area. However, seismicity of low magnitude (M<1) underlying the geothermal reservoir has been detected by the installed MEQ array, and more events can be expected during and after stimulation. Although this is a rural and remote part of Idaho, it would seem to be worthwhile for the team to assess the advisability of public outreach at this stage in the project, before there are any surprises. 2. If not being done already, data from at least one of the MEQ stations should be made available to the Utah seismic net.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0402
Presentation Title: Implementation of a Demonstration EGS Project at Naknek, Alaska
Investigator: Vukich, Donna (Naknek Electric Association)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
This is a very ambitious project working on a low temperature resource, and a combination of regulatory and implementation issues has meant that much money has been spent with very little to show.

Reviewer 6:
The remote setting and high electricity costs in the project location address potential local benefits of enhanced geothermal systems (EGS), but the challenge of low-temperature gradients makes economics unattractive. The project addresses deep drilling and remote site challenges, but little else, with relatively high cost for the expected research returns.

Reviewer 33:
This is a genuine green field project, in an area not known for geothermal development. As such, it is of particularly high impact, if successful.

Reviewer 16:
Based on the expenditures so far, the reviewer strongly believes that this project will never reach completion.

Reviewer 26:
1. No matter how technically successful this project may ultimately be, it is quite unlikely to demonstrate economic use of geothermal energy from enhanced geothermal systems even though the power costs at this site in Alaska are high. It will, thus, not precipitate further development by the private sector on its own (i.e., without significant public funding) at similar sites. The basic problem is that there is no heat source at the site other than the normal (or perhaps slightly enhanced) geothermal gradient. EGS drilling, stimulation and production technology will need to be greatly advanced and costs considerably lowered before these normal-gradient resources become financially viable as stand-alone projects, without considerable outside cost participation. It would be better to have spent the money on EGS demonstrations where they have a chance of spurring economically viable development. 2. The data and results from this project will add another case study to the growing base of EGS projects, which is a positive aspect.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
Site selection seems to have been made on the basis of a very limited understanding of the geological and thermal structure of the region. What was the target? Little rationale was provided for the location of the drilled well, and the geophysical data used (ground magnetics and resistivity) was not presented with any information as to its utility.

Reviewer 6:
Planning for Phases 2-4 is adequate. Phase 1 geophysics and down-hole logging data collection could have been better.

Reviewer 33:
The drilling results have been disappointing. The possibility of flow behind casing, mud contamination, and a lost downhole assembly are significant problems.

Reviewer 16:
Major drilling failures need to be back-analyzed to determine potential causes. The temperature controversy explanation is not on very solid grounds. There was a poor choice of mud clogging pore space, even for a slotted liner.

Reviewer 26:
1. The approach is a standard one, with little innovation evident. Since there is no specific, areally confined heat source, only general exploration to site a borehole could be done. There was little explanation or discussion of the exploration program or the criteria used to site the well, e.g., the ground magnetic or resistivity surveys, why they were run and how they were used. The well G-1 location was not even noted on the geophysical cross sections submitted. The wisdom of performing this work thus has to be questioned. The project to date has been one of simply drilling to determine temperature, temperature gradient, and rock type at depth. 2. Some elements of the project team are well experienced and have expertise in geothermal resource development while others lack these skills. 3. Resources and infrastructure to deal with problems that have arisen and others which might arise are lacking in this remote location, driving up costs and slowing the project. Of course, this situation was known beforehand and was accepted when the project was funded.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
The first hole went grossly over budget due to a combination of local regulatory issues (a lack of understanding of geothermal drilling) and poor drilling standards.

Reviewer 6:
Poor choice of drill-site (in retrospect, the fault zone inferred from geophysics may be a conduit for cool flows rather than hot flows). Temperature inconsistency issues have not been resolved (maximum readout from thermometers of 225°-235°Fare probably erroneous; Kuster and memory tool well logging data are likely to be more reliable). Interpretation of isothermal condition at 4000-8000 feet is in doubt (suspect small internal liquid downflow from top to bottom of poorly cemented production casing, rather than natural external advective flow). High density mud (barite) should not have been used for G1. Most drilling problems and cost over-runs should have been avoidable. No info on micro-seismic monitoring results yet (collected but not yet analysed).

Reviewer 33:
The first well has not been a success. It seems likely that this first well may not be able to be used. The original plan called for the drilling of the second well based on the results of stimualting the first. Without the first well stimulation, proceeding to the second will be a significant problem.

Reviewer 16:
Able to drill the well using substantial funds, which is above expectations.

Reviewer 26:
1. Borehole G-1 reached a depth of 11,400 feet (according to Figure 1 in the presentation) after several problems were overcome, some not the fault of the project personnel. Drilling costs were very high, and it is likely that more experienced drilling management and crew should have been used. 2. Temperature surveys of the hole are available only to a depth of about 10,500 feet, and produced results that differed by 35°-45°F depending on the equipment. The actual temperature at total depth is still unknown. Reliable temperature measurements should be made a top and immediate priority for this project, and the project team apparently understands this. The straight-line bottom-hole temperature gradient projected to a depth of 12,000 feet (the target depth for G-2) is quite optimistic (see Figure 1 in the presentation). The data shown in Figure 1 do not appear to support the idea that the temperature may be 270° F at 12,000 feet. How was this figure derived? No information was given about what temperature would be needed at this

depth for the project to move ahead. There should have been a decision point at this stage of the project. 3. The geologic log appears to be well done, but there is no justification for assigning an arcuate west dip to the faults shown—is this real or artistic license? 4. The table showing projected drilling costs for G-2 is overly optimistic. Although $4.5 million in costs for G-1 were incurred for equipment failures and repairs (not including repair of the top drive after the stevedores dropped it on the dock), only $420K is allowed for similar problems in G-2. Is there any other contingency built into projected G-2 costs? Given the experience with G-1, there should be. 5. No details of the air lift of G-1 were given. It was just described as having "mixed results," whatever that means. This is a significant omission in such an expensive project. 6. No results from the 7 months of data from the seismic net were presented. There is no way to judge the quality of this work for this review.

Comments Regarding Project Management/Coordination

Reviewer 3:

The project management team lacks the high-level skills required to run a geothermal project and to manage the relationship with local regulators appropriately. The latter's insistence on barite muds and the lack of suitable subsequent mitigations proved financially disastrous for the project, which must have been very marginal when conceived. The decision to train and use local workforce for drilling (laudable in many ways) looks to have been responsible for significant issues leading to massive cost blow-outs in drilling well G1, including the top drive accident, the sidetrack failure and bottom assembly loss.

Reviewer 6:

The cost over-run of G1 drilling is excessive. The issue of what data is to be made public needs to be resolved. The temperature and flow rate projections for G2/G3 were overly optimistic to make a three-well program economically sound at 2MW. Future injection testing of G1 is problematic; cleaning out barite from formation and clogged slots is risky. Regulator permission for use of the diverter, aerated drilling fluids, and less frequent BOP tests for G2/G3 may improve the performance, but the future of the project looks shaky. One message is that regulator education was needed before drilling G1.

Reviewer 33:

I find the courage and coordination of the project team to be admirable. A diverse team of experts was assembled and used to good purpose, and also made very good use of local talent.

Reviewer 16:

Drilling G2 before understanding what really happened to G1 is not recommended. Project team should probably consider stimulating G1 to check the condition of the resource.

Reviewer 26:

1. No information was given regarding project costs compared with original budget for Phase 1. This is a serious deficiency in a project this expensive. 2. The statement that much of the information developed from this project is proprietary (Data Sharing slide) is very troubling. One would hope that enough information will be released to the public domain (e.g., project problems and how they were dealt with, what worked and what did not work, detailed project results including all data collected, total project costs, projected electricity costs per kwh, etc.) so that other developers can independently judge the merits of investing in similar projects at similar sites. 3. The statement in the Summary and Conclusions that "net generation capacity of 2MW from a three-well injection/production system would be economically feasible at Naknek" needs detailed, realistic backup. Given the expenditures to date, projected costs for G-2, costs for drilling a third well, stimulation and testing costs, and then ultimately costs for purchasing and installing a 2MW plant, the total cost for this project might easily exceed $50 million or more, or $25 million per installed megawatt!

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project, marginal from the beginning, although well intentioned in aspiring to provide sustainable and non-polluting power to a fragile environment, has been hampered by poor regulatory oversight and weak technical and project management. Insufficient geologically area/site work lead to poorly defined targeting. Overly cautious regulation drove poor requirements for drilling conditions, and inexperienced drilling crews led to massive cost over runs. Prospects for a commercial outcome look to be effectively non-existent.

Reviewer 6:
Overall, this is an expensive and disappointing EGS demonstration project with a high risk of failure. The objectives were bold and commendable, but remote site challenges, drilling problems due partly to bad luck and possibly partly due to inexperience, and a poor exploration model in terms of targeting, have made future success highly unlikely.

Reviewer 33:
This is a project that carries significant risk, perhaps more so now based on the current results than it did when it started. Nonetheless, this really is an innovative project, and its success would have large impact, both for the EGS community and for the people who live in its vicinity.

Reviewer 16:
This project should immediately be redirected (see recommendation below) or terminated at once.

Reviewer 26:
1. This project in unlikely to further DOE's goals of developing technology to spur use of EGS geothermal energy. There is little innovation evident in the project, so no new, broadly applicable technology can be expected. It will, however, be an interesting case history, depending on how much information from the project is actually put in the public domain. 2. EGS projects in normal or slightly enhanced geothermal gradient areas where deep drilling is required (>~5,000 feet) will not be economically viable until substantial advances are made in the drilling and EGS technology required, or until electricity costs reach levels well above those at Naknek. 3. The proposer seems to have quite limited resources to carry this project forward on its own, without infusions of cash from other sources, and unforeseen circumstances could derail the project. 3. The material submitted for this review and the presentation at the meeting were reasonably well done, but deficient in a few areas noted above.

Comments Regarding Strengths

Reviewer 3:
The project has great aspirations and is an area that could benefit from an appropriate choice of geothermal scheme.

Reviewer 6:
Motivation is high; objectives are noble.

Reviewer 33:
This is a different kind of project, and provides a significant broadening of the portfolio of EGS projects.

Reviewer 16:

Reviewer 26:
If ultimately successful, electricity generation from an EGS system in this area of Alaska would provide clean power

in an environmentally sensitive area.

Comments Regarding Weaknesses
Reviewer 3:
As noted earlier, technical, project and financial management looks to have been inadequate. Insufficient geological, geothermal, drilling, project and financial management skills look to have been available to the team.

Reviewer 6:
Drilling problems were excessive. Regulators were not educated in geothermal drilling practices. Exploration model was inadequate. Temperature data from maximum thermometers was not trustworthy.

Reviewer 33:
The well results have been disappointing so far.

Reviewer 16:

Reviewer 26:
1. Training the drilling crew while attempting to drill a deep, production-sized well in this difficult environment is not a wise choice from the perspective of project costs, even though it has created local jobs. 2. Lack of reliable temperature measurements at the bottom of the well prevents a reasonable go/no-go decision, although from the presentation, there are no plans to curtail the project at this point in any case. Reliable downhole temperature information must be obtained as soon as possible. 3. Estimated drilling costs for G-2 are far too optimistic. Yes, it will probably be cheaper than G-1 due to wellpad and other infrastructure now in place, but it is still too optimistic.

Suggestions for Improvement
Reviewer 3:
If the project is to continue, the hiring of personnel with extensive geothermal experience looks to be essential.

Reviewer 6:
This project needs better contingency planning, more geothermal experience on the team, and better understanding of geological/geophysical setting before targeting a drill-hole site.

Reviewer 33:
Bring in some drillers with geothermal expertise.

Reviewer 16:
Strongly recommend that a "scientific" advisory board be formed to help this project.

Reviewer 26:
1. Get a more experienced geothermal drill team on the job. 2. Use one of the available contractors (or Dave Blackwell at Southern Methodist University) to log G-1 to determine accurate temperatures with depth, measure thermal conductivity (if possible) and make the best possible prediction of temperature at 12,000 feet (target depth for G-2). If the projected temperature is lower than hoped, consider drilling G-2 deeper or abandoning the project. 3. Make a realistic financial analysis publicaly available for this project. According to the Future Directions slide, a "construction work plan and financial analysis have been completed." May we see them?

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0403
Presentation Title: Newberry Volcano EGS Demonstration
Investigator: Petty, Susan (AltaRock Energy, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
The project is still in the early stages, but the well-conceived and -executed plan is a positive contribution to DOE objectives.

Reviewer 6:
The project addresses most EGS barriers; it is a practical, realistic and achievable demonstration project in a green field setting, i.e., deep, very hot, very low permeability.

Reviewer 33:
Although this project is located in an area already explored for hydrothermal development, this is a genuine EGS project. This is also perhaps the one most likely to succeed, and if successful, the one with the greatest potential impact.

Reviewer 16:
This project is probably in the "ideal" location with the highest probability of success.

Reviewer 26:
This project addresses development of EGS technology in a new geologic environment known through drilling to have a high-temperature heat resource with low permeability at target depths. If successful, this project would open up a new area for geothermal power generation in Oregon. It, thus, directly addresses the DOE goal of spurring geothermal development using EGS technology while at the same time developing such technology.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
To date the approach taken is excellent. The lack of information on the regional stress magnitudes (as opposed to orientation) is the only matter of current concern, as it will diminish the ability to effectively plan the stimulation.

Reviewer 6:
This is a well-planned scientific investigation, particularly the new stimulation method using diverter agents (ALTASTIM) to target three zones/wells and reach 75 kg/s (at least). Good collaborations have been established. Overcoming challenges – lack of data at high temperature, lack of cores/geomechanical data, lack of natural seismicity. This project included well-planned public outreach.

Reviewer 33:
The team of people is first rate, and they are applying their technical expertise fully to this project. The modeling has been done fully, and the field itself has been well chosen (as it appears very promising).

Reviewer 16:
Stimulation of multiple zones is an acquired technology in the oil and gas industry (i.e., nothing new). Creating "hydroshear" stimulation is an assumption that is not backed up by any theoretical or numerical approach; some attempts should be made to optimize this.

Reviewer 26:
1. The technical approach is well described in the information furnished for this review, and appears to be sound. 2. The technical team for this project is very strong and well experienced. It includes university participation on some tasks, with attendant educational opportunities for students. It also includes Lawrence Berkeley National Laboratory (LBNL) and U.S. Geological Survey (USGS) personnel. 3. One innovative aspect of the project is the plan to stimulate three separate zones in the injection well through use of chemical diverters to isolate each zone in turn. If these diverters work, they would be an important advance in EGS technology that could also find use in conventional production from hydrothermal systems. The ability to control subsurface permeability by blocking specific pathways would be a very valuable technology advancement. 4. The project includes extensive public outreach and specific studies (e.g., water impacts, induced seismicity) to help deal with any public concern before issues get out of hand. 5. Significant effort is being put into the publication of results in the proceedings of the GRC, AGU and Stanford meetings.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
All planned activities have been accomplished on time and under budget if allowance is made for regulatory delays.

Reviewer 6:
The report is comprehensive and detailed. The project took good advantage of Light Detection And Ranging (LiDAR) survey data. The project team had good communication with the public; there were no induced seismicity concerns, but some water resource concerns. The borehole televiewer failed at 265°C; possibly could have used higher temperature-rated acoustic tool for ~300° C. Stress orientation and magnitude near bottom hole are unknown, affecting the reliability of stimulation modeling. Tough2 super-critical temperature modeling of the native state of the resource is a significant advance. The addition of fluid and gas chemistry and the geomechanical model under development should prove more enlightening.

Reviewer 33:
Stage I is almost complete. The well results are very encouraging. Observations match the modeling work well. The public outreach effort is to be applauded, and appears to have been very beneficial.

Reviewer 16:
The project team claims that the fracture opening pressure was predicted—on what basis? Especially if they ignore the in-situ stresses magnitudes. The maximum injectivity magnitude, mentioned on page 4 of the summary, does not seem to compare with the number given on page 5. Apparently a "test protocol" was developed by Texas A&M University, but there is no documentation to verify. Since shear fracturing is the implied mechanism, pumping rate and viscosity become important variables in the optimization of the stimulation treatment.

Reviewer 26:
1. The project is significantly behind schedule, primarily as a result of a delay in completing contract negotiations with DOE and a delay in receiving permits. The current major delay is with the Bureau of Land Management (BLM) and U.S. Forest Service (USFS) acceptance of the induced seismicity risk report and their comfort with the DOE induced seismicity protocol. However, Phase 1 tasks were completed within schedule and below budget. The project is poised, through good planning, to move ahead as soon as permits are obtained. 2. Work in preparation for stimulation has been extensive. Baseline injectivity tests have been performed, effects on local groundwater have been assessed with encouraging results, a microseismic array has been installed and calibrated, a borehole televiewer survey has been run that included borehole breakout analyses, and mechanical properties of rocks from the area have been studied. 3. Extensive publication of project results to date has been undertaken. 4. A model public outreach program has been instituted.

Comments Regarding Project Management/Coordination
Reviewer 3:

An excellent job to date—highly professional. Public outreach appears to have been appropriate and effective.

Reviewer 6:
The project team dealt with some frustrating delays in permitting. The publication of results and public presentations record (2010-2011) is impressive. The project team significantly underspent Phase 1 costs (by about50%). There were delays in starting Phase 2.

Reviewer 33:
It is apparent that this is a well-managed team of people who know clearly what they are doing.

Reviewer 16:
This project demonstrated extremely good project management/coordination and impressive efforts in public outreach.

Reviewer 26:
1. This project is well managed and coordinated. The diverse team assembled appears to be working well together.
2. Logical go/no-go decision points are included in the project, although none have been reached to date.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 3:
This project, taking an area with existing wells with essentially no permeability, and a relatively high temperature resource, is an interesting part of the diversity of DOE's portfolio. The quality of the team involved comes through clearly, with a thoroughly professional and comprehensive progress report documenting clearly the benefit the team‘s competence brings to the project.

Reviewer 6:
Overall, this is a promising and well-planned EGS demonstration project in a green field area. Lack of previous data is a challenge. The public outreach program and the good publication record are positives. Collaboration with reputable scientists has helped. Permitting delays mean progress could have been better; crucial results from stimulation (Phase 2) are still awaited.

Reviewer 33:
This is probably the strongest project of the group. Very promising field, good project team with excellent technical approach. Stage I is almost complete, with the next stage ready to go ahead.

Reviewer 16:
The lengthy summary provided before the review was quite verbose ", but withheld all pertinent data. The fact that breakouts were encountered suggests that the location is subjected to large differential in-situ stresses. Nowhere was there any mention of the possible associated difficulties (e.g., borehole stability issues, stimulation treatments, etc.).

Reviewer 26:
1. This is an important project for DOE's EGS demonstration program in that the project site is known through deep drilling to contain a high-temperature thermal resource (temperature>265° C at 8,860 feet) with low permeability and injectivity. This is exactly the type of target the EGS demonatration program should be going after. 2. A strong team, good facilities and instrumentation, and adequate funding have been assembled for this project. 3. One particularly innovative aspect of this project is the planned use of chemical diverters to isolate specific zones for hydraulic stimulation. 4. The material submitted for review and the presentation were both well done and helpful.

Comments Regarding Strengths

Reviewer 3:

Reviewer 6:
Strengths include planning, collaboration, public outreach, and a new stimulation technology test.

Reviewer 33:
Clearly an expert team. The public outreach effort has been notable, and very worthwhile.

Reviewer 16:

Reviewer 26:
1. The site has a known high-temperature resource at depth. 2. The project team is very strong and well experienced, and appears to be working well together. 3. Significant innovation can be expected to result from this project. 4. The public outreach effort is strong and apparently effective in allaying public concern for geothermal development in this highly environmentally sensitive area.

Comments Regarding Weaknesses

Reviewer 3:
I would like to have heard more about the chemical zonal isolation procedure to be used when stimulating the well.

Reviewer 6:
Weaknesses include permitting delays and modeling with insufficient subsurface data.

Reviewer 33:
None.

Reviewer 16:

Reviewer 26:
None apparent to date.

Suggestions for Improvement

Reviewer 3:

Reviewer 6:
Take advantage of new tools and techniques in high temperature logging and reservoir modeling once more information on subsurface conditions is available.

Reviewer 33:

Reviewer 16:

Reviewer 26:
Get it done.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0404
Presentation Title: New York Canyon Stimulation
Investigator: Raemy, Bernard (TGP Development Company LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Little information was provided to allow assessment against DOE's program goals.

Reviewer 6:
The project is expected to address some of the barriers to EGS, and should demonstrate progress in a particular geologic setting, but it lacks innovative objectives.

Reviewer 33:
This is a green field project, and therefore is a genuine test of the EGS concept. A success here would have high impact.

Reviewer 16:
This project is, at most, questionable, mainly due to the fact that the temperatures encountered at the test site (i.e. 545 degrees) are extremely high, requiring a (HPHT) approach. An advantage of this project is the high temperature gradient; hence, it has shallow wells and low drilling costs.

Reviewer 26:
This project appears to be a fairly strong one in an area with good potential for a high-temperature heat resource at depth (reported high temperature gradients in shallow boreholes previously drilled by others and steam from a shallow well), but no deep drilling has been done to date. It is possible that the first deep borehole could encounter a hydrothermal convection system with no need for EGS stimulation. If a heat source comparable to Dixie Valley, on the opposite side of the Stillwater range, could be confirmed, a potentially large development of new geothermal power could result, whether by EGS or conventional hydrothermal energy. This result would directly address DOE's overall goal of stimulating geothermal energy development.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
Characterization of the site's geology appears to be sketchy at this stage; no results from MT or seismic reflection work were presented. The approach to be taken came across as vague and poorly defined, and the geological concepts appeared to be weak. What is being targeted? No information appears to have been gathered to provide information on the area's state of stress.

Reviewer 6:
The project team has shown adequate planning for this demonstration project. The emphasis is on a geophysics exploration demonstration (MT, ESCAN, Seismic monitoring—not particularly innovative).

Reviewer 33:
There seems to be uncertainty about the site. Moving to the Dixie Valley side of the range would change the character of the project considerably. Not much has been done in the way of modeling,although for good reason; a well is not yet in place.

Reviewer 16:

Proper reservoir characterization will almost be impossible during prestimulation (i.e. Phase 1) due to the scarcity of operational down hole tools. The idea of moderate injection pressures is interesting, but has no foundations; its relation to seismicity has not been established. Indeed, does induced seismicity increase with pressure or with volume injected?

Reviewer 26:
1. The technical approach being taken by the team is straightforward for this type of prospect—first drill to determine whether high enough temperatures exist at depth, then, if the permeability is low, stimulate the well while monitoring microseismic activity. Locate a second full-sized borehole to connect with the stimulated reservoir and then perform circulation tests. 2. There was nothing presented regarding plans for assessing the state of stress in the rocks at target depths to assist in development of a stimulation plan. How will the stimulation plan be developed and by whom on the team? 3. The presentation at the meeting and the material submitted for review were a bit sparse, bare-bones, which makes it more difficult to evaluate this project. A more thorough discussion of results to date, showing data and current thinking, would have helped.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
While progress is very limited, spending on the project to date is proportionate. However, there is major uncertainty on the target to be drilled with talk of moving the focus quite significantly. Given the high temperatures expected, potentially beyond the range accessible to imaging tools, fracture stimulation may well be blind. Further, at this stage there is no conceptual or modeled basis for the proposed low pressure stimulation.

Reviewer 6:
Productivity is relatively poor; most effort to date has been on permitting, geophysics and planning of drilling/stimulation. Cultural issues and water issues have affected permitting delays. Little background on seismicity makes assessment difficult.

Reviewer 33:
The accomplishments can be considered "preparatory," as no wells have been drilled yet. The seismic monitoring is in place.

Reviewer 16:
The project has almost no data so far.

Reviewer 26:
1. There was no information on the original project schedule relative to accomplishments to date. Since the project is only 4% complete, it seems to be behind schedule. However, the Accomplishments slide indicates that "DOE contract terms & conditions" were finalized in 2011. Is this the cause of slow progress? 2. Permitting for the drilling of injection and production wells has been completed—a positive step. 3. No data or interpretations were submitted on the results of the geological and geophysical work to date, nor on the water quality work completed, so their quality can not be judged.

Comments Regarding Project Management/Coordination
Reviewer 3:
Very little clarity was provided on the planned activities, although there still seems to be an expectation that drilling will commence in Q3 2011. No target appears to be identified, water scarcity is still an issue and there is no data on site stress orientation or magnitude.

Reviewer 6:
Poor anticipation of water availability and other permitting issues have apparently placed the project, as originally conceived, at risk. The proposed solution to expand or change the area of focus shows a willingness to adapt and

flexibility, but devalues some of the sunken cost and effort.

Reviewer 33:
At the moment, the project seems unsure as to which would be the best way to proceed. A move to the other side of the range would be a significant modification to the project.

Reviewer 16:
No evidence.

Reviewer 26:
A go/no-go decision point has been placed after drilling of the first well. If "NYC is not suitable for EGS," the project would be discontinued or restructured. Presumably this means that if a producible hydrothermal system is found, the project would be reevaluated as to what to do with the funding allocated for stimulation. Other decision points are made at appropriate stages of the project.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
Far too few details have been provided in the project summary or presentation to allow a real evaluation of this project. What was presented came across as a sales pitch rather than a presentation for technical review, and left me with the profound impression that this project is technically weak. I see little evidence of innovation; based on the information provided, the project comes across as closer to a wildcat type of venture than something that has had serious consideration given the target reservoir and conditions.

Reviewer 6:
Overall, this is an average demonstration EGS project with medium expectations. It has had very limited progress (4% complete) due to a variety of reasons, mostly permitting, water availability and access. It is probably sensible to consider resiting the project (to adjacent Canyon?), and writing off much of the permitting efforts to date. Disappointingly, analysis of geophysical data collected in the 3rd quarter of 2010 is still not complete, so there appears to be an inadequate basis for siting new deep drillholes. Some comment on usefulness (or not) of MT, Escan, and vibroseis methods would be a helpful outcome. Lack of background seismicity from the existing eight-station network may also be of some concern. Installation of borehole seismometers could help resolve smaller events. However, if the project site is to shift, then installation of borehole seismometers at the original site is not justified.

Reviewer 33:
As a completely green field project, this one is very attractive. The uncertainty as to whether it would move to another site is a negative. The drilling schedule seems very short.

Reviewer 16:
This project also needs some help to make the project team aware of existing technology and research tools/results.

Reviewer 26:
1. This project could open up a new field for geothermal energy production in Nevada, and is therefore worthy of support.
2. The presentation and material submitted for review were rather sparse in terms of data resulting from the work so far. For example, the current geologic model of the area, the vibroseis survey ("still under review") and the electrical geophysics were not discussed, nor were the water-quality data. Results from LBNL's microseismic array were shown.
3. The project team is concerned about lack of microseismic activity in the immediate project area. It should be noted that

microseismic activity in many geothermal areas that have not been produced is quite episodic, so this lack may not be too important. 4. No mention was made in the presentation of provision of project data to the National Geothermal Data Repository. It would not be good if much of the data are held proprietary.

Comments Regarding Strengths

Reviewer 3:

Apparently there are high temperatures present, although no evidence was presented.

Reviewer 6:

See Overall comments above.

Reviewer 33:

A successful project here would match many people's concept of what EGS could achieve in early stages—a brand new site in Nevada, where societal impact would be minimal.

Reviewer 16:

Reviewer 26:

1. Existence of a high-temperature heat source at depth in this area has a high probability—this is an excellent area for deep drilling. 2. The project team seems to be competent and well experienced. 3. Terra Gen has sufficient resources to carry a project of this magnitude forward even in the face of unforeseen adverse circumstances.

Comments Regarding Weaknesses

Reviewer 3:

This project appears to lack technical expertise in a wide range of disciplines required, and does not appear to have any clear technical leader but rather a bunch of disparate and separate consultants. There seems to be a poor geological model and a lack of information on site stress conditions. Water scarcity at the site is a real problem;no plan for addressing it was discussed.

Reviewer 6:

See Overall comments above.

Reviewer 33:

The uncertainty about a possible change of location is unhelpful. The time schedule of the project seems very short.

Reviewer 16:

Reviewer 26:

1. The potential lack of sufficient water for injection was noted in the material submitted and the presentation. This is a serious matter and may require additional funding from the proposer (and DOE?) to mitigate. Lack of sufficient water could hamper development of either an EGS operation or conventional hydrothermal operation. 2. There appears to be no plan for measurement of downhole stresses in the potential reservoir rocks. Such measurements could be an important component for development of the stimulation plan. 3. There was no discussion of how the two deep wells will be sited and what use will be made of the geology, geophysics and geochemistry in this task.

Suggestions for Improvement

Reviewer 3:

Hire a technical leader and develop a plan.

Reviewer 6:
See Overall comments above.

Reviewer 33:
Decide where the project will actually be implemented.

Reviewer 16:

Reviewer 26:
1. Add rock mechanics expertise and measurements to the project, if they are indeed missing. 2. Be more forthcoming in materials presented to DOE for review.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0405
Presentation Title: Desert Peak East EGS Project
Investigator: Zemach, Ezra (ORMAT)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
Project has demonstrated injection rates appropriate to the Geothermal Technologies Program's (GTP's) goals, although reservoir conductivity is not quantified at present.

Reviewer 6:
This is a mature project. Three stimulation approaches have been tested in a softer rock setting. A comprehensive research plan was implemented to address issues relevant to creation and testing of stimulated permeability.

Reviewer 33:
A successful project here will have significant impact. However not as much impact as a conventional EGS project in an area not already operated as a hydrothermal field.

Reviewer 16:
Basically, this project's goal is to increase communication with an existing geothermal field.

Reviewer 26:
An important, but still developing, use of EGS technology is the stimulation of certain wells within geothermal fields that do not produce fluids at sufficient rates to be commercial. Many fields contain such wells. This project addresses one instance of this situation in the Desert Peak field. The data gathered in this project will add to EGS technology by producing a case history that will allow operators in other fields to assess investment in similar projects. If successful in reaching its objectives, this project will also increase the production of electricity from Desert Peak.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
There was a lack of clarity concerning the rationale for the 'shear' and 'hydrofracture' stimulations. The tracer work does not appear to have been well thought out based on the very limited information provided in the presentation and discussion.

Reviewer 6:
This project has a sound scientific and technical approach. Its adaptive strategy allowed for plan changes and evaluation of different technology options.

Reviewer 33:
This is a well-considered project, with full analysis of reservoir observations and results.

Reviewer 16:
It is difficult to accept that a "soft" formation could be stimulated without the use of proppants. There is no detailed explanation about the mechanism(s) responsible for the borehole instability when affected by chemicals. The methodology being developed is unclear.

Reviewer 26:

The technical approach has been fairly straightforward and is sound. The project team is experienced and capable of executing the project as planned and evaluating interim results. The research site is well instrumented to improve the reservoir model and gather important data during and after stimulation. Data generated from the innovative three-pronged stimulation approach in "soft rock"—initial shear stimulation, chemical stimulation, and hydro-fracking—will be of interest to the EGS community.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Given the long duration of the project, the results are rather limited. However, a significant increase in the injection rate has been achieved, and microseismicity induced during hydrofracturing was consistent with expectations. Communication between injection well and producer has been confirmed by the tracer work.

Reviewer 6:
Progress is improving, but there continue to be issues associated with technology issues, equipment availability, and seismicity protocol compliance. Some issues—due to formation instability and chemical stimulation—developed in managing the well condition, leading to extra cost of well cleanout.

Reviewer 33:
Results are already in place; the well has been stimulated. Also, the fracture model predictions were shown to be correct. Tracer analysis revealed unambiguous success in achieving a connection within the reservoir.

Reviewer 16:
Apparently, the "soft" formation has been stimulated, although there are doubts about the fracture geometry that has been created. The project team mentioned initial shear, followed by "controlled" hydrofracturing. What is meantby "controlled"? Also, the shear fracture did barely increase the injectivity as compared to the tensile feature—what is/are the reason(s) for this?

Reviewer 26:
1. This project has been underway for years and is now nearing completion, scheduled for the end of 2011. The planned stimulations have been carried out on well 27-15 with mixed results. The initial shear stimulation increased injectivity significantly, the chemical stimulation caused the well bore to deteriorate, and the hydrofracturing increased injectivity further. Tracer testing indicated a connection between the DP injection zone and 27-15, so a connection to the producing field has been formed. However, additional stimulation, now underway, will be required to reach desired injectivity values. 2. The project was apparently delayed by 6 months due to compliance with the DOE induced seismicity protocol. However, at last year's Peer Review, it was stated that the project would be completed in 2010, so other factors, not discussed, must have also caused delay.

Comments Regarding Project Management/Coordination

Reviewer 3:
Without knowing what the original plan was, it is impossible to evaluate the quality of project management. The reason for shifting activity from well 23-1 to 27-15 was not elaborated on. No obvious failings are apparent, other than the delay introduced by the externally imposed necessity to ensure compliance with induced seismicity protocols.

Reviewer 6:
Current stimulation work program and plan is reasonably comprehensive and well managed. Technology evaluation is competent. Some delays, e.g., due to induced seismicity protocol compliance, might have been handled better.

Reviewer 33:
The project has been well managed, successfully bringing together a diverse group of consultants, contractors, and

company people. The only negative was their inability to provide the required materials to this review.

Reviewer 16:

Reviewer 26:
1. The material needed by the reviewers was not submitted in a timely manner, thus compromising our ability to evaluate this project. 2. Overall, the project appears to be reasonably well managed.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
The presentation for this project was only provided at the time it was given and not in advance, and no project summary was made available. The PI was not present and it was not clear that the presenter was entirely familiar with the project as a whole. Further, given that this project has been underway for nearly 10 years, no information was provided on its evolution and the reason for the change in injector well selected. However, progress has been made including the demonstration of significantly enhanced injection rates, though not yet to commercially useful levels.

Reviewer 6:
Overall, this is a good EGS demonstration project, which is relatively mature, has encountered its share of problems in the past, but is now showing promising indications of success. Planning for stimulation activities is sound. Hopefully lessons have been learned in terms of the causes of well instability issues, and the benefits of perseverance with various stimulation techniques and choice of favourable structural settings, because additional stimulation is needed to improve injectivity and make the project successful. Another lesson learned is the need for deep borehole seismometers to characterize very small magnitude events (M= -1 or -2) in order to track the progress of an expanding stimulated reservoir volume. Also, to be successful, there is a need to maintain high pressure stimulation pumping continuously for a week or more and this requires attention to maintenance schedules and water supply.

Reviewer 33:
This is a mature project, and is already achieving its goals.

Reviewer 16:
The reviewers had no access to any documents prior to the meeting. The project is 80% complete, but many unanswered questions remain. Need to spend time in understanding what happened.

Reviewer 26:
This project has been going on for years since its initiation in 2002, and is scheduled to be completed by the end of 2011. It has produced a considerable amount of information that is of interest to geothermal developers, much of which has been presented at GRC and Stanford meetings.

Comments Regarding Strengths
Reviewer 3:
The enhanced flow rates and demonstration of the connectivity created by fracturing to the producer well are both strengths of the project. The lessons learned from working in soft rock will also be of value if appropriately captured.

Reviewer 6:
See Overall comment above.

Reviewer 33:
Good coordination between the modeling work, the measurements, and the implementation of the stimulation.

Reviewer 16:

Reviewer 26:
Developing EGS technology for use in the interior or on the periphery of known, operating fields will help extend the life of such fields, and is a good use of DOE RD&D funding.

Comments Regarding Weaknesses
Reviewer 3:
A lack of clear demonstrated understanding of the local stress regime fracture and the interaction of this with the 'shear' and 'hydrofracture' stimulation pressure regimes is of some concern.

Reviewer 6:
See Overall comment above.

Reviewer 33:
None.

Reviewer 16:

Reviewer 26:
According to the Data Sharing slide, "Ormat will share all non-proprietary data with the DOE Geothermal Data Repository." It will be a significant deficiency if this does not include data and results sufficient to allow other operators to judge the applicability to their own fields. This is especially relevant since DOE provided almost twice as much funding for the project as did Ormat.

Suggestions for Improvement
Reviewer 3:

Reviewer 6:
See Overall comment above.

Reviewer 33:
None.

Reviewer 16:

Reviewer 26:
Finish the project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0406
Presentation Title: Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field
Investigator: Walters, Mark (Calpine - Geysers Power Company LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
This project is looking to exploit high temperatures in an existing, known resource without sufficient permeability; it is an example of the diverse projects captured by DOE's portfolio.

Reviewer 6:
This is a well-conceived project to test deep permeability enhancement in high temperature roots of a large conventional geothermal system. Could have major implications for future economic and sustainable development strategies elsewhere. Outstanding objectives include educational outreach, stimulation tests by cooling contraction and chemical dissolution, and understanding reservoir/recharge properties at >400°C conditions.

Reviewer 33:
This is a very different kind of EGS, but one that has considerable likelihood of producing large amounts of elecrical power.

Reviewer 16:
This project essentially consists in shear reactivation. It is an interesting concept that could extend the reservoir as well as the life of existing geothermal resources.

Reviewer 26:
This project is highly relevant to DOE's goals of spurring geothermal energy development by the private sector. If the project is successful, Calpine can be expected to continue on its own to develop further the high-temperature reservoir (HTR) at The Geysers. The HTR is a very large, essentially untapped thermal resource that could extend the life and production capacity of The Geysers field very considerably. The project includes a great deal of technological innovation on the parts of Calpine and its research partners at universities and labs, particularly at Lawrence Berkeley National Laboratory (LBNL). The educational aspects of the program will help the public to be more accepting of geothermal development. Importantly, all information and results of the project will be available in the public domain, adding measurably to the geothermal literature.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
The team and its approach are scientifically and technically sound. The changeover of producer and injector wells was rationally conceived.

Reviewer 6:
Approach of testing high-temperature, low-permeability rock for relatively shallow stimulation trials (low-pressure cold water) at The Geysers, as a test bed, is economically sound and cost efficient. Challenges tackled include: well repairs, numerical models, understanding seismicity, chemical issues, geomechanical issues, downhole measurement issues, and non-condensable gases (NCG) , in a field setting that is relatively well instrumented and understood.

Reviewer 33:

The scientific and engineering approaches show considerable maturity, which can be attributed to the many years of familiarity with this particular site. The drilling is complete and has been achieved with very good success. Modeling of the activities has also been carried out successfully.

Reviewer 16:
This project mostly relies on existing technologies. Need to better understand the growth of the microseismicity. The speaker led the reviewer to believe that some data and information was going to remain confidential.

Reviewer 26:
This project is well designed to achieve its objectives. The project team is well experienced and very strong. The years of experience on the parts of the Calpine and LBNL scientists and engineers in The Geysers field will help ensure that the project is carried out in the best possible manner. Use of the area as a laboratory for testing high-temperature downhole tools will help advance such technology. The public education aspects of the project will help ease public concern about EGS development through its openness and candor.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
Well deepening and (initial) completion, pipeline construction for stimulation and geomechanical model development have all been completed on schedule.

Reviewer 6:
Recompletion of production and injection well pair and injection pipeline was successfully completed. Adaptive approach allowed for strategy changes (reverse doublet) where justified by new information. Improvements in seismic monitoring, super-critical temperature reservoir/geotechnical modeling, and educational outreach, are on track.

Reviewer 33:
A very high temperature has been achieved, and drilling results have been very successful. An augmented seismic array has been installed and is in use.

Reviewer 16:
The project is on time.

Reviewer 26:
The project appears to be on schedule as planned. The two wells, P-32 and PS-31, are ready for recompletion and stimulation will begin soon. The pipeline to bring water to the project is complete and tested. LBNL has supplemented its microseismic monitoring system in the area as planned. LBNL's participation through development of coupled thermal, fluid flow, and geomechanical modeling capabilities is an important adjunct to this project in that such models will ultimately be available for others to use. Most of the DOE funding has been spent, and Calpine will continue work on its own funding.

Comments Regarding Project Management/Coordination
Reviewer 3:
Progress is on track and under budget.

Reviewer 6:
This project is well managed and coordinated with strong industry support and a focus on improving modeling and measurement technology. Some technical issues with the current status of recompleted wells may cause future problems.

Reviewer 33:

This project has an experienced, technically expert team, working well together.

Reviewer 16:
Satisfactory.

Reviewer 26:
The project appears to be very well managed and coordinated. Most of the project team has worked together well over a period of years, and this can be expected to continue.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
The project comes across as being technically and managerially very competent, with the prospect of opening up a significant portion of the Geysers resource that has not been utilized to date. The experience of working at very high temperatures will be of significant benefit to the DOE Geothermal Technologies Program.

Reviewer 6:
Overall, this is a high quality EGS demonstration project in the high temperature roots of the well-known but depleted Geysers geothermal system (—a EGS project made in heaven"). If successful, returns will be significant, and knowledge gained will help guide development strategies for the roots of many other high-temperature geothermal systems. Strengths are in the areas of high-temperature instrumentation, modeling, public outreach, understanding induced seismicity, mitigation of NCG, and cold water stimulation methods. Weaknesses are the potential for problems with discharging fluid and gas chemistry, and with longevity of recompleted old well bores, to cause premature failure of a longer-term flow test.

Reviewer 33:
This project looks very promising and is likely to be successful. Although different than the conventional image of an EGS project, it seems very likely to succeed and produce significant electrical power.

Reviewer 16:
This project is almost complete; it could be a good demonstration of EGS. The issue of potential supercritical flows has not yet been resolved.

Reviewer 26:
1. This is an important project for the EGS program in that, if successful, it will spur the development of a very large heat resource—the recently discovered high-temperature zone—at The Geysers, which has not been very extensively developed to date due to high content of non-condensable gases, including a high chlorine content which causes unacceptable rates of corrosion in downhole and surface equipment. One objective is to develop and test technology to lower NCG content and corrosion in this reservoir and others of its kind. The objective of stimulating such high-temperature rocks (750°F) using cold water at controlled injection rates will yield new information on the stimulation process itself and on any related microseismic activity. 2. The project has made good progress, is on target and within budget. It appears to be well managed and incorporates a strong team. 3. The material submitted for review and the presentation at the meeting were both very well done.

Comments Regarding Strengths
Reviewer 3:
Good progress and technical competence, based on years of production experience in the area.

Reviewer 6:
See Overall comments above.

Reviewer 33:
The project benefits from substantial experience in the field itself, as well as from having a project team that is intimately familiar with the specific geology and reservoir properties.

Reviewer 16:

Reviewer 26:
1. The project is important in furthering development of, and extending the life of, The Geysers field. DOE's funding is well spent on this project. 2. Stimulation of permeability in very high-temperature rocks by controlled injection of cold water will produce data and results of broad interest in the geothermal community. 3. The reservoir modeling development being incorporated into the project will help advance this technology, and the advances will be available in the public domain. 4. The continued study of microseismicity associated with fluid injection and projection will add to this growing body of knowledge. 4. All data from the project will be available publicly through the National Geothermal Data System. 5. Strong liaison with and participation with universities, the European Geiser FP7 project and LBNL are positive aspects.

Comments Regarding Weaknesses
Reviewer 3:
I would have liked to have heard more about the mitigations associated with producing highly acid fluids.

Reviewer 6:
See Overall comments above.

Reviewer 33:
None.

Reviewer 16:

Reviewer 26:
None apparent.

Suggestions for Improvement
Reviewer 3:

Reviewer 6:
A question the investigators may wish to consider is what are the implications, in terms of ductile versus stick-slip strain relief, and MEQ behavior, of long- and short-term changes in temperature and pressure arising from utilization of these deeper super-critical. resources?

Reviewer 33:
None.

Reviewer 16:

Reviewer 26:

None.

High Temperature Tools, Sensors, Systems, Drilling Systems

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0700
Presentation Title: High Temperature 300C Directional Drilling System, including drill bit, steerable motor, and drilling fluid, for Enhanced Geothermal Systems
Investigator: Dick, Aaron (Baker Hughes Oilfield Operations Incorporated)

Comments Regarding Relevance/Impact of Research

Reviewer 13:
This project addresses a central requirement for geothermal drilling, namely the development of an integrated system of drill bit, steerable motor and mud system suitable for high temperature operation. This is clearly of high importance to the overall Geothermal Technologies Program.

Reviewer 78:
Current practices are more costly because of the various workarounds that are needed. Insulated drill pipe was an approach that permitted a downhole environment that was acceptable for instrumentation and tools as well. But the result was a drill string that was very heavy. This is an area that needs attention. Logging instrumentation and monitoring instrumentation *are* in need of high temperature non-heat-shielded tools, especially the monitoring for stimulation and production. Better understanding of reservoir flow patterns and how to *fix* them will need monitoring capability.

Reviewer 39:
This project represents a thorough, systems-level approach to the development of high-temperature directional drilling technology. The technical findings and technology developed should provide significant benefit to future EGS efforts.

Reviewer 75:
The actual meat of this project is entirely consistent with the mission and goals of the DOE EGS program. The drilling bits, directional motors and drilling fluid developed for 300°C environmental temperature and 10km depths, if successful, will have considerable impact on the drilling of hard and fractured formations.

Comments Regarding Scientific/Technical Approach

Reviewer 13:
A well-balanced project and program. At some stage, possibly as a follow-on project, the authors should give thought to adding a MWD capability. The present scope is sufficient for now, however.

Reviewer 78:

Reviewer 39:
The design and execution of the technical approach have been logically formulated and systematically achieved.

Reviewer 75:
The technical approach of this project is clearly stated, organized and well thought out. The project has pretty good focus; four drill bit types and two motor concepts were evaluated and down-selected. The complexity of the current problem facing extreme conditions in general is the material selection of the elastomer and coatings of the rotor/stator. The technical path towards the next phase, in particular the testing plan of the high-temperature positive displacement motor, is being shown to be sufficient to validate the design.

Comments Regarding Accomplishments, Results and Progress

Reviewer 13:

A key requirement of the program, and the element with the highest reward but also the highest risk, is the development of a motor with no polymeric sealing element between stator and rotor. This, in turn, depends on finding a suitable wear-resistant coating for the stator and/or rotor. The project members are aware of this issue and are taking appropriate actions to ensure success. Building of the motor test stand is somewhat behind schedule, but is on track to catch up. Some interesting developments were presented concerning drill bits, particularly in the design of the hybrid bit and new sealing technology.

Reviewer 78:

Reviewer 39:

Progress to date has, in general, been good.The ultimate benefits cannot be assessed until the high-temperature prototypes, the mud motor in particular, have been developed.

Reviewer 75:

The quality and productivity of the accomplishments/results in terms of feasibility study and conceptual design have been good on overcoming the technical barriers and in relation to the resources expended. In the reviewer‘s opinion, the feasibility study and conceptual design stage is appropriately completed. The coupon tests and fluid properties identification at 260°C are well conducted. A key criterion of success of the project in the next phase will be the laboratory test of the high-temperature motor.

Comments Regarding Project Management/Coordination

Reviewer 13:

Management appears on track, apart from the slow progress on the motor test stand, noted above.

Reviewer 78:

Reviewer 39:

No issues of note.

Reviewer 75:

Regarding the project management, every task that was committed looks to be on schedule, if not slightly delayed. The resources that were coordinated and the budget spent are both in good positions.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:

An important and well thought out project. Providing a bit-motor-mud-directional drilling system is a key requirement for any geothermal drilling project. Significant advances have been provided in drill bit design and the bent sub for directional drilling is straightforward. Good progress is being made on the motor and this is the most critical and highest-risk part of the project. Time will tell if this will be successful.

Reviewer 78:

A number of organizations are attempting to develop high-temperature instrumentation and tools. There needs to be better organization about what tools are most needed at this time. The reviewer sees nothing wrong with more than one organization being funded to develop technology. But there does not seem to be any attempt by DOE to orchestrate the tools and technology to be developed. It appears that whoever comes to the door often enough will get funding. Resistance wins. That is because identifying a really new *relevant* concept is more difficult.

Reviewer 39:
In this reviewer's opinion, this project represents a good investment of resources with the potential to bridge the gap between conventional or moderately high-temperature capability and high-temperature capability. The development effort is in general evolutionary, as opposed to revolutionary, but will provide valuable assets to the geothermal drilling tool kit if successful.

Reviewer 75:
The reviewer found this project to be a well-organized plan that clearly outlines the strategic direction EGS intends to take in exploring high-temperature directional drilling systems. The overall strengths, weaknesses and suggestions are listed below.

Comments Regarding Strengths
Reviewer 13:
Good work on bit design. Some good thoughts on the motor, but time will tell.

Reviewer 78:

Reviewer 39:
Critical technical obstacles are well defined and understood, permitting a methodical approach to the development of the technology.

Reviewer 75:
The project has demonstrated expertise on drilling system design. The project is well managed and currently delivering to schedule. The quality of deliverables has been good. Risks have been controlled and mitigated.

Comments Regarding Weaknesses
Reviewer 13:
Need to catch up on the motor test stand; motor testing will be critical.

Reviewer 78:

Reviewer 39:
There is very little attention being paid to the steering components of the system. This is probably not a significant weakness at this stage as the development of the bit rotation components is probably more critical at this juncture of the development.

Reviewer 75:
Weaknesses are difficult to say at this point. If the project can address the key technical challenges such as elastomer components, coating materials and tolerance control in the next stage, it is potentially a successful project with a big impact on EGS.

Suggestions for Improvement
Reviewer 13:
Reviewer suggests some thought in the future to be given to acquiring MWD capabilities; that's beyond the scope of the present project, however. As with all of the presentations reviewed, the presentation slides had much too much detail that could not be assimilated in the time available.

Reviewer 78:

Reviewer 39:
None.
Reviewer 75:
It might be helpful to coordinate with Honeywell Aerospace or GE Global Research on getting potential solutions/instruments for high-temperature measurement while drilling.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0701
Presentation Title: Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems
Investigator: Oglesby, Kenneth (Impact Technologies, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 13:
Drilling of small diameter laterals may be of value in gaining access to natural fracture arrays that are not intersected by the main borehole. While this is a desirable capability, the reviewer feels that this is of lesser importance than concentrating on reducing the cost and increasing the reliability of the main borehole.

Reviewer 78:
The approach addresses concepts that may be helpful in reservoir flow management. Sensing of the flow is very important, as is reservoir modeling. Sensing the flow patterns in fractured reservoirs is difficult, but needed. More instrumentation and flow altering research is needed. Need to address issues around short circuits.

Reviewer 39:
It is not clear how this technology

Reviewer 75:
The basic objectives of this project aim to develop a configuration of microhole arrays in order to increase heat recovery and the efficiency of EGS. The FLASH ASJ system and the entire microholes completion method are innovative and consistent with EGS mission and goals.

Comments Regarding Scientific/Technical Approach
Reviewer 13:
Much work has been done in the past on drilling small diameter lateral holes from an existing borehole, and in particular by using high pressure jet technology (mostly high pressure water jets, but some abrasive jet work, both in the United States and Australia). The current proposal uses an abrasive slurry jet at relatively lower pressure, which may be novel, but the reviewer believes that there is sufficient similarity to previous work to be concerned about difficulties that were experienced with the previous efforts. In particular, problems were encountered in controlling the direction of the lateral holes, and in dealing with cuttings removal. The idea of dumping the cuttings (provisionally) in a rat hole of the main larger diameter bore has been tried and has proven difficult. These problems were experienced when water was the only cutting medium . In the present case, a quantity of abrasive material is to be added to the solids burden. How much this will be, as a proportion of the cuttings, is unknown, and the authors were unable to estimate the volume ratio of rock debris to abrasive. The reviewer thinks that this will be less than one, since it is hard to believe that a single abrasive particle will be able to remove more than its own volume of rock, particularly in hard rocks. In past efforts to drill using abrasives, nozzle wear has been a big problem, but the authors did not seem concerned, although no work in this area was reported. Modeling work being done at Lawrence Berkeley National Laboratory (LBNL) appears disconnected and is probably premature before the drilling method has been shown to work.

Reviewer 78:

Reviewer 39:
Laboratory testing to prove the feasibility of the approach in a geothermal environment is conspicuously absent from the project plan. Testing of the technology in conditions with no confining pressure is of limited value in the opinion of the

reviewer. There has also been insufficient evaluation of the surface system and fluid conveyance required for the approach. Other significant issues such as hole cleaning are not adequately addressed.

Reviewer 75:
The program evaluates and further develops the FLASH ASJ microhole drilling system in order to make it compatible with EGS specifications, and designs the layout of the arrays by using numerical evaluation to optimize the heat removal from the hard rocks. In the reviewer‗s opinion, this technical approach is clear and effective in terms of addressing knowledge gaps.

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:
Reasonable work has been done so far, but much remains to be done before the technology can be considered ready for even a modest field test. The proposers may not be aware of previous work done and difficulties experienced by other workers attempting to drill lateral boreholes from a main large-diameter hole using coiled or flexible tubing and water-jet cutting. As noted above, the modeling work done at LBNL appears disconnected and is possibly premature.

Reviewer 78:

Reviewer 39:
The relevance of the drilling results obtained to date are of limited value for reasons mentioned in the section above.

Reviewer 75:
The quality of the accomplishments/results/outcomes has been good. However, the productivity of the accomplishments up to date looks to be just adequate in relation to the resources expended. The FLASH ASJ system and the core numerical software, such as TOUGH2, used in this program are existing products. The reviewer didn‗t see significant accomplishments beyond what already exists. In addition, since the configuration of the arrays has been identified, the presentation should at least include a figure that illustrates the configuration.

Comments Regarding Project Management/Coordination
Reviewer 13:
A higher priority should have been given to issues such as nozzle erosion and to determining the ratio of cuttings produced to abrasive used. Previous similar work has struggled with difficulties in these areas as well as issues to be dealt with later such as steering and the removal of cuttings, both from long lateral holes and connected with the dumping of cuttings into rat holes. Poor coordination between the drilling work and the modeling being done at LBNL appears to be a project coordination issue.

Reviewer 78:

Reviewer 39:
The inclusion of the simulation tasks seems misplaced for this project. There are fundamental feasibility issues that must be addressed for this drilling technology that should take precedence over reservoir simulation studies. System level integration and field deployment of the technology is insufficiently covered.

Reviewer 75:
Regarding project management, the project did well on coordinating the resources from multiple organizations and building partnerships. The tasks that were committed for FY 2010 have a slight delay. The future plan for the project seems well structured on the simulation side, but should also focus more on the testing, if applicable.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
The proposers appear to not be aware of difficulties experienced by previous workers in the field of jet drilling (with or without abrasives), notably in the United States and Australia. The present work is approximately where high pressure water jet drilling was from 1990to 2000, with much work having been reported as far back as the 1970s. Several key issues may turn out to be show-stoppers, including nozzle wear, dealing with cuttings and/or spent abrasives, directional drilling control, and, in the case of geothermal drilling, the possibility that the expected large quantity of abrasives required will fall into existing fractures and plug them. All of these issues need to be assessed before modeling reservoir behavior.

Reviewer 78:

Reviewer 39:
The task focus for this project is poor. This is at best a laboratory level technology at this stage. Project tasks should focus on demonstrating field-like conditions in a laboratory environment along with more thorough planning for field deployment technologies.

Reviewer 75:
The project clearly states the strategies toward EGS direction. The overall assessment of this program has been good. There is always a fine line between providing too little and too much information when describing particular results, but I feel the accomplishments shown in this project are slightly below the desired level of detail.

Comments Regarding Strengths
Reviewer 13:
None noted.

Reviewer 78:

Reviewer 39:

Reviewer 75:
Project is on track. Expertise on microholes drilling system is evident. Budget allocated was sufficient at this point. Risks have been identified and controlled.

Comments Regarding Weaknesses
Reviewer 13:
Several weaknesses noted above may be show stoppers. These potential problems should be addressed before moving forward.

Reviewer 78:

Reviewer 39:
Critical feasibility issues such as the ability to drill in high-pressure and -temperature conditions are not addressed. Numerous field deployment issues are also not adequately addressed, including a description of the surface equipment needed for the operation; hydraulic modeling of the process flow from the surface pumps, through the coiled tubing and back to the surface (required pumping pressure to overcome pressure drops through the coiled tubing, across the jet nozzle

and back to the surface, in particular, must be addressed); and hole cleaning.

Reviewer 75:
As aforementioned, the presentation should try to provide more technical details in terms of accomplishments and results in the next review.

Suggestions for Improvement
Reviewer 13:
The reviewer suggests conducting a thorough search of the literature to learn from the difficulties encountered and solutions developed by previous workers in the field.

Reviewer 78:

Reviewer 39:
The reviewer suggests developing a laboratory test plan and setup for simulating drilling at application pressure and temperature conditions.

Reviewer 75:
In addition, the project should be able to address the abrasion of the nozzles with high speed flow and the removal of the injected slurry within the microholes.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0702
Presentation Title: Roller cone and rotary drag drill bits with a novel cutting insert and a centralized jack/hammer are proposed for three fold increase in overall EGS drilling.
Investigator: Hall, David (Novatek, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 13:
This project was not presented.

Reviewer 39:
Did not review project because no presentation of work was given at the review.

Reviewer 75:
The presenter didn't show up to in this DOE Peer Review. Please go to Overall Assessment below to find some comments, which are made based on reading the project summary and the slides.

Comments Regarding Scientific/Technical Approach
Reviewer 13:

Reviewer 39:

Reviewer 75:

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:

Reviewer 39:

Reviewer 75:

Comments Regarding Project Management/Coordination
Reviewer 13:

Reviewer 39:

Reviewer 75:

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
This project was not presented.

Reviewer 39:

Reviewer 75:
The presenter didn‘t show up for the review, and apparently, the report/presentation has been written in a hurried fashion. The summary was not well structured and missed most of the sections that DOE required. Regarding the project management, this program has already spent 88% of the total budget with another one and half years to go. The reviewer would suggest that DOE talk to the principal investigator and evaluate this program as soon as possible.

Comments Regarding Strengths
Reviewer 13:

Reviewer 39:

Reviewer 75:

Comments Regarding Weaknesses
Reviewer 13:

Reviewer 39:

Reviewer 75:

Suggestions for Improvement
Reviewer 13:

Reviewer 39:

Reviewer 75:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0703
Presentation Title: Development of a Hydrothermal Spallation Drilling System for EGS
Investigator: Potter, Jared (Potter Drilling, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 13:
Reducing overall geothermal energy costs by reducing the cost and increasing the rate of penetration while drilling is central to gaining acceptance for the technology. In spite of steady advances over the years, improving the efficiency of hard rock drilling by conventional means (rotating a drill bit on the hole bottom and cutting mechanically) has been a slow process. There is a need to find out if alternative methods can be successful. Many attempts to find such methods have been tried, with limited success so far. However, the present approach does seem to hold promise and should be supported.

Reviewer 78:
There is a misguided belief that it is not possible to drill at elevated temperatures—not true!! Can it be done more efficiently? Yes. Should work be done on the non-production (flat time) part of drilling? Yes!! A long-range project to line the wellbore as it is drilled would aim to eliminate numerous time consuming non-production actions and time. Drilling has been the "whipping boy" for 30 years, because it is the easiest to show progress. Rock breaking, or drilling ahead is not 60 plus percentage of drilling costs. Cement and casing make up the majority of drilling costs. The rate of penetration is less than 18%. If the drilling were infinite, the cost would come down by about 18%. Other things dominate, not rate of penetration.

Reviewer 39:
This is a high risk developmental technology but progress has in general been reasonably good given the associated technical difficulty. Although the technology is far from a commercial stage, the benefits could be useful in niche geothermal applications if ultimately commercialized.

Reviewer 75:
The project objectives are to build and test a prototype hydrothermal spallation drilling system with higher rates of penetration and limited bit wear and drill string fatigue. If successful, this system will reduce the drilling cost of EGS wells by approximately more than 10%, which agrees well with the EGS mission and has considerable impact on the commercial scale of deep, hard rock drilling.

Comments Regarding Scientific/Technical Approach
Reviewer 13:
The current approach seems well thought out and has made good progress. Thermal drilling has been tried in the past (notably by using oxy-fuel "rocket-type" burners for drilling taconite in iron ore mines), and has been moderately successful in certain rock types (can't drill carbonates?). However, no method has been developed that has seen wide application. The current thrust, to investigate methods for drilling granitic rocks, has merit. The development of field trial equipment appears well thought out and to be proceeding in a logical manner.

Reviewer 78:
A poor choice of GOD funding.

Reviewer 39:
The approach is well planned and relevant to establishing commercial viability. Technical obstacles are being adequately

addressed with appropriate project focus.

Reviewer 75:
The scientific/technical approach developed for this project is well thought out and well organized. The earlier stages that demonstrated the scaled concepts of 1-inch and 4-inch diameter drilling bits have been successful and addressed several key technical barriers. The execution of the project is outstanding. The site preparation has been completed for the actual system testing.

Comments Regarding Accomplishments, Results and Progress

Reviewer 13:
The approach is steady, and has made good progress. Rates of penetration achieved so far have been about 15 ft/hr in the field, with the potential to reach 30 ft/hr. Field trials have been broadly successful, with some questions raised, but potential solutions are under investigation. Certain problems, such as limited catalyst life, and the occurrence of pre-ignition in the premixed fuel-oxidizer mix appear to be capable of a solution, as is the issue of variable hole diameter, which should be controllable by a mechanical stand-off system. More questionable is how the combustion system will be able to deal with uncontrolled influxes of reservoir fluids and in general how the total drilling system will be able to deal with issues of lost circulation (e.g., how to introduce lost circulation materials, weighting agents to control subsurface pressures, and so on).

Reviewer 78:

Reviewer 39:
Integration of this technology for a field demonstration is a sizable technical challenge. The progress to date appears to be respectable given the challenge of the objective. The specific technical objectives of the field trials (e.g., desired time period of continuous operation, desired continuous depth drilled, etc.) were not entirely clear from the presentation. The achieved progress to date is nonetheless significant.

Reviewer 75:
The quality and productivity of the accomplishments/results/outcomes in terms of system design and testing have been excellent in relation to the resources. From the reviewer‘s point of view, the surface equipment, assembled system design, and the trail cutting are shown to be appropriately finished at the desired rates of penetration.

Comments Regarding Project Management/Coordination

Reviewer 13:
In general, the project appears well planned and to be on track. The field work has thrown up some delays, but not beyond what is usual in projects of this type. The work being done by and with the collaborators is relevant and appears well tied-in.

Reviewer 78:

Reviewer 39:
Overall planning and execution appears to be good.

Reviewer 75:
Management of this project has been very effective toward the deliverables that were committed. Future plans are well organized around improving tool performance and producing commercial products.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
This is a well-run attempt to find an alternative to mechanical (rotating drill bit) means of advancing a borehole in hard rock. Progress in mechanical drilling has been slow but steady over the years, while novel techniques (including thermal drilling) have come and gone. Because rate of penetration (and contributory bit wear) still leave a lot to be desired, it is worth continuing to investigate novel technologies. This project holds promise of being able to deliver.

Reviewer 78:

Reviewer 39:
This is an interesting technology with inherent developmental risk and perhaps limited use based on lithological applicability. The project focus on field deployment of the technology is relevant and valuable because it will provide much needed insight into applicability beyond a laboratory environment.

Reviewer 75:
Overall, the reviewer thinks this is a strong, well-written, clearly executed program.

Comments Regarding Strengths
Reviewer 13:
It is good to see a straightforward effort to experiment with full-scale drilling in a field environment, in rocks that are of importance in geothermal drilling.

Reviewer 78:

Reviewer 39:
The project focus on field use of this technology will help address fundamental feasibility questions. The project appears to thoroughly approach the systems-level considerations for deployment of the technology.

Reviewer 75:
The project team has expertise in drilling system design. The project is on the right track, is well managed and currently delivering to schedule. The quality of deliverables has been good. The budget allocated was sufficient at this point. Risks have been controlled and mitigated.

Comments Regarding Weaknesses
Reviewer 13:
The reviewer suggests assessing whether the technology will be capable of drilling in the range of rocks likely to be encountered in geothermal wells. Carbonates, being infusible, are not well penetrated by flame drills, but they may not be of importance in geothermal applications. What about other hard rocks such as basalt? Can the drill penetrate shales or clays? Stringers or intervals of such strata may be encountered in geothermal wells, so it might be worth estimating whether the coiled tubing unit can be adapted to carry an interchangeable down-hole motor for conventional drilling. Nobody will want to stand down the thermal drill and bring in a conventional rig to drill through 50 feet of carbonate or clay.

Reviewer 78:

Reviewer 39:

Reviewer 75:
Weaknesses are minor at this point.

Suggestions for Improvement

Reviewer 13:
The reviewer suggests investigating how the drilling performance may be affected by high ambient pressure in, e.g. a water filled hole.

Reviewer 78:

Reviewer 39:

Reviewer 75:
The testing has been carried out for one hour of continuous drilling. It might be more convincing if the system could continuously work for 30 hours on hard rock formation.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0704
Presentation Title: Technology Development and Field Trials of EGS Drilling Systems
Investigator: Raymond, David (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research
Reviewer 13:
This project represents an unexciting but probably necessary step in the introduction of new technologies. There is no radically new technology introduced; instead, the project team proposes to drill two (?) wells to about 3,000 ft to demonstrate the technology readiness of two developed but not yet widely accepted improvements (a PDC bit for hard rock and a down-hole hammer). The program will be largely concerned with testing and/or demonstrating the utility and reliability of the two technologies in a practical field environment. Achieving the transition from research to field application is clearly important, but under other circumstances one would have hoped that this process would have been undertaken and funded directly by commercially-interested parties. Whether such a project then falls into the domain to be funded under this program is a question for the project managers within DOE.

Reviewer 78:
Sandia National Laboratories and its researchers have a long history of working on the drilling effort. David is a good person to carry that effort forward. He should be aware of the limitations of his work should it be successful.

Reviewer 39:
Successful demonstration of the proposed drilling tools should open the door for acceptance of superior conventional drilling technologies in the geothermal industry. If these technologies can be successfully demonstrated and subsequently utilized in a geothermal environment, they will provide an immediate improvement in the geothermal drilling cost structure. This is a relatively inexpensive, low-risk effort with significant potential benefits.

Reviewer 75:
This program aims to develop fit-for-purpose EGS drilling solutions for high-temperature geothermal exploration and production drilling on hard fractured rock. The impact of the project will be considerable on factors of geothermal energy development in terms of reducing the drilling costs by improving the rates of penetration and bit life.

Comments Regarding Scientific/Technical Approach
Reviewer 13:
The scientific and technical approach is sound. As noted above, the reviewer's main concern is whether the proposed project has a sufficient "research" component, or whether demonstration projects of this type should be more appropriately funded directly by industry. The choice of collaborators and the two main technologies to be demonstrated are sound.

Reviewer 78:

Reviewer 39:
There is no substitute for field experience when introducing previously avoided technologies in any industry. The project approach appears to focus on the appropriate technical and perception issues. The enlistment of bit and drill manufacturers as collaborative partners should improve prospects for success.

Reviewer 75:
The technical approach for this project seems to be reasonable on development and demonstration of the PDC bits, high

temperature percussive hammers, as well as the field tests. The three-year work plan on page 12 raises a little concern on the validation of the new technologies developed in this program. The reviewer, in his opinion, did not find any testing plans to prove the high-temperature bits and percussive hammers that will be developed in this program will fit for the extreme conditions in EGS wells.

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:
Progress is steady and appears to be on track.

Reviewer 78:

Reviewer 39:
Site selection, bit selection and well profile are well matched with project objectives.

Reviewer 75:
The accomplishments and results of the program at this point have been good in relation to the resources expended. The project has been focusing on identifying the drilling companies and the potential geothermal site, as well as coordinating the service organization and drilling plan. Hopefully, more outcomes on the technical side will be completed in the next stage.

Comments Regarding Project Management/Coordination
Reviewer 13:
Choice of collaborating organizations is good and appears to be working satisfactorily. Having the U.S. Navy involved should provide a (commercial) bias-free environment.

Reviewer 78:

Reviewer 39:
Execution of project plan components appears to be as scheduled. Coordination between project players including site operators and drilling manufacturers has been good.

Reviewer 75:
The project management has been good on coordinating the resources from multiple organizations. The tasks committed seem to be on schedule.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
As mentioned above, this projects represents a necessary step in bringing new technologies from laboratory to field. However, no really new technology is to be developed, and so it can be asked whether this project is sufficiently research-oriented to fall within the acceptabilerange for the EGS geothermal research program.

Reviewer 78:

Reviewer 39:
The project represents a cost-effective investment with the potential to transition superior technologies that are widely

accepted in the oil and gas industry into the more conservative geothermal industry. The involvement of bit and percussive hammer manufacturers may also help bring attention and technology development focus to a small market that might otherwise be of little interest to them.

Reviewer 75:
As general comments, the reviewer found the project summary to be a clearly stated, well organized document to help further the understanding of the whole vision of the project. This program captures very well the essence of the EGS mission; it also extends the scientific thinking underlying the EGS vision in several areas with respect to the funding provided.

Comments Regarding Strengths
Reviewer 13:
None noted.

Reviewer 78:

Reviewer 39:
Field demonstration of technology is the best method for gaining acceptance of otherwise shunned technologies. This project will attempt to prove two technologies with the potential to significantly improve geothermal drilling performance.

Reviewer 75:
The project is well managed and currently delivering to schedule. The quality of deliverables has been good. Key technical barriers were identified and resolved. Risks have been controlled and mitigated.

Comments Regarding Weaknesses
Reviewer 13:
None noted.

Reviewer 78:

Reviewer 39:
PDC bit selection and performance tends to be highly tailored to the intended application. This project is planning on trying only one PDC bit type in the field trial. It might be prudent to have multiple bits available as alternatives if the selected bit's performance is lackluster.

Reviewer 75:
The reviewer understands that the funding on this program is limited compared to other projects working on drilling systems, but the reviewer would like to see more details or accomplishments on technology development.

Suggestions for Improvement
Reviewer 13:
None noted.

Reviewer 78:

Reviewer 39:
The reviewer suggests selecting multiple PDC bit designs and comparing their performance in the field trial.

Reviewer 75:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0705
Presentation Title: Enhance And Deliver A High Temperature Directional Drilling Instrument For Geothermal MWD Tools
Investigator: Anderson, Eric (Honeywell International Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 13:

Measurement of downhole direction and inclination (D&I) of a borehole is an important, if not essential, part of well drilling. In the context of geothermal drilling, it is always of interest to be able to increase the thermal resistance of D&I instruments. Wireline D&I instruments that are lowered down a borehole can be placed inside an insulated container and will survive if the time of exposure is short enough. The proposed instrument is to be part of a measurement while drilling (MWD) system. This is obviously of greater value than a wireline system, but requires, of course, the capability to withstand downhole temperatures for long periods. The proposal to build such an instrument is therefore of great value.

Reviewer 78:

High-temperature instrumentation and tools are important for EGS since we run up against the limits on almost every front. The wells can be drilled using current technology and some innovative "workarounds." On the instrument side that is not the case on all measurements needed. In particular, the downhole stress state is limited to the Alt (Sandia based) borehole televiewer. High temperatures and other more direct measurements of the downhole stress state and direction are needed.

Reviewer 39:

Diagnostic tools are enabling technologies in the drilling industry that have made otherwise difficult or cost-prohibitive well construction programs feasible. Much of the technology that is commonly available in the oil and gas industry is absent from the geothermal industry. This project should help bridge this gap. This development is essentially evolutionary because it is built on similar, but lower temperature previous work, but is still challenging.

Reviewer 75:

The objective of this program is to develop an EGS MWD instrument. The high temperature technologies, such as Honeywell electronics, micro electro-mechanical systems (MEMS) accelerometer, sensors and flus-gate magnetometer developed for 300°C environmental temperature, will have considerable impact for EGS to explore hotter geothermal reservoirs and reduce drilling costs, which are in line with EGS mission and goals.

Comments Regarding Scientific/Technical Approach

Reviewer 13:

The approach appears sound, and was well explained. The project will build to some extent on existing technology and components, but these will require testing and integration. Several detailed tasks must be addressed— improvement of the thermal resistance/life of the silicon-on-insulator (SOI) chips themselves, and the making of specific chips; the development of support materials and interconnects, and the development of the external container, among others. All of these aspects appear to be in hand and well thought out. The primary measuring instruments (magnetometer and accelerometers) appear adequate for the job.

Reviewer 78:

Reviewer 39:

The project is focused and systematic in its development of higher-temperature SOI technology and tool assembly processes.

Reviewer 75:
The scientific/technical approach of developing the high-temperature electronic components is clearly stated, organized and well thought out. The project clearly understands the technical barriers, and has had good focus, leveraging the existing products or technologies and extending their capability to 300°C. The material identifications and high-temperature assembly seem to be on the right track.

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:
The project appears well on track.

Reviewer 78:

Reviewer 39:
Results are encouraging and in line with project expectations. The project is still in a design phase so results are limited with the exception of high-temperature magnetometer testing and previous SOI data. There will be more to comment on once boards are fabricated and component assembly begins.

Reviewer 75:
The quality and productivity of the accomplishments/results of this program have been good in relation to the resources expended. The system architecture and interfaces have been defined. Component-level detailed design is making progress. Magnetometer prototype has been tested under 300°C for 6 months. The titanium housing design ensures light weight and will be easily machined.

Comments Regarding Project Management/Coordination
Reviewer 13:
Management and coordination appear well in hand for the immediate task, but perhaps the team needs to take a longer view (see below).

Reviewer 78:

Reviewer 39:
No issues.

Reviewer 75:
Regarding project management, the tasks appear to be completed on schedule. The Integrated Product Delivery and Support process used in this program is effective. The program has been reviewed frequently in the past. The future plans are well organized.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
The project addresses an important need (MWD measurement of D&I in wells to 300°C). The project will require progressive development of existing SOI and other technologies, but the plan does not appear to be too ambitious. Notably lacking was the mention of what is to be done with the sensor package once it is developed. There was no mention of how the instrumentation is to be incorporated into a complete MWD tool; for example, how are the data to be

transmitted to surface? While this may not be an immediate concern, and is probably beyond the competence and interest of the current project team, it would have been useful to know that someone had been in contact with one of the oilfield service companies (Schlumberger, Sperry, etc.) to see if they have MWD data transmission systems that can operate at 300C. If not, some research should be started to make sure that once the instrumentation package is developed, there is an MWD sub to put it into.

Reviewer 78:

Reviewer 39:
This project will provide a much needed development push for technology that is needed by the geothermal industry. DOE support of projects of this type provides valuable incentive to manufacturers that otherwise have only moderate interest to push the high-temperature operating envelope of electronically packaged devices due to market considerations. This project also benefits from past efforts in similar applications that should help refine the development effort.

Reviewer 75:
Overall, I think the project clearly states the strategies toward EGS direction on development of a high-temperature MWD instrument. What it has achieved in terms of ideas, technical designs and tests has been notable and will contribute to EGS.

Comments Regarding Strengths
Reviewer 13:
The project has a solid and well-integrated team with a high level of competence for the immediate task.

Reviewer 78:

Reviewer 39:
This project leverages results from other high-temperature drilling tool development efforts to extend the temperature operating limit. The experience from these earlier efforts should provide a firm foundation and indication of a path forward to evolve the technology.

Reviewer 75:
The project team has demonstrated expertise on high temperature sensing systems design. The budget allocated was sufficient at this point. The quality of deliverables has been good. Risks have been controlled and mitigated.

Comments Regarding Weaknesses
Reviewer 13:
Perhaps insufficient long-term view. Who is planning the next step regarding the inclusion of the instrument package into a field-capable MWD tool?

Reviewer 78:

Reviewer 39:
No big issues were observed. It would be nice to see some focus on shock and vibration testing to facilitate laboratory-scale evaluation of the ability of the packaging to survive the expected harsh environmental conditions.

Reviewer 75:
Weaknesses are minor at this point.

Suggestions for Improvement

Reviewer 13:

The reviewer suggests beginning discussions with an oilfield MWD company with a view to planning the integration of the instrument into an MWD tool.

Reviewer 78:

Reviewer 39:

The reviewer suggests including shock and vibration testing of the assembled tool.

Reviewer 75:

One of the future directions should be demonstrating that the Vibrating Beam Accelerometer maintains the desired accuracy at the extreme EGS conditions.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0706
Presentation Title: Pressure Sensor and Telemetry Methods for Measurement while Drilling in Geothermal Wells
Investigator: Vert, Alexey (GE Global Research)

Comments Regarding Relevance/Impact of Research
Reviewer 78:

Reviewer 23:
Demonstration of an IC circuit capable of functioning at 300°C was completed in this phase. The circuit is an integral part of the sensor device and critical to the downhole tools needed in monitoring EGS geothermal wells.

Reviewer 39:
The successful development of this technology would provide a much needed tool to the geothermal drilling inventory. Tools of this type are widely used in the oil and gas industry to facilitate optimization of drilling programs but are generally not available for the more difficult geothermal environments. The technology would provide a steep change in capabilities if successfully developed.

Comments Regarding Scientific/Technical Approach
Reviewer 78:

Reviewer 23:
The project team took a systematic approach with clear workstreams and has met every milestone.

Reviewer 39:
Fabrication and assembly issues are being approached systematically. The complexity and sequence of development appears to be manageable with reasonable risk.

Comments Regarding Accomplishments, Results and Progress
Reviewer 78:

Reviewer 23:
The project team has been able to meet all of its current objectives and milestones.

Reviewer 39:
Some delay in the schedule was reported as a result of fabrication issues. This is not uncommon for this type of semiconductor development. Reasonable progress has nonetheless been made.

Comments Regarding Project Management/Coordination
Reviewer 78:

Reviewer 23:
The only concern is the fabrication yield losses that created a delay.

Reviewer 39:
No major issues.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 78:

Reviewer 23:
The project team was able to deliver a prototype that can operate at 300°C for short duration. The reviewer would have liked to see testing done for longer time periods and would have liked to get a sense of what the cost implications would be versus other material systems. The reviewer would also have liked to see the team address the issue of their low yield fabrication process; this could impact the manufacturability of the final device.

Reviewer 39:
As mentioned above, this technology would provide a step change in high-temperature tool capabilities if successfully developed. Results are reasonable for this stage of the project given the relative immaturity of the technology. The PI appears to have a good understanding of the technical challenges and solution path.

Comments Regarding Strengths
Reviewer 78:

Reviewer 23:
The project team has a good testing protocol and met milestones that were set.

Reviewer 39:
In addition to subject matter expertise in material and electronics packaging, the research organization performing the work has an oil and gas group versed in the application conditions of the desired assembly product. This should bring attention to development concerns related to tool packaging and construction that might otherwise be neglected.

Comments Regarding Weaknesses
Reviewer 78:

Reviewer 23:

Reviewer 39:
No major issues.

Suggestions for Improvement
Reviewer 78:

Reviewer 23:

Reviewer 39:
Although preliminary at this stage, it might be useful to begin estimating expected tool cost to better understand market placement. This will especially be relevant for geothermal where the use of expensive tools is avoided.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0707
Presentation Title: Resistant NanoComposite Stainless Steel Coatings and Bits for Geothermal Drilling
Investigator: Peter, William (Oak Ridge National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 13:
It is desirable to develop wear resistant materials that are strong, tough and fracture-resistant, and are also of lower cost than conventional materials. This is the aim of this project.

Reviewer 78:
There are numerous applications for this technology in tools and casing and other wear-related surfaces in geothermal drilling and completions. The anti-corrosion characteristics are outstanding. There is a need to look into using the same "mixing technology for bearing surfaces in bits and on the exterior of tools." A workshop should be convened to identify the targets. Corrosion is important. Wear resistance is important. The ability to "clad or chemically bond to the host steel" is very important. Horton Clad steel was a product of Chicago Bridge and Iron in surface storage tanks. There are many other areas of need. Materials are part of almost all improvements.

Reviewer 23:
Results suggest that the project team's composite is not any better in wear resistance than existing materials, which is a key property needed for drill bits.

Comments Regarding Scientific/Technical Approach

Reviewer 13:
The authors present as an objective the intention to make a wear-resistant material that is as hard, wear- resistant and tough as tungsten carbide-20% cobalt (tungsten carbide-cobalt, or WC/Co) compositions but is cheaper. The approach has been to use rapidly-cooled powders of an iron-based austenitic steel that are either amorphous or nanocrystalline. This approach is said to allow the attainment of higher alloy content. However, amorphous, nanocrystalline or not, the powder is subsequently either hot-pressed to provide a compacted bulk material or is (laser) fused onto a suitable substrate. This subsequent heating with near or complete melting will likely allow the recrystallization of the alloy into a structure hardly dependent on its previous condition. Thus, the reviewer sees no advantage to the use of amorphous or nanocrystalline powders. The critical issue here is whether the pressed material has a superior combination of properties to the competitive material—either pressed and sintered tungsten carbide-cobalt or various flame, plasma or laser fused coatings. The authors claim that their material will be significantly cheaper than the conventional WC/Co material, but in many drilling applications, the cost of the cutters is not important. The cost of the WC/Co material or the PDC inserts used as the cutting elements of a typical drill bit is a tiny fraction of the cost of the complete bit, and the overriding concern is superior performance, regardless of cost. So far they have succeeded in making a material that is of similar or lower hardness, lower strength and similar or lower fracture toughness to WC/Co. (Slide 7 shows the SSAM material to have a hardness in the range 900-1100 HV, but slide 6 shows no values greater than 835; c.f. WC/Co ~ 1100). This will not be sufficient to displace WC/Co or diamond. The authors compare their material with various steels, but do not compare it with flame-sprayed iron-nickel-chromium-carbon-boron alloys that have been available for many years and compete directly with the present product in the field of flame, plasma or laser coating. To summarize, the new material appears to be a cheaper but less performing material in a field where performance is far more important than cost. For certain applications, the authors appear not to have compared their material with conventional coating materials that have been available for many years.

Reviewer 78:

Reviewer 23:
The methods used to test the properties of the composite were acceptable.

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:
The project has not yet produced materials that are competitive with existing materials. The apparent novelty of using amorphous or nanocrystalline materials appears to be almost irrelevant. See Scientific/Technical Approach comments above for a more complete discussion.

Reviewer 78:

Reviewer 23:
No improvement in wear resistance versus W-C composite means the project team will likely need to reformulate the compound.

Comments Regarding Project Management/Coordination
Reviewer 13:
The project appears to be on track.

Reviewer 78:

Reviewer 23:
The project team recognizes what is needed and is restating its future milestones to address the issue.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
The project appears to be based on a misleading idea—that amorphous or nanocrystalline powder materials will provide superior properties in pressed and sintered or fused compacted material. One of the main drivers in the project is to be able to produce compacts or coatings that have similar hardness, toughness and wear resistance to the main competitor, WC/Co, but are cheaper. So far, materials have not been produced with superior properties in a field of application where performance is much more important than cost. Concerning fused coatings, the authors have not compared their material with competitive fused coatings that have been available for many years.

Reviewer 78:

Reviewer 23:
The coating on drill bits is attractive from a manufacturability standpoint but bits are an important part of the system, and cost is generally a non-issue. The reviewer is not sure he sees anything here that would be a step change improvement over the incumbent.

Comments Regarding Strengths

Reviewer 13:
None noted.

Reviewer 78:

Reviewer 23:

Comments Regarding Weaknesses
Reviewer 13:
No additional technical comments. The set of slides contains far too much material, much of which was not explained or discussed (so why show it?), while other elements were simply not understandable. For example, slide 4 (bottom right) shows a plot of hardness vs. toughness to compare the performance of various families of materials (no numbers on the axes). However, the text identifying each rectangle is much too small and could not be read when projected. In subsequent examination, the field of HSS powder materials is shown to have much greater toughness than the cemented carbides, yet data on slide 7 show the toughness to be 12-15 MPa root m. vs. 10-20 for WC/Co. Without numbers on the axes, these values cannot be situated on the graph in slide 4.

Reviewer 78:

Reviewer 23:

Suggestions for Improvement
Reviewer 13:
The authors should compare their material when applied as laser-fused coatings with a range of laser, plasma and flame-applied coatings that have been available for many years. Typical compositions are in the iron-chromium-nickel-carbon-boron alloys.

Reviewer 78:

Reviewer 23:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0708
Presentation Title: High Temperature Perforating System for Enhanced Geothermal Applications
Investigator: Howard, Peter (Schlumberger Technology Corp.)

Comments Regarding Relevance/Impact of Research

Reviewer 13:
The development of perforating systems that will perform well under high-temperature conditions is of definite value to the geothermal community. This project presents a useful approach to advancing the state of the art in this area.

Reviewer 78:
The basic question is whether high-temperature perforation is a part of enhanced geothermal system (EGS) development or not. There are likely to be other applications for high-temperature perforation use or high-temperature chemical reactions. Most EGS will likely be completed open hole or with perforated liners—not by perforation. The reviewer may be in the minority who believes that there may come a time when large-scale perforation sets are used to access, preferentially, certain intervals of an injection (or production) wellbore. There may be other uses for the high-temperature chemical reactions that are part of the perforation work that may be used for other purposes downhole.

Comments Regarding Scientific/Technical Approach

Reviewer 13:
The approach is systematic if unspectacular. The authors present a logical approach to the problem, and appear to have identified all of the development steps along the way to a successful conclusion.

Reviewer 78:

Comments Regarding Accomplishments, Results and Progress

Reviewer 13:
Steady progress has been made in the various contributory sub-projects and the overall program appears on track.

Reviewer 78:

Comments Regarding Project Management/Coordination

Reviewer 13:
This appears to be a well-managed project.

Reviewer 78:
This project has demonstrated the required cooperation needed across companies and personnel, which is not necessarily easy.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
This project is a necessary but unspectacular piece of development that will be of value in completing high-temperature geothermal wells. The reviewer's only concern would be that such a development program would probably have gone ahead without the need for DOE funding. DOE funding should be reserved for more risky projects

that industry might not have funded without external help.

Reviewer 78:

Comments Regarding Strengths
Reviewer 13:
None noted.

Reviewer 78:

Comments Regarding Weaknesses
Reviewer 13:
None noted.

Reviewer 78:

Suggestions for Improvement
Reviewer 13:
The first slide of the presentation has far too much material. None of the content was discussed, not even the ten headline topics, and the smaller text was unreadable even if there had been time to read it. Everyone knows Schlumberger and what they do, so what is the point of showing such a slide? It's just wasted material and annoys the audience. Other slides (3, 16) were also difficult to read and absorb. Slide 5 was not easily understood; what performance parameter is being represented as a function of time and temperature? Is it thermal stability, and if so, what is the criterion for the material being "stable"?

Reviewer 78:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0709
Presentation Title: High-Temperature High-Volume Lifting for Enhanced Geothermal Systems
Investigator: Turnquist, Norman (GE Global Research)

Comments Regarding Relevance/Impact of Research

Reviewer 13:
The development of powerful and reliable submersible pumps will be of value in extracting hot water from geothermal reservoirs that have insufficient pressure to allow adequate flow to surface.

Reviewer 34:
This program will help extend the available geothermal resources to deep resources. The team has chosen a design that is modular and can be adapted to any depth. However, even though this was clear in the written materials, it was not featured in the presentation. Thus many reviewers incorrectly concluded that the research was only applicable to very deep reservoirs.

Reviewer 53:
The impact of this project is clearly beneficial to the geothermal community. A need exists to develop a high temperature (HT) downhole pump capable of surviving long-term at temperatures up to 300°C. This advancement would benefit many geothermal applications (not limited to EGS). Many applications may not require 300°C operation, but a pump design for such temperatures will result in increased reliability at lower temperatures. This can result in longer life between maintenance intervals, thereby decreasing the cost of the project. If successful, the developed pump could have a significant impact on future geothermal activities.

Reviewer 79:
DOE‘s primary goal is to demonstrate a 5-MW EGS reservoir by 2020. This project is not on the critical path of reaching that goal (the goal could be achieved by existing electric submersible pumps, or ESPs, if they were reliable). 300°C probably represents no more than ~1% of geothermal ESP applications and thus should not be the overriding ―criterion.” More important is reliability and life cycle cost at ―average” geothermal temperatures. Once reliability and cost effectiveness can be demonstrated for average temperatures, increases in temperature can become an incremental target. Let steam assisted gravity drainage (SAGD) pay for temperature increases in ESP operating temperature. Geothermal‘s problem is that even at ―average” geothermal temperatures, run times are not long enough to make ESPs economic. Adding to cost by shooting for extra high temperatures doesn‘t help. Often increased temperature tolerance is a way of achieving reliability, but that was not given as a justification for targeting 300°C.

Comments Regarding Scientific/Technical Approach
Reviewer 13:
The approach appears sound. The authors present a combined project that addresses the need to develop both the driving motor (a permanent magnet design) and the submersible pump in combination. Details of the approach to solving specific problems—wire insulation, seal and bearing design, etc.—appear to be well in hand. Some interesting additional information appeared in the supplementary slides.

Reviewer 34:
The reviewer thinks that the investigator examined a wide variety of pump types and correctly concluded that the electrical submersible pump was the most promising. It is unfortunate that the applicant did not have any experience in

this design. The applicant bravely stated that this is an advantage since it allows them to start with a clean slate. However, it also allows the pump design to proceed without knowledge of standard design tricks to avoid problems that may be common. It is fortunate that since the award of the project, GE acquired John Wood Group, which has extensive experience in electric submersible pumps. The project should be significantly changed due to this acquisition, and DOE should encourage this change.

Reviewer 53:
The technical approach is organized clearly and should lead to a demonstration of a prototype pump. The approach is divided into three phases briefly stated as: 1) determine system requirements, 2) Develop required components, and 3) Demonstrate subscale pump. In general, this approach seems adequate to meet the outlined objective. Previous work in similar areas (gas/steam turbines, oil and gas pumps, compressors, generators, motors) provides a basic understanding of the details required for this project. Unfortunately, during a short program review, not enough detail can be presented to fully evaluate the details of the design. Many potential issues exist, such as material selection/compatibility, thermal expansion consideration (close tolerances), and wellbore contamination issues (effects on interior components). It appears the technical approach attempts to address many of the concerns. The design of the pump is stated at 3 years at 300°C. This is a worthy goal, but difficult to determine within the scope of this project. A few concerns were noted during the review. They include: 1) Testing of motor wire. To date, the wire is only tested at a much lower voltage and only in small straight pieces. This is a good place to start, but the wire should be tested as it will be utilized in the motor. A suitable wire insulation may have been identified. While not clearly outlined in the presentation, it was indicated that follow-on tests in a more suitable configuration will be included. The wire insulation is critical in a motor design and is not readily available. As such, this could adversely affect the lifetime of the motor. The proprietary wire should be fully characterized in parallel with the outlined tasks. 2) Downhole power requirements. The required power to produce the lift outlined in the funding opportunity announcement (FOA) are great and as such large cables will be required to operate the motor. This topic was discussed, but should be looked at in more detail. Ultimately, it may determine the maximum practical pump performance (may need to be scaled back from the specification indicated in the FOA). 3) Ground wall material selection. This topic was not discussed at the review, but may require additional consideration.

Reviewer 79:
This project is outstanding as per project objectives. Permanent magnets and internal heat transfer via advection is novel and potentially significant to achieving high reliability. High voltages could be a break through. Nothing was said about AC vs. DC and if AC, how many phases. Do permanent magnets open new doors in these areas? Execution of the project plan was very good. Need clarification on the following: slide 5 says motor power is 5.8 MW, but slide 7 says shaft power is 70 kw. The sectionable motor is important.

Comments Regarding Accomplishments, Results and Progress
Reviewer 13:
Steady progress appears to have been made.

Reviewer 34:
The reviewer was surprised by the low efficiency of the motor and pump set that was reported, however, the reviewer does not have any experience to evaluate this (pumps and motors that the reviewer has experience with are above ground pumps and not geometrically constrained). The power level of this pump is significant enough that transmission losses will become important. The applicant might consider staging this pump at different elevations so that all of the electrical power does not have to be conducted to the lowest level of the well. The reviewer was not able to critique the design since he is not familiar with this type of pump.

Reviewer 53:
Many accomplishments were discussed and the preliminary results are encouraging. For the most part, the accomplishments are in line with the stated goals and progress has been made to help ensure success is possible. A few

concerns include: 1) Wire testing. The proprietary wire requires additional qualifications to determine if it is adequate for this application. To date, the test configuration is not adequate to fully evaluate the performance. 2) Bearing tests. It is evident that several bearing tests are planned. It is difficult to evaluate every aspect of the downhole environment. The outlined test plan includes testing the bearings under load with water and sand (for evaluation of abrasion and erosion performance). Since it is not practical to test the bearings at temperature in addition to the above tests, the same viscosity fluid as present in 300°C wells will be used. This is a compromise due to issues that might develop in the well, but an attempt was made to produce a similar condition.

Reviewer 79:
Progress is in line with program plan and objectives, neither beyond or less than that required for success. 80 kg/sec and 300 bar output from a 6.3m pump section would appear to be a significant accomplishment. This suggests that the overall design approach is good. However, a 5.8 MW motor is an excessive parasitic load. The Geothermal Electricity Technology Evaluation Model (GETEM) does not allow simulation of 300°C resources, but simulating an unpumped hydrothermal resource with GETEM gives insight into the issue. According to GETEM, 300°C and 80 kg/sec after subtracting the power plant parasitic loads would produce ~8.0 MW (levelized power to grid) per well for a flashed cycle. Binary would be somewhat higher but not enough to change the comparison. A 5.8-MW motor would consume 73% of the power which would be a huge economic loss. This may be a non-issue—the motor and pump may just have to be resized to fit the application.

Comments Regarding Project Management/Coordination
Reviewer 13:
The reviewer understood that GE has recently bought a company with significant expertise and experience in the making of submersible pumps. It will be of value if the project managers are able to benefit from the expert knowledge that will become available.

Reviewer 34:
The organization of this program is fine; however, at this point, the organization should change significantly due to the recent addition of John Wood Group.

Reviewer 53:
The program management appears to be adequate for this developmental effort. The project was presented well at the review. As stated at the review, GE recently acquired the Wood Group. This will benefit the program by providing additional expertise. Early collaboration with a company involved in geothermal production would help to ensure potential issues are identified early and may be helpful in the final design.

Reviewer 79:
The timeline chart shows the current phase ending in 1Q 2012, but the Future Directions slide has a go/no go in 2011. How does this reconcile? Level of investment by both DOE and GE is large enough that one would have expected input into system requirements by operators with actual experience with ESPs in geothermal wells and/or equivalent inputs from knowledgeable sources.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 13:
This is a useful project that should contribute to the development of enhanced geothermal systems.

Reviewer 34:

The project is concentrated on getting a pump design that will work. However, an optimal pump design should also include other considerations. Other considerations should include: 1) cost, operations, and maintenance. 2) the ability of the pump to operate at a variety of temperature and temperature transients that may exist (especially if the pump is installed at an intermediate depth above the thermal reservoir). Clearances may change as the pump heats up. 3) the ability to handle a sand fraction, especially in early operations. These items were not addressed in the presentation.

Reviewer 53:
A need exists to develop a high temperature (HT) downhole pump capable of surviving long-term at temperatures up to 300°C. This advancement would benefit many geothermal applications (not limited to EGS). This project is well organized and should lead to a functional prototype downhole pump.

Reviewer 79:
To contribute to DOE's goals it is important that ESPs be able to achieve market penetration, which depends on cost effectiveness and reliability. Being able to operate at temperatures above 225°C will not have much impact on marketability. Discussions should be held with geothermal operators and Wood Group to insure that the product being developed is marketable. The diameters being designed for represent current technology, not the vision of future well designs considering innovations such as monobore wells, etc. That may be the place to start, but it would be useful to know if the innovations of this project could allow smaller diameters.

Comments Regarding Strengths
Reviewer 13:
The project should benefit from GE's wide experience in a wide variety of electrical engineering and energy-related areas.

Reviewer 34:
The modular nature of the design will allow easy use of this design in many applications.

Reviewer 53:
This project is required for the further development of geothermal resources.

Reviewer 79:
Strengths include R&D capability and acquisition of Wood Group. Other strengths include innovation through the use of permanent magnets, advective cooling, and high voltages.

Comments Regarding Weaknesses
Reviewer 13:
Testing of the new wire insulation might have been more relevant if it had been carried out in hot water rather than air.

Reviewer 34:

Reviewer 53:
Additional testing is required in the area of motor windings and overall power considerations.

Reviewer 79:
The program plan shows lack of understanding of geothermal ESPs and market penetration issues. Input should have been sought from operators with geothermal EPS experience.

Suggestions for Improvement
Reviewer 13:

No attention was paid to the possible high cost of the power cable that will power the high-power submersible pump. In oilfield operations, the cost of the cable is often a limiting factor. In a geothermal application, it may be expected that the cable may be even more expensive because of the need for a thermally stable insulation on the cable. Erosion may be a factor leading to reduced life of the pump, but may not be significant in deep, hard rock wells. Has this been examined? As for many of the other presentations, far too much material was crammed into the slides, but was then not discussed. What did the two graphs on slide 9 really mean? Who had the time to read and understand what was in the numbers presented on the middle right-hand side of slide 14-, and what is "cross-coupled stiffness”? If such information is not discussed, why present it?

Reviewer 34:

Reviewer 53:
The reviewer suggests reevaluating the pump performance verses power requirements.

Reviewer 79:
The reviewer suggests engaging Wood Group and Ensuring manufacturing cost is competitive with existing ESPs. Market penetration depends on delivering a better pump at lower cost. A better pump (especially if better means higher operating temperatures) without lower cost will not make it. Reliability in the geothermal environment needs to be addressed explicitly.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0710
Presentation Title: Gas generator development and testing for controlled rapid pressurization using liquid propellants for EGS well stimulation
Investigator: Grubelich, Mark (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research
Reviewer 77:
Standard explosive fracturing in the borehole has the disadvantage of offering relatively little control of the fracturing process. High explosive (HE) fracturing appears to use mainly shock effects to produce near-borehole permeability, which we have simulated and observe to be closer to pulverization only of the near field. A need exists for controlled pressurization of the borehole that allows (1) adjusting the level of near-field pulverization and (2) propagation of fracturing farther away from the borehole regime using the gases from the propellant burn to produce gas propagated fractures. The proposed method is novel in allowing for a high level of control by using essentially a liquid-fuel rocket motor on the surface to produce more gradual pressurization of the borehole. To this the PI suggests adding HE down hole as necessary to tailor a pulse with very rapid initial rise (the shock) and sustained pressuring required for propagation of the fractures away from the borehole. This approach seems definitely worthy of experimental evaluation and could have significant impact on enhancing permeability in injection/extraction wells leading to improved flow, heat transfer and geothermal system efficiency.

Reviewer 13:
This project addresses an interesting topic in the development of a geothermal reservoir, namely the need to be able to stimulate a reservoir by pressurizing the borehole so as to fracture the rock in the vicinity of the hole, while neither applying a sufficiently violent pressure rise to cause pulverization of the near- borehole region, nor letting the pressure rise be so slow that the pressurizing fluid escapes into existing surrounding fractures before the pressure can rise enough to cause the desired additional fracturing. If the project provides a means to achieve this objective, it could be very valuable.

Reviewer 75:
The basic objectives of the project aim to develop a liquid propellant gas generator to generate a controlled pressure pulse to provide energy to stimulate a geothermal field. The goal is in line with the EGS mission of establishing advanced reservoir stimulation tools. If successful, the technology proposed in this program will potentially increase the permeability and have notable impact on the growth of EGS.

Comments Regarding Scientific/Technical Approach
Reviewer 77:
(This should be a 3.5 corresponding to Good + or Outstanding -, but such fine divisions are not possible in this grading system). Minor room for improvement exists in that some form of solid mechanical modeling of the effect of time-dependent pressurization of the borehole with gas-propagated fracturing would seem to be helpful to the designers. Sandia's Bob Nilson has done excellent work in the area of gas-propagated fracturing, and the F-Cubed code he co-developed with Norton Rimer might provide some insight into determining the best pressurization profiles to keep in mind during the design process. The reviewer would be surprised if by now Sandia doesn't have even more advanced codes that couple detonation/deflagration to solid mechanics and fracturing.

Reviewer 13:
The approach is to develop two methods for generating a rising pressure in the borehole. The first is a liquid propellant pump-fed gas generator, presumably for the lower pressure rise regime, and some sort of high-pressure propellant

combustion device that will provide a more rapid pressure rise. As the authors mention, well stimulation by explosive means has been tried in the past ("shooting" the well with explosives), and has had a checkered history. This project concentrates on developing the hardware that should be capable of generating a range of pressure rise rates, so that in principle one should be able to select a tool and set of fuelling conditions that will generate the required pressure rise in any reservoir. The reviewer believes that even if the set of tools can be developed to produce a range of pressure rise rates, it may be very difficult to determine the rate actually required in a real well. The rate will depend on rock strength and also, critically, on the distribution and permeability of any existing fractures in relation to the geologic stress field. This is an example of a project that desperately needs some sort of analytical support in the form of computer modeling of the way in which hoop stresses in the near borehole region can be brought up to the fracture threshold while the pressurizing medium is simultaneously being allowed to leak away into a (defined) set of existing fractures. Questions clearly include the orientation of the existing fractures in relation to the geologic overall stress field, and the fact that as the pressurizing fluid leaks away into the fractures, it will provide support to the rock, discouraging fracture formation. This appears to be a challenging problem, but unless some feeling for the required rates can be obtained, selecting the required loading rate will be simply whistling in the dark. This then raises the question in the reviewer's mind as to how the projected tools can be tested in the field. Will one go into the well, determine the presence of any existing fractures, and then fire a series of shots of progressively increasing power until subsequent permeability measurements show that some increase has been achieved? This part of the project seems not to have been addressed at all.

Reviewer 75:
The scientific/technical approach of the project is straightforward, well stated and organized. It focuses on low toxicity gas generation candidates, and develops and tests corresponding hardware for pressurization. In the reviewer‘s opinion, the first phase on feasibility study and conceptual design has been well completed.

Comments Regarding Accomplishments, Results and Progress
Reviewer 77:
The project team seems to be doing an outstanding job of moving this project toward the field test phase. The reviewer was most satisfied with what he saw in the presentation and write-up on the project, and has no significant criticisms at this stage. This all assumes that when the team tests the system that there will be sufficient borehole instrumentation to accurately characterize the time-dependent pressure field.

Reviewer 13:
Progress in developing pieces of hardware appears to have been adequate, but, as discussed above, it is not clear to the reviewer that the proposers actually know what rates of pressure rise will be needed in a given field situation.

Reviewer 75:
The reviewer understands from the presentation that the program leveraged several existing technologies and hardware that would potentially overcome the technical barriers, but the reviewer would be more convinced if he could be provided with more details on modeling or simulation from the angle of aero-thermal dynamics. As general comments, the quality and productivity of the accomplishments/results of this program have been good in relation to the funding level.

Comments Regarding Project Management/Coordination
Reviewer 77:
This project appears to be managed as well as could be subject to real world constraints and uncertainties. The reviewer has no recommendations regarding project management.

Reviewer 13:
Project management and coordination appears OK.

Reviewer 75:

The project management is seen to be effective and well thought out. The program has been coordinating with different resources from multiple organizations and universities. The tasks that were committed for the first fiscal year have been finished on schedule.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 77:

Based on the potential advantages of using propellant burn in propagating permeability, this project is very much needed especially given the level of control that might be achieved compared to an in-borehole explosive or propellant charge. Significant progress has been made with all year 1 activities complete and year 2 activities in process. This is a technically interesting project that could have significant implications for how fracturing is done commercially. I look forward to learning about the outcome of what seems like a very promising and novel effort. Overall, the reviewer rated the project as outstanding.

Reviewer 13:

As discussed in the section on "Scientific and Technical Approach" it appears that the proposers have a reasonably good grasp of how to make pressurization devices having a range of pressure rise rates. However, it is not clear if that range is in fact the range that will be needed, and how one is to judge the rate that will be needed in any particular well.

Reviewer 75:

Overall, the reviewer thinks the key goals articulated in this program are well reasoned and very supportable, and reflect positively on the EGS mission of applying innovative science and technology in pursuit of reservoir stimulation. The execution of the proposed plan is on the right track.

Comments Regarding Strengths

Reviewer 77:

See comments in the individual sections above.

Reviewer 13:

The proposers appear to have a good grasp of what is needed to build adequate hardware.

Reviewer 75:

The project team has expertise on pressurization control system. The quality of deliverables has been good. The project is well managed and currently delivering to schedule.

Comments Regarding Weaknesses

Reviewer 77:

See comments in the individual sections above.

Reviewer 13:

There is a definite need to connect the existing hardware project to some sort of analytic or modeling approach in order to determine the pressurization rates that will be needed in a well of given rock strength, permeability, remote stress and existing fracture pattern.

Reviewer 75:

Weaknesses are minor at this point. But as aforementioned, if the program could have some numerical models to help with the prediction of gas expansion and how the gas will interact with the geothermal reservoir, the reviewers would have more confidence in the outcomes of the coming year.

Suggestions for Improvement
Reviewer 77:
Some effort to simulate the temporal pressure regime, including gas-propagated fracturing and its effect on the near-field regime, might have been beneficial for providing useful information during the design stage of this project.

Reviewer 13:
The reviewer suggests adding a project to model the fracture initiation and propagation process.

Reviewer 75:
The report/presentation appears to have been written in a hurried fashion, and it contains a few typos such as the total budget on slide 2. Also, it might be helpful to coordinate with some organizations working on the combustion/aero-thermal dynamics to review the design before testing.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0711
Presentation Title: Feasibility and Design Studies for a High Temperature Downhole Tool
Investigator: Akkurt, Hatice (Oak Ridge National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 53:
High Temperature (HT) gamma and neutron detectors are needed to expand the suite of measurements currently available to the geothermal community. HT silicon-on-insulator (SOI) electronics are available and are currently used in downhole geothermal tools. Electronics based on this technology are designed to work at 225°C for 5 years and many continue to work up to 300°C. Detectors are limited and the development of them will enable the design of spectral gamma tools and porosity tools. Unfortunately, only the detectors themselves are evaluated. The complete package would require additional components, such as HT photomultiplier tube and high voltage power supply. This is a great first step in the development process, but more work is needed if the detectors are determined to be adequate. This work will have a direct impact on the detector manufacturers. It was quite evident that the detector manufacturers are interested in the ultimate temperature performance of their detectors and this data may help them improve the performance of their detectors. Detectors to help characterize and model the subsurface are needed for future geothermal activities.

Reviewer 67:
This research has the potential to lead to the future development of the first true high-temperature nuclear logging tool. The only thing that could make this project more useful is if the high-temperature performance of photomultiplier tubes was also investigated. However, given the resources and time frame for this project, photomultiplier tube investigations would likely not have been possible.

Reviewer 48:
Nuclear technique-based tools are extremely important in reservoir characterization. The existent tools are performing well for temperatures up to 150°C, but the new higher temperatures expected in EGS systems require improved tools adapted for these conditions. The authors are trying to cover the existing gap with improved nuclear tools.

Reviewer 23:
New scintillator materials that can operate at 300°C+ are needed; this work is considered impactful.

Comments Regarding Scientific/Technical Approach
Reviewer 53:
The technical approach concerning the evaluation of the gamma and neutron detectors is good. The technical approach is between good and fair based on the following comments: The detector manufacturers clearly have an interest in developing HT detectors. Many detectors were provided free of charge and the data conveyed by this project will help them to improve their detectors. Due most likely to limited funds, the complete detector package is not being evaluated. If an adequate detector is determined, considerable work will be required to qualify the complete detector package. (This effort is concentrated on evaluating the detector element with the other required components outside the test chamber.) This is the first step and should be complete before moving forward to the remaining components. Unfortunately, no mention of this likely follow-on work was presented. While it is excellent to determine the maximum operating temperature of the detectors, in reality, HT electronics would be required to make use of the detector. To date, SOI electronics are rated to 225°C for 5 years with many components continuing to work up to 300°C. A more concentrated effort up to 300°C would be useful. Also, longer testing at the elevated temperatures would also be helpful to determine the lifetime. The data presented was based on temperature hold times of approximately 15 minutes per temperature. This is a starting point, but additional longer-term tests will be required. Funding was probably not adequate for an expanded

test matrix. Many more detectors would be required.

Reviewer 67:
The technical approach of this project is good from the standpoint that the investigators are not only looking at high-temperature effects on gamma and neutron detectors, but also vibration and shock. This should result in a full environmental understanding of these detectors in a simulated high-temperature logging environment.

Reviewer 48:
The scientific/technical approach is sound, and logical. The authors are trying to extend the functionality of nuclear instruments to temperatures characteristic of EGS.

Reviewer 23:
The reviewer would have expected the project team to do a full assessment of all possible materials; still more work is needed in order to select a good candidate. Perhaps the screening approach needs to be reevaluated.

Comments Regarding Accomplishments, Results and Progress
Reviewer 53:
Accomplishments to evaluate the detectors are on track and should conclude with a recommendation on the best detector for HT. The stated goal is to ―perform feasibility and design studies for a high-temperature downhole tool, which uses nuclear techniques for characterization purposes, using measurements and modeling/simulation." Many of the topics under this objectives are or will be performed, such as the evaluation of gamma and neutron detectors (both static and under vibrational loads) and modeling/simulation work. At the completion of this project, it should be known if an HT gamma and/or neutron detector exists and what its upper temperature limit is. Based on the findings, a determination can be made if follow-on work regarding the additional components making up the complete detector package is warranted. If successful, the work can lead to a downhole gamma/neutron tool.

Reviewer 67:
It appears that the investigators have produced useful and credible results to date. Each of the tasks outlined in the presentation has either results or work in progress associated with it. In addition, the results seem to show that detector materials exist that can provide the baseline for the development of a high-temperature nuclear logging tool.

Reviewer 48:
The authors performed several experiments related to scintillators, with some promising results, and investigated He3 detectors at high temperature. Additionally, they performed some modeling for He3 detectors in fluid-filled borehole.

Reviewer 23:
The project team has downselected a few candidates but more screening work is needed.

Comments Regarding Project Management/Coordination
Reviewer 53:
The program management appears to be adequate for this developmental effort. The project was presented well at the review. Good collaboration with the detector manufacturers has been noted. It would be helpful if collaboration with entities working in the area of HT tools were established.

Reviewer 67:
The project management for this project appears to be on target. All of the tasks have been started, and it appears from the presentation that the remaining work can be completed prior to the end of FY 2011.

Reviewer 48:

The management/coordination side of the project is in line with expectations. Additionally, the authors are taking steps toward future collaboration opportunities, based on available future funding.

Reviewer 23:
Plans for future work are not well defined.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 53:
HT detectors are needed to further the development of HT tools for geothermal and other HT applications. If successful, this work can lead to the development of a downhole tool which uses nuclear techniques for characterization of the subsurface.

Reviewer 67:

Reviewer 48:
The authors of this project have promising candidates for photon detectors that can withstand adverse conditions of temperature, and they investigated a couple types of neutron detectors. Additionally, they performed some modeling related to He-3 neutron detectors.

Reviewer 23:
Overall this project is average. The reviewer would have expected to see results from screening the entire material set. Future plans are not well defined—much of the same from the last milestone.

Comments Regarding Strengths
Reviewer 53:
Detectors to help characterize and model the subsurface are needed for future geothermal activities.

Reviewer 67:
The project appears to be very well focused on high-temperature shock and vibration characterization of a variety of nuclear detectors. This comprehensive assessment will likely prove very valuable to future developers of a high-temperature nuclear logging tool.

Reviewer 48:
The project team investigated several scintillators at high temperatures, and narrowed down the list to four. Also, there are plans to investigate additional scintillators in future work. The project seems very well executed and the results are very promising.

Reviewer 23:

Comments Regarding Weaknesses
Reviewer 53:
If an adequate detector is determined, considerable work will be required to qualify the complete detector package. (This effort is concentrated on evaluating the detector element with the other required components outside the test chamber.) This is the first step and should be complete before moving forward to the remaining components. Unfortunately, no mention of this likely follow-on work was presented.

Reviewer 67:
A weakness of this project is that only detectors are being addressed. In order for a true high-temperature solution, the high-temperature performance of photomultiplier tubes must also be addressed.
Reviewer 48:

Reviewer 23:

Suggestions for Improvement
Reviewer 53:
It would be helpful if collaboration with entities working in the area of HT tools was established.

Reviewer 67:
The presenter indicated that the gain dependence of the He3 neutron detector tube is being investigated. This issue needs to be resolved in order to ensure reliable operation at high temperature.

Reviewer 48:

Reviewer 23:
Leadership could be improved.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0712
Presentation Title: 300°C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems
Investigator: Vert, Alexey (GE Global Research)

Comments Regarding Relevance/Impact of Research

Reviewer 63:
This project is advancing technology needed by the geothermal industry. Silicon carbide (SiC) is the future of power electronics worldwide and will enjoy growing market support over the next twenty years.

Reviewer 48:
SiC electronics are extremely important for EGS downhole measurements. There is a great advantage to having electronics downhole, and the present project is addressing this problem. In the present configuration, the analog SiC electronics will be interfaced with a temperature sensor, which is a good way to demonstrate the performance of the device developed. It is worth mentioning that SiC electronics can be interfaced with a suite of different sensors for downhole measurements and it can have a huge impact in sensing technology in high-temperature wells, not necessarily related to EGS only.

Reviewer 23:

Reviewer 65:
The research contractor demonstrates outstanding relevance and impact for this project. Many DOE geothermal projects bemoan the lack of technology for high-temperature electronics and temperature measurement for downhole data collection. This research project directly addresses this issue. The contractor does not try to retrofit equipment from the oil and gas industry, but instead is developing an electronics platform, complete with substrate, interconnect, active electronic elements and passive electronic elements. The success of this project will indeed fill a very great need in the Geothermal Technologies Program mission by providing valuable downhole data for temperature under high-temperature situations.

Reviewer 39:
As for the preceding GE SiC project, the successful development of this technology would provide a much needed tool to the geothermal drilling inventory. Tools of this type are widely used in the oil and gas industry to facilitate optimization of drilling programs but are generally not available for the more difficult geothermal environments. The technology would provide a step change in capabilities if successfully developed.

Comments Regarding Scientific/Technical Approach

Reviewer 63:
SiC electronics can operate at 300°C without much effort. The largest technical challenge comes from everything else needed to build a system inside the geothermal well. This project is addressing a number of issues including mounting the SiC devices without organic materials.

Reviewer 48:
The scientific approach for the SiC metal–oxide–semiconductor field-effect transistors (MOSFETs) developed in this project is sound, and the authors are also investigating in detail the packaging and the passive components used in the device. The integrated circuits developed in this project use a frequency modulated output, with great advantages over amplitude modulation.

Reviewer 23:

Reviewer 65:
The researcher is following an outstanding approach for both the science and technology of developing the high-temperature electronics platform. The researcher is successfully leveraging previous efforts in SiC junction gate field-effect transistor (JFET) technology to make possible electronic circuits that can "chopper-stabilize" analog signals from instruments via a 50% duty cycle square wave at approximately 400Hz frequency. The researcher is carefully evaluating discrete, surface-mounted passive elements (resistors and capacitors) for thermal reliability. The researcher is developing the surface mount technology as well as the macro interconnect technology to make the electronics platform useful in the field.

Reviewer 39:
The approach is logically structured and appears to address most development concerns. This type of electronic packaging development effort is generally challenging and the fundamental project components are well conceived.

Comments Regarding Accomplishments, Results and Progress
Reviewer 63:
The development of a SiC operational amplifier is an outstanding result. However, there appears to be no commercial outlet for this technology such that the geothermal industry can take advantage of the amplifier.

Reviewer 48:
The operational amplifier (op amp) developed in this project was tested at 300°C for 1,000 hours without any failures. This is a very promising result, proving that the SiC circuitry can be deployed in the field for a long time. The high-temperature board seemed to fail after 250 hours, but steps are taken toward identifying failure modes and corrective actions.

Reviewer 23:

Reviewer 65:
The researcher is making outstanding progress following the technical workplan. A great deal of effort has been expended (at modest expense) to gather and thermally qualify passive components. A large existing body of researcher expertise in JFET active element technology has been incorporated into this project.

Reviewer 39:
It appears that integration of the board and assembly is slightly behind schedule. Although individual component testing has been successful to date, it is often at the component integration stage where major problems are revealed.

Comments Regarding Project Management/Coordination
Reviewer 63:
GE is a major government contractor with assets for controlling and running DOE projects.

Reviewer 48:
The start of one of the tasks was delayed due to PI change. However, according to the current PI, the estimated completion date will not be affected.

Reviewer 23:

Reviewer 65:
The researcher is demonstrating outstanding project management and coordination for this project. Despite issues with

upper management (which can be very difficult to solve) the researcher has managed to keep the project well and successfully managed to time and cost targets.

Reviewer 39:
From the presentation it appears that there was a PI change during the final year of the project. This does not appear to have hindered progress excessively.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 63:
This is a desirable project for developing the technology needed by the geothermal industry.

Reviewer 48:
Overall, the present project seems well executed and well conceived. The need for high-temperature electronics in EGS is obvious. Research in the direction of SiC-based electronics development is the most promising solution for high-temperature applications, at least at the present time.

Reviewer 23:
This team has done an outstanding job in making a temperature sensor that can operate in a lab environment at 300°C—meeting critical criteria for functionality. They also have a solid plan on what the next steps ought to be.

Reviewer 65:
Overall, the research is being performed at an outstanding level. The researcher has chosen an excellent topic of extreme relevance to the Geothermal Technologies Program. Success of the research will have a strong impact because it will make possible the acquisition of critical data concerning downhole conditions. The scientific and technical approach is sound, and is a solid mixture of heuristics/testing along with advanced design. The researcher is managing the project extremely well, despite challenges from upper management, which seem to have been successfully resolved.

Reviewer 39:
This project appears to be a variation of 0706, the other GE project. The reviewer‘s summary comments for that project apply to this one as well. The presentation for this project presents more detail on the board-level assembly. The project focus appears to be appropriate but the reviewer suspects that there will be issues associated with the high coefficient of thermal expansion mismatch between the alumina substrate and metalized features.

Comments Regarding Strengths
Reviewer 63:
Overall strength is the the development of a SiC operational amplifier. Operational amplifiers are a basic building block for all electronic instrumentation systems.

Reviewer 48:
The project team developed and tested a SiC operational amplifier at 300°C for a long period of time. Stable and continuous operation was demonstrated.

Reviewer 23:

Reviewer 65:
Comments of the myriad strengths of the project have been made in the sections above.

Reviewer 39:
In addition to material and electronics packaging subject matter expertise, the research organization performing the work has an oil and gas group versed in the application conditions of the desired assembly product. This should bring attention to development concerns related to tool packaging and construction that might otherwise be neglected.

Comments Regarding Weaknesses
Reviewer 63:
The overall weakness is the lack of any direct process for the geothermal industry to make use of this technology. GE Oil and Gas is just that—a fossil energy technology company based in Houston.

Reviewer 48:

Reviewer 23:

Reviewer 65:
There are no overt weaknesses identified.

Reviewer 39:
Thermal cycling fatigue testing does not appear to be included in this project. This is a common cause of failure when inorganic substrates are used and should be addressed.

Suggestions for Improvement
Reviewer 63:

Reviewer 48:

Reviewer 23:
None.

Reviewer 65:
No suggestions for improvement identified.

Reviewer 39:
The reviewer suggests incorporating thermal cycle testing of integrated assembly.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0713
Presentation Title: Harsh Environment Silicon Carbide Sensor Technology for Geothermal Instrumentation
Investigator: Pisano, Albert (The Regents of the University of California)

Comments Regarding Relevance/Impact of Research
Reviewer 53:
Innovative high temperature (HT) sensors that can survive 374°C and 220 bar are needed to advance the technology required to develop HT tools for geothermal applications. The selection of sensors and electronics that will operate continuously at temperatures of 250°C is a challenge and as the operating temperature increases, the selection is reduced considerably. Silicon carbide (SiC) is an advancing technology and in theory will operate at temperatures up to 500°C. To date, SiC sensors are not commercially available. NASA has successfully demonstrated a SiC-based pressure sensor that will operate up to 500°C. SiC devices are commercially available but are limited to power devices, such as junction gate field-effect transistor (JFETs) and diodes. DOE is funding research to advance SiC technology in the area of electronic components. Basic building blocks such as an operational amplifier have been successfully demonstrated. The SiC project has elements that will be quite useful if they are successfully developed. Developing the process to produce SiC pressure and temperature sensors can lead to more advanced sensors in the future. The bonding process also has importance outside the scope of this project such as the enhancement of die attach inside multi-chip modules (MCM). Also, the process might be useful as an alternative method of attaching conductive material to ceramic substrates, thereby advancing the development of an HT circuit board (needed when more HT SiC devices are available).

Reviewer 63:
The objectives are extremely broad, listing 15 sensors. However, the application is limited to pressure and temperature. Temperature sensors rated to supercritical temperatures already exist. SiC pressure sensors have been demonstrated for temperatures as high as 500°C, however, these have not found a commercial market. On the positive side, there is a need for students to learn SiC-based sensor technology.

Reviewer 48:
Sensor development for temperature and pressure determination in harsh environments is of great importance for the geothermal industry, and has potential applications in other industries.

Reviewer 23:

Reviewer 47:
Development of novel robust pressure and temperature sensors for continuous operation at supercritical temperatures would provide the geothermal industry with better solutions than currently available technologies.

Comments Regarding Scientific/Technical Approach
Reviewer 53:
The basic technical approach is sound. The end result should be the demonstration of a SiC capacitive-based temperature and pressure sensor. The objective is to have the sensors operate at 374°C 200 bar, without the use of pressure housing. Elements of this approach can be useful in future projects. The standard configuration is to have the sensors and electronics in a pressure housing. This protects the sensor and electronics from the pressure effects and eliminates the concern of conductive/corrosive effects on the sensor and electronics. The exception is when the sensing element must be exposed to the wellbore to react to the desired parameter, such as pressure. In traditional pressure transducers, this is handled in two ways. The first is to utilize a diaphragm capable of direct contact to wellbore chemistry. This is the approach of this project. The other approach implements an isolation barrier, such as an oil-filled cavity, to protect the

sensing element from the corrosive environments. The suggested approach is ok, but considerations should be made to protect the electrical connections from the conductive environment. After the talk, this topic was discussed and a potting compound was mentioned, but would need to be developed. Probably the main concern is the fact that a complete solution was not well presented. In order to make any measurement downhole, more than a sensor is needed. Normally, the sensor is connected to signal conditioning circuits, followed by a circuit to enable the measurement to be conveyed at the surface. The complete system would be sensors, electronics and a cable to the surface. All of these elements are not trivial, and without them, the sensor cannot be utilized. In the presentation, the electronics is stated as ―simple electronics". The presently developed sensor has a sensitivity of only a few picofarads (pF, a unit of capacitance) over the range intended (ambient temperature to 374°C and ambient to 220 bar). It is not trivial to condition signals of this nature using conventional electronics and is presently impossible with existing HT electronics. After the presentation, a brief discussion was presented to enhance the sensitivity. In reality, the sensitivity would need to be improved by a factor of at least 500. As a reference, many other elements in a functioning system are likely to vary more than a few pF, thereby making it difficult to distinguish between the desired measurement and ―other" variations in the system. Interconnect wires and the board material itself are a couple of examples to be considered. In is unclear if this is feasible and certainly no work is presently outlined to improve the sensitivity. It seems a better approach may be to concentrate more effort in making a practical sensor and less on bonding the sensors to casing. It seems having a complete solution is years away and in reality, would be better implemented if the sensor and required electronics were co-located in a pressure housing. This can eliminate the issues with conductive fluids and interconnection issues to the electronics. Also, a cable could be envisioned to power and recover the downhole data. While temperature and pressure are good basic sensors to begin development efforts, additional sensors are clearly desired. Measurements requiring direct fluid contact such as wellbore PH, resistivity or conductivity would be ideal for a sensor technology that can survive direct contact with wellbore chemistry. In other words, while downhole temperature is an important measurement, it is difficult to compete with a resistive thermal device (RTD) or thermocouple (inexpensive temperature sensors). Also, it is worth noting that most electronic sensors and devices are all-temperature sensitive and care must be taken to eliminate/minimize the temperature effects. Another point is the method of bonding the sensors to the casing. A procedure is presented but the method used in the lab is not practical in the field. This point was brought up during the review and the field method of bonding the sensor is basically a torch (lab students refer to it as a flame thrower). This method may not be allowed in the field due to the temperatures required. The casing material may be annealed, which will weaken the area where the sensor is bonded. This approach would need to be looked at in more detail to ensure it is a viable method. Also, if this is the approach to be utilized in the field, the same procedure should be demonstrated as part of the early tests to ensure the same bonding strengths can be achieved.

Reviewer 63:
The project summary is short on any technical details. The presentation is better. The Research based on SiC is good because it is able to operate at very high temperatures with little temperature effects. It's a hard material to work with and fairly expensive. The decision to work only with capacitive-based sensors is a good idea. This allows for the measurements to be frequency-based which can be done with simple SiC operational amplifiers. The development of 80% Au with 20% of Sn for 600°C bonds to steel is very interesting. Some life testing on this process should be undertaken.

Reviewer 48:
Design and fabrication of temperature and pressure SiC-based sensors was performed, along with finite element modeling. This demonstrates a well-thought scientific/technical approach. The bonding procedure to create high-temperature bonds with reduced process temperature is a smart solution for the applications sought.

Reviewer 23:

Reviewer 47:
The selected approach for pressure and temperature sensing utilizes capacitive-based sensor designs fabricated on SiC. High-sensitivity capacitive measurements could be difficult to realize on the system level in harsh environments. Sensor

capacitance, its dynamic range and parasitic package capacitances should be taken into account at early stages of sensor design. Besides die attachment technology, interconnects and interconnect insulation suitable for sensor signal readout have to be developed and incorporated into the sensor development plan.

Comments Regarding Accomplishments, Results and Progress

Reviewer 53:

The presented accomplishments are in line with the funding spent. Up to this point, they have demonstrated that the die itself can tolerate the wellbore chemistry, but this does not necessarily mean the completed sensor will also tolerate it, and a path forward to demonstrate the complete sensor is briefly discussed. SiC is known to be chemically stable and as such, the die is likely to survive. Until a circuit is fabricated, it is difficult to determine if the approach presented is viable. The needed testing to demonstrate the concept is scheduled by the end of August.

Reviewer 63:

The field trip to The Geysers for the students was good. The level of output from this project is reasonable given the delays and the fact that university professors are only available part time.

Reviewer 48:

Exposure testing at supercritical conditions of Si and SiC dies proves the definite advantage of using SiC for sensor materials. However, the reviewer is not clear on the effect of supercritical brine on the other components involved in sensor fabrication, e.g. bonding material.

Reviewer 23:

Reviewer 47:

The project appears to be on track according to the project plan. Some minor delays were encountered during the first year and sensor fabrication milestones remain to be achieved.

Comments Regarding Project Management/Coordination

Reviewer 53:

The program management appears to be adequate for this developmental effort. The project was presented well at the review.

Reviewer 63:

No comments.

Reviewer 48:

The project appears to be running well, according to plan.

Reviewer 23:

Reviewer 47:

Working with industry refining sensor target characteristics and tailoring the design and packaging approaches will ensure technology readiness for use as part of the sensor system at a later stage.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 53:
HT sensors are needed to further the development of HT tools for geothermal and other HT applications. SiC is a logical advancement in technology. It potentially will operate at higher temperature than competing technologies such as silicon-on-insulator (SOI). Commercially available SiC sensors/electronics are currently limited to power devices. An expansion into the suggested sensor would be helpful, but the complete system is not clearly defined. It appears this is more of a basic research project and a practical sensor is not likely at the completion of the project.

Reviewer 63:
Good research for a university. A little too broad in its topics. The pressure and temperature sensors are unique. Testing of SiC and Si in direct contact with supercritical water is unique and has value in future sensor designs.

Reviewer 48:
Overall, a well-thought project that has a good chance of success.

Reviewer 23:
The program is in its early stages but shows promise and good solid leadership. The milestones have been met and those listed for the future look solid. The reviewer would like to see additional longer-term high-temperature testing.

Reviewer 47:
Although the project is making progress, several significant technical challenges related to the sensor design have not yet been addressed. It could be critical to address packaging and system level issues in the early stage of the project. Potential consultation with other groups working on high-temperature measurement tools may help to improve the design and suggest alternative design approaches, which could be harder to implement at a later time.

Comments Regarding Strengths

Reviewer 53:
HT sensors are needed to further the development of HT tools for geothermal and other HT applications. The end result should be the demonstration of a SiC capacitive-based temperature and pressure sensor.

Reviewer 63:
One of the noted strengths is working with students to teach them SiC material properties and applications in geothermal.

Reviewer 48:
In-situ exposure assessment is very important for determining the life and functionality of the sensors developed.

Reviewer 23:

Reviewer 47:
Good research topic. Significant sensor performance improvement is expected if the project is successful.

Comments Regarding Weaknesses

Reviewer 53:
Unfortunately, a complete solution was not well presented. In order to make any measurement downhole, more than a sensor is needed. Normally, the sensor is connected to signal conditioning circuits, followed by a circuit to enable the measurement to be conveyed at the surface. The complete system would be sensors, electronics and a cable to the surface.

Reviewer 63:
There is no commercialization plan and no consideration of existing technologies.

Reviewer 48:

Reviewer 23:

Reviewer 47:
There is a lack of a clear strategy for sensor signal readout and packaging.

Suggestions for Improvement
Reviewer 53:
The reviewer suggest a significant increase in the sensor's sensitivity. The presently developed sensor has a sensitivity of only a few pF over the range intended (ambient temperature to 374°C and ambient to 220 bar).

Reviewer 63:
Future work should consider sensors as inclination. Inclination is easily measured using silicon micro electro-mechanical systems (MEMS) capacitive devices. I would assume a SiC inclination sensor could operate at supercritical temperatures with applications in determining the wells high side.

Reviewer 48:
Not sure about the values for some of the properties on the table on slide 4. In reality, the two polytypes of SiC (3C and 6H) have different elastic properties.

Reviewer 23:

Reviewer 47:
Need to adjust sensor design to make them more attractive for system-level integration.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0714
Presentation Title: Development of a High Temperature Fiber Optic Transmission System
Investigator: Henfling, Joe (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research
Reviewer 48:
A fiber optic transmission system can have a great impact on high-speed data transmission in EGS. The main impediment is related to the harsh conditions present in geothermal environments.

Reviewer 23:

Reviewer 65:
The researcher has just begun the research program and has limited accomplishments at this point through no fault of his own. The projected relevance and impact of this work is good, since it offers a way to achieve high-bandwidth sensor data collection, presumably for such sensors that have video streams.

Comments Regarding Scientific/Technical Approach
Reviewer 48:
The approach for the beginning of the project was to investigate high-temperature optical modulators, along with adequate packaging to enable operation at high temperature. This appears to have been accomplished. The modulators were down-selected to two, lithium niobate (LiNbO3) and silicon (Si). Later on, a complete fiber optic data system will be designed, built and tested in the field.

Reviewer 23:

Reviewer 65:
The researcher is taking a good approach to the problem, in devising a system that places an electro-optical coupler downhole to communicate directly to electronic instruments, and then uses a fiber optic cable to communicate from the electro-optical coupler to the surface. The research has identified changes in polarity of light (as it passes through the optical fiber) as a major challenge, and has proposed a way to surmount this challenge.

Comments Regarding Accomplishments, Results and Progress
Reviewer 48:
The project team demonstrated system operation for a low-temperature modulator, with data rates greater than 1million bits per second (Mbps), and showed that polarization control is important for maximizing the amplitude of the received signal. Also, they have a first generation receiver board for uphole electronics. The project seems to be moving in the right direction. High-temperature experimentation has to be performed in the future.

Reviewer 23:

Reviewer 65:
Given that the researcher has recently begun the research, there are only a modest number of results to report. But the progress seems good at this point.

Comments Regarding Project Management/Coordination
Reviewer 48:

The project seems to be 25% completed and the funds spent in the same neighborhood.

Reviewer 23:

Reviewer 65:
The researcher seems to have put forward a good management plan for the project, but at this early stage, it is difficult to make a more detailed assessment than this.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 48:
Overall, this is an interesting project that has great potential.

Reviewer 23:
The project team has met its milestones. The reviewer's only concern is how they handle the hydrogen darkening effect; they should comment on that issue and list ways to resolve it.

Reviewer 65:
Overall, the researcher seems to be making good progress toward the goals of the project. The relevance and projected impact are good, in that the researcher addresses a need to have a higher-bandwidth sensor link from downhole instruments to the surface, and cites video data as one of the motivating factors for this. Although early in the project, the researcher seems to have identified the critical issues required for successful completion of the project and is making good progress towards those goals.

Comments Regarding Strengths
Reviewer 48:
Temperature-resistant high-speed fiber optic data transmission is an important problem to be solved.

Reviewer 23:

Reviewer 65:
The strong point of this research is the promise for high-bandwidth (10 Mbps) communication rates from downhole to surface.

Comments Regarding Weaknesses
Reviewer 48:
Not sure what optical fiber will be used. Optical fibers have their own problems when it comes to harsh environments.

Reviewer 23:

Reviewer 65:
The weakness of this research is the presumption that the laser illumination source must be at the surface and that high-temperature illumination sources (LED or Laser Diode) are not or will not be available to make downhole, direct illumination possible. This is a *minor* weakness.

Suggestions for Improvement
Reviewer 48:

Reviewer 23:

Reviewer 65:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0715
Presentation Title: Well Monitoring Systems for EGS
Investigator: Normann, Randy (Perma Works)

Comments Regarding Relevance/Impact of Research
Reviewer 55:
The work addresses an important need within the geothermal industry, specifically downhole logging tools that can operate reliably for extended periods of time and at elevated temperatures. The project team is leveraging advances from the aerospace industry (electronics for aircraft) and adapting those technologies for use in geothermal well monitoring. By applying technologies from other industries, the cost of the products should be reasonable due to the larger manufacturing base. Issues such as high-temperature solders must still be addressed, but the project team appears to be well aware of those challenges and the technologies available. While the team is primarily focused on logging tools, high-temperature electronics would also be useful for monitoring equipment and other installed components. These applications would expand the use of the products developed with this funding.

Reviewer 48:
Monitoring tools for pressure, temperature and flow in harsh environments is of great interest to the geothermal community, and this project is addressing just that.

Reviewer 23:

Reviewer 47:
The research project sets a very relevant goal of demonstrating high-temperature downhole tools capable of surviving 300°C environments without cooling for prolonged periods of time. The outcome of the project will definitely set the trend for high-temperature electronics manufacturers, accelerate electronic parts development and provide a platform for building more complex high-temperature tools for use in geothermal data logging and exploration.

Comments Regarding Scientific/Technical Approach
Reviewer 55:
PermaWorks has established a solid team of contributors to address the various technical challenges. The project includes sub-awards to Electrochemical Systems Inc. and Frequency Management International. Subcontractors and other participants include cable producers, high-temperature electronics manufacturers, and companies engaged in geothermal energy development. The three-year project plan includes the development and demonstration of several unique components (e.g., spinner flow sensor, high-temperature clocks, high-temperature batteries, circuit boards, etc.). These components will be useful for future EGS and other downhole applications.

Reviewer 48:
A nice intermingle of 300°C solutions—circuit boards and solders, high-temperature batteries, digital clocks, flow sensor, and cables.

Reviewer 23:

Reviewer 47:
The approach of leveraging high-temperature silicon-on-insulator (SOI) circuits from multiple vendors and demonstration of key missing components enables a platform for building not only a P/T/flow measurement system, but also provides

testing instrumentation suitable of supporting tests of other sensor systems. The project addresses not only the need for missing high-temperature electronics, but also explores high-temperature clock, high-temperature board materials and assembly processes, high-temperature batteries and cabling.

Comments Regarding Accomplishments, Results and Progress

Reviewer 55:

The results to date have been very good, with accomplishments that include building an analog PT tool for 300°C operation, demonstrating a 300°C digital clock with 800 hours of operation, and demonstrating high-temperature circuit board technology.

Reviewer 48:

The project team has had good accomplishments, with some setbacks that are being addressed.

Reviewer 23:

Reviewer 47:

The demonstration of high temperature clock, P/T tool and innovative flow sensor all functional at 300°C is a very key milestone toward providing reliable downhole instrumentation for the geothermal industry. It is expected that availability of these tools should reduce the cost of EGS by enabling measurements at depths and temperatures where no tools are currently available.

Comments Regarding Project Management/Coordination

Reviewer 55:

The project management plan appears to be logical, however, the large number of components being considered will require a high degree of coordination throughout the project.

Reviewer 48:

The project seems to be managed well. Setbacks and behind-schedule situations are managed properly.

Reviewer 23:

Reviewer 47:

The project is well on track according to its schedule with most key milestones demonstrated. It would be great to see full completion of second and third phases of the project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 55:

The project involves the development and demonstration of a variety of components needed for high-temperature data logging. Where possible, the team is applying technologies from other industries (such as aerospace) to leverage existing capabilities for geothermal applications.

Reviewer 48:

Overall, this is a very good project that attacks a very diverse well monitoring system for EGS, with some very promising results to date.

Reviewer 23:

Overall, the project team has made good progress, but the reviewer feels they are trying to do too much (i.e. working on too many solutions). It would probably be best to separate out and devote more resources so that they can achieve 300°C performance for all of their applications.

Reviewer 47:
The approach and accomplishments of the project contribute a large number of innovations in the form of high-temperature electronic and sensor building blocks addressing broad goals and needs. Demonstration of key fundamental components of high-temperature electronic systems undoubtedly will accelerate high-temperature tool development and provide a platform for testing them. The outcome of this project will set the pace and standards in the emerging high-temperature electronics field with a benefit for geothermal exploration technologies.

Comments Regarding Strengths
Reviewer 55:
The project involves several organizations that are contributing to the project goals. By utilizing these inputs, PermaWorks has thus far been able to meet its program goals and demonstrate several new components.

Reviewer 48:
This is a very ―adventurous" project, in the good sense. It intends to cover a broad suite of unique high-temperature technologies for downhole solutions.

Reviewer 23:

Reviewer 47:
Good results have been achieved. The project is oriented for demonstration of fundamental high-temperature electronic building blocks.

Comments Regarding Weaknesses
Reviewer 55:
By addressing numerous technologies, the project plan has some inherent risk. Thus far this does not appear to be a problem, but the team must ensure that unexpected challenges in one component of the work plan do not limit the resources available to the others.

Reviewer 48:

Reviewer 23:

Reviewer 47:
The reviewer would like to see the project team accelerate the development of digital tools capable to operate at 300°C.

Suggestions for Improvement
Reviewer 55:

Reviewer 48:

Reviewer 23:

Reviewer 47:
The reviewer suggests addressing design issues and risks in depth to enable optical sensor readout.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0716
Presentation Title: High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications
Investigator: Hooker, Matthew (Composite Technology Development Inc. Production)

Comments Regarding Relevance/Impact of Research
Reviewer 48:
High-temperature circuit boards designed for geothermal wells are of great interest. Electronics downhole can help tremendously in data processing and data transmission.

Reviewer 23:

Reviewer 47:
The existing gap in high-temperature electronics capable of operating at temperatures above 250°C also points to the absence of established techniques for high-temperature packaging and cost effective high-temperature circuit boards. The development of novel circuit board materials and substrates which can be manufactured at a lower cost may reduce the cost of high-temperature tools used in the geothermal field.

Comments Regarding Scientific/Technical Approach
Reviewer 48:
Composite Technology Development, Inc. has experience in special electrical insulators, and this proposal is based largely on their past expertise.

Reviewer 23:

Reviewer 47:
The technical approach of utilizing polymers and copper metal interconnects for board construction will have to address circuit board stability and reliability issues when exposed to temperatures in excess of 300°C during component attachment steps and long-term stability of copper interconnects when soaked at high temperatures. Untreated copper metallization chosen for the process development may not have adequate performance to achieve long-term targets for the board performance, hence, additional jugular experiments may be needed to study these issues and incorporate changes into the board design.

Comments Regarding Accomplishments, Results and Progress
Reviewer 48:
There are promising results related to high-temperature mechanical performance of one of the possible candidates (CTD-1280X). It has strong adhesion to copper.

Reviewer 23:

Reviewer 47:
The long-term evaluation of board materials at 300°C and short-term exposure to temperatures significantly exceeding 300°C is an important task and should be made a priority of the project test plan.

Comments Regarding Project Management/Coordination
Reviewer 48:
Project management is in line with expectations.

Reviewer 23:

Reviewer 47:
The project is on track according to its schedule. Collaboration with industry and high-temperature electronic components manufacturers may help to develop qualification tests which are needed to evaluate board materials and identify potentials issues when boards are used in high-temperature systems.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 48:
Overall, this is a well-executed project that moves along as expected.

Reviewer 23:
The project team has been able to achieve their milestones; the only concern is that future work needs more definition.

Reviewer 47:
Novel high-temperature board materials provide an alternative to the ceramic board materials currently used in high-temperature applications. The performance and cost of developed board materials could be evaluated against ceramic-based materials. Novel materials should be also developed to be compatible with die attachment techniques, solders and high-temperature electronic components. A set of lifetime evaluation tests, including electrical characterization of metallization, could be one of the methods to gauge long-term performance.

Comments Regarding Strengths
Reviewer 48:

Reviewer 23:

Reviewer 47:
This is a cost-effective way to build high-temperature boards.

Comments Regarding Weaknesses
Reviewer 48:

Reviewer 23:

Reviewer 47:
Long-term stability of the board materials and metallization when exposed to harsh environments are unknown.

Suggestions for Improvement
Reviewer 48:

Reviewer 23:

Reviewer 47:
The reviewer suggests implementing electrical qualification tests in various ambient conditions to complement

mechanical stability testing.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0717
Presentation Title: Base Technologies and Tools for Supercritical Reservoirs
Investigator: Henfling, Joe (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research

Reviewer 48:
There is a great need in the geothermal community for downhole electronics that can withstand adverse conditions of pressure, temperature and corrosive media.

Reviewer 23:

Reviewer 47:
High-temperature tools capable of operating continuously for more than a year at temperatures up to 240°C provide advanced instrumentation for a large number of geothermal wells. Such tools, when used with advanced flasking, protecting electronics for prolonged periods of time, will also enable exploration and logging in wells where temperatures are expected to be in excess of 250°C.

Comments Regarding Scientific/Technical Approach

Reviewer 48:
The project deals with development of multi-chip modules with different functionality, both analog and digital. They can be used for a large suite of tools, and this makes it very attractive. The approach of using dewared/dewarless tools for different temperature ranges is a very good and realistic approach.

Reviewer 23:

Reviewer 47:
The technical approach of multi-chip module development using already proven high-temperature silicon-on-insulator (SOI) components seems to be capable of achieving set goals. A novel dewar technology will be developed to enable operation of the electronics at temperatures above maximum rating of SOI components. The flasking approach is being successfully used by the oil and gas industry, although it has its own disadvantages. Combination of these approaches provides a reasonable and adequate way to achieve project goals.

Comments Regarding Accomplishments, Results and Progress

Reviewer 48:
The accomplishments, results and progress of this project are in line with expectations. Field tests are planned for the future. This is really important for equipment testing in ―real-life" situations.

Reviewer 23:
It seems many workstreams are in progress, few are complete and spending has been high. More definition is needed to better define the milestones and deliverables.

Reviewer 47:
Good progress has been demonstrated to date. Redesign of system architecture was completed timely due to the unavailability of originally-selected parts. Demonstration of the next milestone is slightly delayed.

Comments Regarding Project Management/Coordination

Reviewer 48:

Project management is in good shape. Collaboration with academia and industry is notable.

Reviewer 23:
The project needs a project leader that can effectively manage the deliverables.

Reviewer 47:
The project relies on electronic parts supplied by Honeywell. This seems to be working well; although some technical difficulties were encountered, they have been resolved and alternative parts were identified and selected.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 48:
Overall, this is a good project that is looking at several issues related to downhole tooling: packaging reliability, interconnect issues, improved dewars, high-temperature cables, and high-temperature batteries.

Reviewer 23:
Subject matter and deliverables are critical to the success of geothermal sensing. The reviewer would like to see more around ghard and quantifiable outputs, and a better job of managing the workstreams.

Reviewer 47:
The project objectives are adequate to support goals of the Geothermal Technologies Program and achieve realistic results in an efficient manner with an acceptable schedule. The combination of solid project accomplishments and technical approach should provide a large impact by demonstration of high-temperature tools in the near term by closing the existing gap in high-temperature capable electronics.

Comments Regarding Strengths
Reviewer 48:
This project strengths include looking at problems from different perspectives, and designing innovative tools for high-temperature geothermal reservoirs.

Reviewer 23:

Reviewer 47:
This is a practical and achievable near-term solution for building complex high-temperature electronic systems.

Comments Regarding Weaknesses
Reviewer 48:

Reviewer 23:

Reviewer 47:
Long-term 300°C and higher-temperature operation will not be possible.

Suggestions for Improvement
Reviewer 48:

Reviewer 23:

Reviewer 47:
The reviewer suggests exploring capabilities of SOI technology at temperatures up to 300°C when operated uncooled, exploring available lifetime and addressing lifetime improvements by innovative circuit design.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0718
Presentation Title: Waveguide-Based Ultrasonic and Far-Field Electromagnetic Sensors for Downhole Reservoir Charcterization
Investigator: Sheen, Shuh-Haw (Argonne National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 48:
Downhole reservoir characterization sensors for harsh environments are needed in the geothermal industry.

Reviewer 23:

Reviewer 39:
It is not clear how this work advances the state of the art in downhole acoustic sensing technology. The utilized technology is in itself conventional. All performed laboratory work represents idealized conditions with limited relationship to the application environment. Critical issues such as adaptation of the setup to a fieldable configuration are not addressed.

Comments Regarding Scientific/Technical Approach

Reviewer 48:
This project has a good scientific approach for the temperature sensor, based on an ultrasonic waveguide sensor. The reviewer is not very sure how the empirical model will work for determining rock fractures, porosity and permeability.

Reviewer 23:

Reviewer 39:
It is not clear how this work will help overcome any limitations of current high-temperature acoustic sensing technologies. A variety of cursory examinations of potential measurement techniques, including electromagnetic radiometry, were attempted with little focus on field application details. The path forward for performing many of the proposed measurements, such as formation porosity and permeability, is also not adequately justified.

Comments Regarding Accomplishments, Results and Progress

Reviewer 48:
The project has shown good results for temperature determination using the ultrasonic waveguide sensor. Determining temperature from the sound speed of water can be used up to 70°C. It is not clear why this is needed, as the ultrasonic waveguide sensor seems to work just fine for temperature measurements. Additionally, this tool will require a separate vessel with pure water. The ―water" in a geothermal reservoir is usually a brine that has a different sound speed than water.

Reviewer 23:

Reviewer 39:
The feasibility studies performed in water at fairly low temperatures (up to ~60° C?) are of little value. At the very least, experiments in mixed media should have also been performed.

Comments Regarding Project Management/Coordination

Reviewer 48:
Project management has been well executed.

Reviewer 23:

Reviewer 39:
The tasks and objectives for this project were poorly defined. Too many parallel, unrelated efforts were undertaken resulting in a superficial exploration of each sensing method.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 48:
Overall, this is an interesting approach to downhole tools design.

Reviewer 23:
The team made solid progress, met milestones (data was available), and has a clear and focused plan for next steps.

Reviewer 39:
This work does not appear to have made much progress in either providing a new technique for making measurements relevant to the geothermal environment or bringing an otherwise conventional, but unutilized measurement technique closer to commercialization. The exploration of numerous potential measurement methods resulted in superficial exploration of each at best. Given the funding level, the project would have been of more value if the focus had been on one technique with a more comprehensive test program reflecting closer to field-like conditions.

Comments Regarding Strengths
Reviewer 48:
The temperature sensor seems to work very well.

Reviewer 23:

Reviewer 39:

Comments Regarding Weaknesses
Reviewer 48:

Reviewer 23:
None.

Reviewer 39:

Suggestions for Improvement
Reviewer 48:

Reviewer 23:

Reviewer 39:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0719
Presentation Title: Acoustic Sensor for Downhole Fluid
Investigator: Pantea, Christian (Los Alamos National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 23:

Reviewer 39:
The use of a prescribed cavity geometry to identify fluid properties based on measured resonances may be a novel approach (the reviewer is not an expert in this technology, but it may merit further investigation). The high-temperature focus of the effort appears to be based on the use of materials such as lithium niobate ($LiNbO_3$) which have been reported in the literature, but the project does not advance the state of the art for high-temperature tool construction. For example, the plans for packaging and integration details of the technology for operation up to 300°C are not particularly well defined and have been developed to much greater degrees by service companies and other labs.

Reviewer 49:
Sensors to measure critical reservoir parameters including temperature, pressure, and fluid flow properties are valuable to the development and monitoring of an enhanced geothermal system. These measurements can provide in-situ guidance to the drilling and stimulation processes and thus will have direct impact on the cost reduction of reservoir development.

Comments Regarding Scientific/Technical Approach
Reviewer 23:

Reviewer 39:
If this cavity-based resonance technique is not currently utilized by other acoustic sensing technologies, then the technical approach appears to be reasonable. The experimental validation for different salinity conditions and over a range of temperatures is a logical progression.

Reviewer 49:
The proposed technical approaches are based on two physical principles—swept frequency acoustic interferometry (SFAI) and resonance tracking. It is not clear how the proposed techniques lead to measurements of the proposed parameters. Use of a $LiNbO_3$ resonator to measure temperature may be reasonable if other parameters such as pressure and fluid composition remain constant. The SFAI technique may give measurements of sound velocity and attenuation, but again, both will not directly lead to any meaningful parameter measurements. Attenuation is a function of many things, as is the sound velocity.

Comments Regarding Accomplishments, Results and Progress
Reviewer 23:

Reviewer 39:
The results seem reasonable given the funding level and technical objectives.

Reviewer 49:
Very little progress was given in the review package. Available data are temperature measurement using the acoustic resonator and sound speed measurement over a range of salt concentration. It is not clear how the present technical accomplishments can lead to development of the proposed sensor system.

Comments Regarding Project Management/Coordination

Reviewer 23:

Reviewer 39:
Tasks and schedule are reasonably defined and have been reasonably executed.

Reviewer 49:
The project is behind schedule on technology development.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 23:
The project team spent a good portion of the project in the materials selection phase; at this point in the project, the reviewer would expect to see preliminary results on the sensor performance.

Reviewer 39:
The use of acoustic tools is fairly mature in the oil and gas industry. The use of a cavity to define resonant behavior of the system and identify fluid properties may be a novel aspect of this project that can be further pursued but it is unclear how far this work can be extended in its current form to make it commercially relevant. The high-temperature transducer and system integration operational considerations have already been more thoroughly explored in the work of others.

Reviewer 49:
A flow characterization sensor can benefit the geothermal process if the measured parameters can guide the drilling or stimulation processes, particularly parameters that can predict the reservoir permeability and rock fractures. The proposed work does not address these issues at all. The progress of this project has not demonstrated the feasibility of the proposed techniques for the targeted measurements; only temperature measurement using an acoustic resonator has been demonstrated. Can the resonator measure both temperature and pressure or viscosity? Maybe one can measure the combined effect; that may not have much value.

Comments Regarding Strengths

Reviewer 23:

Reviewer 39:

Reviewer 49:
Use of acoustic techniques for downhole measurements of critical parameters such as temperature, pressure, flow, and fluid properties is the strength of this project.

Comments Regarding Weaknesses

Reviewer 23:

Reviewer 39:
The current work brings little to the table with regard to developing an actual downhole tool or measurement technique understanding. The service companies that currently produce downhole acoustic tools have a tremendous advantage in both of these areas due to their vast experience building such tools and analyzing the associated acoustic signals.

Reviewer 49:
The proposed techniques, acoustic resonance and interferometry for the geothermal reservoir characterization most likely will not provide reliable measurements of the target parameters.

Suggestions for Improvement

Reviewer 23:

Reviewer 39:

Reviewer 49:
The project team needs to demonstrate in the lab the measurement capabilities of the proposed techniques and identify their problems when applied to a realistic environment.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0720
Presentation Title: Geothermal Ultrasonic Fracture Imager
Investigator: Patterson, Doug (Baker Hughes Oilfield Operations Incorporated)

Comments Regarding Relevance/Impact of Research
Reviewer 23:

Reviewer 39:
This work provides a valuable evolution of acoustic imaging technology in the high-temperature environment. The development of materials and assembly practices for a package deployable in the 300°C temperature regime will advance the state of the art and provide a useful asset for geothermal applications. The elimination of a rotational mechanism and incorporation of an electronic scheme for scanning the borehole circumference are novel, to the reviewer‘s knowledge. The quoted 3-4 hour permissible operation time as limited by the thermal insulation of the electronics seems inadequate.

Reviewer 49:
Fracture characterization and identification of a geothermal well are important and valuable to the reservoir development. Availability of a downhole imager that can map out the reservoir fractures is critical to well drilling and has significant economic benefit in geothermal well development.

Comments Regarding Scientific/Technical Approach
Reviewer 23:

Reviewer 39:
The R&D tasks and experimental program are in line with project objectives.

Reviewer 49:
A downhole ultrasonic imager can at best only map out the surface feature of the well reservoir. In an enhanced geothermal well, the well is mainly composed of granites. Ultrasound does not propagate much inside the granite, so only the surface features may be captured by the ultrasonic imager. The surface features may not have any correlation with the permeability and fractures of the reservoir. The project proposes to use a cylindrical transducer array to perform downhole ultrasonic imaging. The downhole environment is not an ideal one for imaging; it is most likely a mixed-phase environment, with scattered waves everywhere. Signal processing will be a big effort. The proposed technique is not appropriate for geothermal applications.

Comments Regarding Accomplishments, Results and Progress
Reviewer 23:

Reviewer 39:
Results to date appear to be reasonable and the project appears to be on track to deliver a useful tool as expected.

Reviewer 49:
The project has only accomplished the sensor design. The feasibility of the imaging capability has not been shown.

Comments Regarding Project Management/Coordination
Reviewer 23:

Reviewer 39:
Project management and coordination appears to be reasonable, although a delay in prototype delivery was reported (when were the prototypes originally scheduled to be delivered?).

Reviewer 49:
After two and half years, the project only made very limited progress. It has not even demonstrated the performance of the array transducer for imaging application.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 23:
The project team has done a great job with the initial evaluation of materials; they've met all milestones. The project has been well managed and the team has met its deliverables.

Reviewer 39:
The delivery of another 300°C acoustic fracture imaging tool will be a valuable addition to the geothermal toolkit which should facilitate the fracture characterization needs for both hydrothermal and EGS applications. The high-temperature components and assembly practices developed as a result of the work should also help advance the state of the art in downhole tool development.

Reviewer 49:
The proposed ultrasonic imaging system that detects both direct reflections and/or leaky surface waves (Stoneley waves) is of value to the geothermal reservoir characterization. Particularly, the Stoneley wave may provide the reservoir porosity measurement.

Comments Regarding Strengths
Reviewer 23:

Reviewer 39:
The project team obviously has vast experience developing and deploying commercial tools of this type. This should translate into a greater likelihood of success and the production of a tool that meets field needs.

Reviewer 49:
Development of a circular ultrasonic array transducer that can withstand high-temperature environments is the strength of the project.

Comments Regarding Weaknesses
Reviewer 23:

Reviewer 39:

Reviewer 49:
Without measuring the Stoneley wave, the imager will have limited benefit in detecting permeability or porosity. The capability of detecting internal fractures by this imager is remote.

Suggestions for Improvement
Reviewer 23:

Reviewer 39:

Reviewer 49:
Demonstrating the array sensor imaging capability, even in room temperature, needs to be accomplished soon. Developing the Stoneley wave imaging system may be a better approach.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0721
Presentation Title: Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells
Investigator: Lowell, Mark (Draka Cableteq USA, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 63:
The development of optical fiber for geothermal well monitoring is important if EGS is going to become a real energy resource. The potential for 400°C, optical fiber is very favorable. This is a complete program with a clear development and commercialization path.

Reviewer 50:
The PI has met the criteria for making substantial progress toward a longer-life cable. Furthermore, the cable has a copper cable to attach a traditional industry pressure/temperature sensor to calibrate and validate the fiber-optic measurement.

Comments Regarding Scientific/Technical Approach
Reviewer 63:
The laboratory hydrogen testing was as complete as the reviewer has seen. Testing in the well is still required because laboratory hydrogen is H2 while well hydrogen is a free H.

Reviewer 50:
Lab and field are a good combination for this project.

Comments Regarding Accomplishments, Results and Progress
Reviewer 63:
Results look very good and the planned demonstration is primed for creating a future market in geothermal.

Reviewer 50:
The reviewer judges progress to be at the 50% level and the jury is still out about success with regard to hydrogen resistance and high-temperature polyimide coatings.

Comments Regarding Project Management/Coordination
Reviewer 63:
The list of suppliers is very strong. Their organization appears to be mature.

Reviewer 50:
The three phases of the project are well defined and tasked. The project has a good set of partners for developing and testing the new fiber and coatings.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 63:
This is a good project with the potential to change the geothermal industry for both supercritical and EGS geothermal development. The potential for 400°C, optical fiber is very favorable. This is a complete program with a clear

development path and commercialization path.

Reviewer 50:
The project has shown good progress toward developing a longer-life cable.

Comments Regarding Strengths
Reviewer 63:
The project‘s strength is the potential commercialization of a sensor for all geothermal wells.

Reviewer 50:
The real strength is Draka's ability to make pre-forms with different properties.

Comments Regarding Weaknesses
Reviewer 63:
The reviewer did not note any real weaknesses.

Reviewer 50:
This project is mostly a development, rather than research, project.

Suggestions for Improvement
Reviewer 63:
The reviewer suggests developing a testing agreement with ISOR for very high-temperature wells.

Reviewer 50:

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Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0722
Presentation Title: Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems
Investigator: Challener, William (General Electric Company)

Comments Regarding Relevance/Impact of Research

Reviewer 63:
Supercritical temperatures inside a geothermal well will affect the optical fiber, both mechanical and optical. It is asking a lot to develop sensors utilizing the optical fiber under one DOE project. However, the development of optical fiber and sensors will greatly benefit the geothermal industry for both supercritical and EGS applications. Work presented here has made reasonable progress given the scope of this project.

Reviewer 23:

Reviewer 50:
The goal is to meet the specifications of 374°C and 220 bar in the presence of hydrogen. Industry asks for this.

Comments Regarding Scientific/Technical Approach
Reviewer 63:
The fiber testing at temperature is good. Lab testing uses H2 while fiber in the well will see free H. So, well testing is very important. The micro electro-mechanical systems (MEMS) pressure sensor at the end of the fiber is a good idea. Making a MEMS resonator work inside a geothermal well is very difficult. Many attempts at lower temperatures have failed in the oil industry because the pressure offset reading is lost with time. The distributed pressure system is a needed item for geothermal well monitoring. However, the system must be very robust or well owners will not pay for it. Normally, a robust system eliminates any fiber splices and/or tubing splices. The proposed system has a lot of splices.

Reviewer 23:

Reviewer 50:
A lot of the approach is mundane, e.g., procure pure silica core fibers and metallized and polyimide-coated fibers from multiple vendors. Others seem more challenging, such as developing a reliable high-temperature Bragg grating. Others seem what industry does any, e.g., optical drive/read out of MEMS sensor.

Comments Regarding Accomplishments, Results and Progress
Reviewer 63:
In spite of the lack of well testing, good progress has been made. Effort to stay on topic at 400°C is represented.

Reviewer 23:

Reviewer 50:
The testing program is proceeding apace.

Comments Regarding Project Management/Coordination
Reviewer 63:
Project management/coordination seems reasonable.

Reviewer 23:

Reviewer 50:
This is really a project that is all about management, acting as a general contractor putting the pieces together.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 63:
This is a difficult project to undertake. There will be issues once a system is placed in a geothermal well. The researchers would have benefited from working with experienced fiber systems people from the oil industry.

Reviewer 23:
The project team has effectively demonstrated the grating sensor and has a solid plan to achieve this year's milestones. The reviewer would like to be able to see more details about the various workstreams this year. Time management is also an issue—there were several delays.

Reviewer 50:
The jury is out as to whether or not this testing and packaging of existing fiber and coating will yield sensors up to specification. The next year will tell.

Comments Regarding Strengths
Reviewer 63:
The project has creative concepts.

Reviewer 23:

Reviewer 50: Project management is the main strength.

Comments Regarding Weaknesses
Reviewer 63:
Distributed pressure measurements are weak because each sensor requires two fiber splices and two tubing welds.

Reviewer 23:

Reviewer 50:
This is a development, not a research, project.

Suggestions for Improvement
Reviewer 63:
The reviewer suggests working with a fiber deployment company, even if from the oil industry.

Reviewer 23:

Reviewer 50:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0723
Presentation Title: High-Temperature Motor Windings for Downhole Pumps Used in Geothermal Energy
Investigator: Hooker, Matthew (Composite Technology Development Inc. Production)

Comments Regarding Relevance/Impact of Research
Reviewer 67:
It appears from the results shown in the presentation that the high-temperature wire insulation developed during this project could significantly enhance the performance of downhole pumps.

Reviewer 76:
High-temperature composites for use in windings is needed for enhanced geothermal wells. The reviewer believes the presenter vocalized the background literature well.

Comments Regarding Scientific/Technical Approach
Reviewer 67:
The technical approach taken during this project appears to have produced good results. The only thing that would have made the results stronger is more long-term life testing of the motor winding insulation. The author acknowledged this point and indicated more testing will be undertaken.

Reviewer 76:
The reviewer appreciates the setup and apparatus for tests. He -wishes there was a more significant push to bring this project to commercialization (e.g., additional partners).

Comments Regarding Accomplishments, Results and Progress
Reviewer 67:
The results of this project meet the expectations as explained in the presentation. In addition, motor winding insulation developed through this project may not only enhance the reliability of downhole pumps, but perhaps downhole wiring in general.

Reviewer 76:
Results would have been outstanding if the 30-day results had been visually shared. However, results were impressive for the length of time at temperature.

Comments Regarding Project Management/Coordination
Reviewer 67:
All of the goals of this project were completed in December 2010.

Reviewer 76:
Little was covered in the presentation regarding project management/coordination; however, the company met the timelines of the project and completed its tasks.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 67:

Reviewer 76:
The reviewer believes the technology is pertinent to geothermal. He would have liked to see more results, but appreciates the performance at temperature of the composite.

Comments Regarding Strengths
Reviewer 67:
This project has developed what appears to be a novel material and application process for motor winding insulation capable of operating (for 30-60 days) at 300°C.

Reviewer 76:
The project has shown impressive results against PEEK.

Comments Regarding Weaknesses
Reviewer 67:
A life testing program would have demonstrated the capability of the motor winding material and application process to endure high-temperature operation for longer periods of time. This will be necessary to prove the capability of extended operation in a geothermal environment.

Reviewer 76:
The reviewer would like to see more quantitative data presented.

Suggestions for Improvement
Reviewer 67:
While this project is complete, the high-temperature insulation material and application methodology should be investigated for application to other downhole wiring and interconnect applications.

Reviewer 76:

Innovative Exploration Technology

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1100
Presentation Title: Black Warrior: Sub-soil Gas and Fluid Inclusion Exploration and Slim Well Drilling
Investigator: Casteel, John (Newberry Geothermal Holdings, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
This projects addresses the need for validated exploration methods for blind geothermal systems. If carried out well, it should determine the effectiveness of shallow soil samples for identifying the hydrocarbon signature of a hidden field. This project also has the potential to confirm a moderate-sized geothermal system, and to provide an exploration method that will be used in a large number of areas, especially in the Basin and Range.

Reviewer 9:
If successful, the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increasing the geothermal resource base.

Reviewer 12:

Comments Regarding Scientific/Technical Approach
Reviewer 28:
The use of deeper fluid inclusion data to validate surface measurements is a good idea. Beyond that, the presentation and documentation provide very little technical information about the method, making it difficult to assess the approach. The "fair" rating indicates this lack of information, and does not indicate that I know of flaws in their approach. For example, to design the field sampling, one would like to have a model of the spatial variability of the soil gasses. Would two samples 10 feet apart be expected to have similar results? Questions like that would be important for design of a careful sampling plan. Depending on the spatial correlation of data and the number of points that can be collected, one might sample on a uniform grid, or concentrate measurements in highly promising areas. Was information like that used in the planning? The PI indicated that some geophysical data were previously collected in Pumpernickel Valley, but did not indicate its quality or how it would be used to guide the surface sampling. Slide 4, discusses "statistical and process model methodology." The reviewer does not know what that is. Does it relate to the reviewer‘s concerns about the sampling plan? Another question that was not answered relates to maps. Presumably the results will be plotted on maps. Will the maps just show where specific hydrocarbons were found, or will they be concentrations? If they are concentrations, then the values are probably strongly influenced by the amount of air passing the buried absorber. If that is the case, are they really going to be mapping high flow-zones rather than variations in chemical content? The team should explicitly describe the relationship between "old" fluid inclusion data and "current" shallow soil gasses. Is that a straightforward relationship, or is some kind of modeling required to make the connection? No information was presented that would allow one to assess how well the project team will integrate previously gathered exploration data, and how well they will construct a reservoir model.

Reviewer 9:
Too much depends on the ability to detect the hydrocarbon signature of the hydrothermal system in the shallow gas samples. It would be advisable to also look for other volatile components indicative of hydrothermal activity.

Reviewer 12:

The combined approach to interpret hydrocarbon signatures offers the potential to resolve distribution and target exploration efforts. The hydrocarbon methodology is unspecified. He isotopes are usually applied in magmatically-heated environments. How has this helped in other Basin and Range environments? The account is strong on institutional information but does not specify theory, practice, analytical methods or how results apply.

Comments Regarding Accomplishments, Results and Progress

Reviewer 28:
There has been essentially no expenditures and progress due to permitting issues. The project seems to have dealt with the permitting issues in the best way possible by selecting another site.

Reviewer 9:
There are no accomplishments yet.

Reviewer 12:
The original project site was supposedly an optimum location. What has changed and why is the current selected Pumpernickel Valley site more applicable?

Comments Regarding Project Management/Coordination

Reviewer 28:
Little information is known about the management, as no progress has been made. Overall, the sequence of planned activities makes sense. The permitting issue may not reflect management capability, as the activities were originally thought to be very low impact, and many other projects have been surprised by permitting issues. (The reviewer wonders if these issues would have made drilling impossible at Black Warrior even if the shallow holes had been approved.) The permitting delay has very little impact on the project, as no money was expended (assuming the new site is a good place to do this). The reviewer encourages the PI to become a little more familiar with some of the technical issues. The reviewer would have liked him to have a two-sentence description of why geothermal fields are expected to have a hydrocarbon signature.

Reviewer 9:
After it became clear that the project could not be developed in the originally selected site, they managed to find an alternative site, thus saving the project.

Reviewer 12:
Reasons for dismissing regulatory requirements for this project are vague and unsubstantiated. The DOE funding opportunity announcement (FOA) submittal required that regulatory and environmental permitting must be completed before initiating the project. Best project management should have evaluated and completed this task.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:
This is a focused program to test and validate a low-cost exploration method that could potentially locate blind geothermal systems. Hydrocarbons are often seen in conjunction with thermal features. In this project, soil gas samples are analyzed for hydrocarbons. If appropriate targets are found, then slim holes will provide deeper fluid inclusion samples to be used to validate the method and constrain models that would be used to target a production well allowing the site to be exploited. Progress has been severely limited by permitting issues, and has been moved to a new site where work is just beginning. The reviewer would look forward to hearing of the progress in the next several months and the future validation with data from slim holes.

Reviewer 9:

Reviewer 12:
This is a reasonable attempt to develop another exploration methodology but with limited details and unspecified theory and applications. There have been few accomplishments to date.

Comments Regarding Strengths
Reviewer 28:
The use of deeper fluid inclusion samples should provide valuable constraints needed to determine if the shallow surveys are meaningful.

Reviewer 9:

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 28:
The presentation did not provide much information about the technical aspects of the method, and the presenter acknowledged that colleagues who were not here would need to respond to technical questions.

Reviewer 9:

Reviewer 12:
This project has had poor project planning and permitting issues.

Suggestions for Improvement
Reviewer 28:
The reviewer encourages the team to develop an explicit justification for the design of the surface sampling locations, based on some sense of the spatial coherency of the parameters to be measured and a "back of the envelope" conceptual model of how hydrocarbons might be distributed about a geothermal system.

Reviewer 9:

Reviewer 12:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1101
Presentation Title: Caldwell Ranch Exploration and Confirmation Project
Investigator: Walters, Mark (Geysers Power Company, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
This project will contribute to putting power online, not only at this power plant, but perhaps at others in The Geysers field. The reviewer would rate it as excellent if there was a larger component of technique validation or if the results would impact exploration at other fields as well.

Reviewer 9:
The project will contribute substantially to the goal of increasing the geothermal resource base. However, the reviewer finds the project to be lacking in innovation content.

Reviewer 12:
This project offers new and truly innovative methodologies to analyzing and evaluating the nature and extent of The Geysers geothermal reservoir in a difficult and problematic part of the field.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
The group had the correct capabilities to finish the drilling despite technical difficulties. The measurements are all relevant, and should provide information that is relevant to the goal of putting this area back online. However, it was not clear what the significance of the data on Slide 7 is. Why are there no changes in the one well that was not deepened? The PI alluded to temperature measurements indicating conductive transport rather than convective transport. Does that change how the shut-in data might be interpreted? A minor point: the reviewer could not tell if the cores were collected and preserved in a manner that was appropriate for the measurements to be made, especially those by Dr. Bonner, which were not described.

Reviewer 9:

Reviewer 12:
The project team has accomplished all goals to date with the ultimate goal of well testing within reach.

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
The project is on time and within budget.

Reviewer 9:
The project has made important advances and can already be called successful.

Reviewer 12:
Beyond interesting research, the project actually offers the possibility of adding megawatts (MW) to The Geysers' output.

Comments Regarding Project Management/Coordination
Reviewer 28:
Management has kept this project moving toward its goal. Their major coordination appears to be with the nearby

enhanced geothermal systems (EGS) project, although the details of that collaboration are not clear. Staff from Lawrence Berkeley National Laboratory (LBNL) are providing research from other DOE funds. Have they been involved in the planning in any way? There are no remaining decision points in the project, so the primary management task is to make sure that the collected data are integrated into a conceptual (or mathematical) model of what has happened in this area since production. How is this work coordinated with the EGS project? Would the measurement program have been even better if a group of experts/collaborators acted as an advisory panel to the project?

Reviewer 9:
Project management has been excellent.

Reviewer 12:
Phases have been completed apparently as planned. Cost overruns were made up through the operator but reasons were not accounted for.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 28:
The purpose of this project is to determine the current conditions in a "previously depleted" portion of The Geysers, with the intent of bringing about 20 MW of energy on-line from it. The new information will come from measurements in and on samples from wells that are newly deepened. The planned measurements are the current state of practice, and will provide new information about the reservoir and its response to wastewater injection. This work will support Calpine's plans to increase production from the NW Geysers, and may provide information that is of wider use within the whole geothermal field.

Reviewer 9:

Reviewer 12:
This is the most relevant project reviewed to date.

Comments Regarding Strengths
Reviewer 28:
This is a focused project that has moved towards completion on schedule, despite "typical" drilling problems. Calpine obviously has a lot of experience in The Geysers, and is using this project effectively toward increasing production from this large and important resource. They are performing measurements and tests that have proven useful in the past, and will incorporate this information into their current reservoir model, which is based on a lot of sub-surface knowledge. The access to slotted liners in the production zone should lead to a more complete understanding of heat transport within the production zones. By collecting core, they will have access to information about the physical and chemical properties of the reservoir rock, and are getting measurements done by two experienced groups, Terra-Tek (under contract) and Dr. Bonner (no-cost collaboration).

Reviewer 9:

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 28:
The measurements being made will not define new methods that could be used at a variety of sites. However, specific

knowledge at The Geysers could have a large impact because of the size of the system and the large amount of power it produces.

Reviewer 9:

Reviewer 12:

Suggestions for Improvement
Reviewer 28:
It is not obvious what has been learned from the changes in chemical data seen in Figure 7. The slide says "pressures have increased [with time]" but the only wells with changes are the two that were actually deepened. The reviewer encourages the author to be very explicit about the modeling used to interpret data like this, and to consider alternative hypotheses such as "changes with time" versus "changes with depth."

Reviewer 9:

Reviewer 12:
DOE funding opportunity announcement (FOA) proposals required a project management plan and timeline when submitted. It would be useful to include that time/budget line graphic with notations of planned vs. actual accomplishments.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1102
Presentation Title: Innovative exploration techniques for geothermal assessment at Jemez Pueblo, New Mexico
Investigator: Kaufman, Greg (Pueblo of Jemez)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
This is a good plan that will lead to a determination of the geothermal potential of the Jemez Pueblo area. The specific information learned may not apply to other potential geothermal areas, but this will provide a well-documented case study of value to other exploration efforts. If it is carefully validated, the seismic decomposition into horizontally moving waves may be used in many other fields with steeply dipping faults.

Reviewer 40:
The primary knowledge gap to be addressed is the innovative use of advanced seismic imaging technologies to attempt to image high-angle faults. If the effort is successful, it might have an impact on resolving faults near geothermal prospects worldwide and improving drilling success rate. It also might pave the way for more geothermal projects in New Mexico.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
The scientific approach is comprehensive and is being energetically pursued. I cannot evaluate how good the new models are, or the appropriateness of the decision to drill east of the Indian Springs Fault, as these were derived from a lot of data that was not presented. However, there is a strong technical team reviewing this decision. To date, the only innovative method involves decomposition of signals from a seismic survey into horizontally-travelling waves in order to illuminate near-vertical faults. The speaker implied that they had some skepticism about the inferences from that method, and they plan a numerical validation/verification experiment to evaluate this method. The reviewer encourages them to evaluate what happens to these signals as the S/N level decreases. In his talk and in response to questions, the Technical Program Leader demonstrated a broad understanding of the entire project, a healthy skepticism about the certainty of the results, and a level of enthusiasm and openness that will most certainly keep the project moving forward with lots of people engaged in it.

Reviewer 40:
Mapping has been performed using a variety of methods (MT, seismic, mapping, and mapping). This project has a thorough and comprehensive approach. Some 2D seismic have been shot. Standard processing and a new imaging algorithm to identify high-angle faults have been applied. It appears that discrepancies exist between the two methods although the standard processing showed pretty good results and clear faults. It is not clear how the new techniques will be verified. Passive seismic monitoring is in response to stakeholders rather than exploration. Evidently the depth of the reservoir was shifted downwards as a result of the exploration but this was not explained well.

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
The project seems to be right on target.

Reviewer 40:
Mapping has been completed, so the project is on schedule. Additional work (seismic monitoring) was added in response to stakeholders. A comment was made about a 9-month delay and shift to a two-year plan. Drilling will be to 5,000 feet rather than 3,000 feet; this may impact the budget but contingency plans have been made.

Comments Regarding Project Management/Coordination

Reviewer 28:

Between the PI and the Technical Project Leader, there is a comprehensive understanding of all aspects of this project. The PI described the project succinctly and usefully. The technical team appears to be communicating well, and the project has clear decision points. The reviewer likes the way data are put on line, and the fact that they have a project Wiki so that all members can easily stay up-to-date and comment on others' work. The reviewer hopes that they have enough funding to complete the drilling, which is now known to be to a deeper depth than was anticipated.

Reviewer 40:

Management and coordination seems to be handled well but with some problems. Management shows flexibility to handle the seismic monitoring and to handle the extra drilling.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:

A large, strong technical team is carrying out integrated state-of-practice exploration (with one innovative method) to site a slim hole that may eventually lead to drilling a production well into a new small-to-medium resource. They have developed an updated geological model of the area (which cannot be evaluated by this reviewer), and are using it to decide on the location of a slim-hole test well. Additional measurements (both conventional and innovative) will be made in the slim well, and then a decision will be made about drilling the final hole. It is very likely that this effort will produce the first accurate characterization of this system, which lies under the outflow plume of the Valles Caldera, and there is a good chance they will identify an exploitable resource.

Reviewer 40:

The project has made good progress despite some minor problems. The results of exploration are not explained well and hence it is difficult to tell if moving forward is advisable.

Comments Regarding Strengths

Reviewer 28:

The project has a strong technical team, who are paid and are therefore committed to the success of the project. Data is made available to others freely. The PI and technical leader have comprehensive understanding of the project, coupled with enthusiasm that will keep it moving forward.

Reviewer 40:

The project is nominally on schedule despite problems and implementation of the seismic network. Good response to stakeholders.

Comments Regarding Weaknesses

Reviewer 28:

None noted.

Reviewer 40:

The geologic model seemed weak as it appeared that the cross-section had weaknesses (a thrust fault at depth changing to no offset at shallow depth which is surprising given the setting). The standard seismic processing yielded good results and it is not clear why there was an apparent discrepancy between the new methods and the standard ones. Simple balanced cross-sections (e.g. Midland Valley software) would likely work well in this area to further validate the model before drilling.

Suggestions for Improvement

Reviewer 28:

None noted, provided there are comprehensive tests of the validity of the innovative technologies. (Question: have they discussed redirecting funding from any part of the project into drilling?)

Reviewer 40:

The rationale for the change in depth from 3,000 to 5,000 feet was not clear from the presentation. The reviewer suggests trying a balanced cross-section to test the model; this may (or may not) illustrate problems.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1103
Presentation Title: Detachment faulting and Geothermal Resources - An Innovative Integrated Geological and Geophysical Investigation in Fish Lake Valley, Nevada
Investigator: Stockli, Daniel (University of Kansas Center for Research, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
If successful, this project will demonstrate and document a technique that could be added to the arsenal of exploration methods, and that gives unique information about uplift and circulation histories. If this method proves to be valuable, it could be used throughout the Basin and Range, and perhaps in other geothermal environments. In addition, if well siting is successful, it might add to the confirmed resources in the area.

Reviewer 9:
If successful, the project will contribute to both objectives of the Innovative Exploration Technology program; it will develop/test innovative technologies and it will contribute to increasing the geothermal resource base.

Reviewer 12:
This project's integrated methodology is relevant to other exploration areas.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
Evaluating thermochonometry is an important aspect of this project. The PI is an expert in that field, and those measurements will be well done. The presentation indicates these measurements will be used to constrain the time history of the 3D model, but there is no explicit discussion of how the value of the measurements will be determined. The reviewer encourages the PI to explicitly consider how the contribution of the measurements to the model will be demonstrated and evaluated. A lot of data have been collected in a fairly short time, and the data are currently being integrated. The examples of data shown suggest that a lot will be learned. There was not much information about the expertise of the others who planned and interpreted other datasets. For example, the seismic survey was a somewhat unusual mix of reflection and refraction. Given no information about the rationale for the choices made, the reviewer can't evaluate this approach. Also, it is not clear that there is an individual (or group) that is making certain that all the disparate methods are collected with a coordinated strategy that will maximize their value. Similarly, it is not clear who is taking responsibility for interpretation and integration of the data. For example, the information that an excel spread sheet is being used for gravity processing does not convince the reviewer that someone with gravity experience is doing it! Is there much value to resistivity data that can only be interpreted down 100 meters?

Reviewer 9:

Reviewer 12:
Integrating data sets is a common, rather than innovative, practice. The term ―detachment faulting" is mentioned in the title and does not appear anywhere else in the narrative. Other than assuming that the reader understands that one exists in the nearby Silver Peak Range, what exactly is being evaluated about detachment faults?

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
A lot of data have been collected in a short time, and the examples presented suggest that a lot will be learned. There is no indication of the money spent to date, so the reviewer cannot assess how this effort relates to the resources expended.

Reviewer 9:

Reviewer 12:
The results are unjustified by the timeline. All DOE funding opportunity announcement (FOA) proposals required a timeline for accomplishing the planned work phases. That timeline and the current project status relative to planned/actual accomplishment would be a minimum aid in evaluating the project.

Comments Regarding Project Management/Coordination
Reviewer 28:
The presentation did not indicate how decisions are made about the allocation of resources to different techniques, nor did it indicate who will be responsible for the integration of these results into a model of the Basin and its history. How will that be managed and what mechanism is there for reviewing the model? The PI did manage the delays due to contracting well, and has gathered a lot of data despite that problem. Plans to let the operator control the drill portion of the project are good. The PI's enthusiasm will probably compensate for some of the perceived management weaknesses. The reviewer has one question, because he does not know how long the mass spectrometry measurements take and how much time is involved in their interpretation. Will thermochronometry measurements be completed and integrated into the model in time for the July 2011 decision point?

Reviewer 9:

Reviewer 12:
What are the results? What are the planned vs. actual results? The project site/area has shifted but much of the summary statement still deals with the original site. The report dates extend through the January 2011 seismic shot hole/thermal probe holes. Where are these data?

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:
Accurate structural and thermal models are valuable for geothermal exploration and exploitation. This project plans to produce such a model for a Basin and Range geothermal prospect, and augment it with (U-Th)/He thermochronometry to constrain the time-histories of uplift and hydrothermal circulation. This model will be used to site a slim-hole exploration well, and, perhaps eventually, production wells resulting in a new proven geothermal resource. The PI and his students have a number of publications using the thermochronometry method. Exploration data have been collected in the target area and are being analyzed. Thermal gradient measurements indicate a geothermal anomaly. Samples have been collected and an inductively coupled plasma mass spectroscopy (ICP-MS) system has been obtained to analyze them. The model is expected to be ready in a few months, and will be used to decide where a slim hole should be sited and if it should be drilled.

Reviewer 9:

Reviewer 12:
Financing research is commendable but where are the results? The accomplishments section includes four bulleted sections noting that the "single biggest achievement" is the acquisition of a high-resolution ICP-MS. This is an enabling step, not an accomplishment.

Comments Regarding Strengths

Reviewer 28:
The PI has a track record with the innovative method, and the method will provide geologic time history information that is not normally available to geothermal operators, and that could put valuable constraints on models. Transfer of leadership to the operating company when drilling starts is a good idea. Dual use of drill holes for temperature measurement and explosives is proving very useful.

Reviewer 9:

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 28:
The PI is moving to a new university. It is not clear how this will impact the project, specifically regarding the availability of graduate students and the use of the ICP-MS system. DOE should monitor and manage this change, so that the impact is minimized. Another long contracting delay would hurt the project. The model will be based on a range of techniques—geophysical, geological and thermochronometric. This is a good thing. However, it is not clear from the presentation who has the overview of these results and is ultimately responsible for the model. Is the operator the driver of the model, or is the PI? The PI says that there is not much apatite in many of the rock samples. How will this limit the thermochronometric evaluation? Could that have been known before the site selection was made?

Reviewer 9:

Reviewer 12:
Justify why this is "...one of the Nation's arguably most promising high-temperature geothermal targets."

Suggestions for Improvement
Reviewer 28:
Evaluation of the innovative technique is an important aspect of this project. The reviewer encourages the PI to explicitly discuss the costs and benefits of the method. How much did it influence the model and the drilling decisions? How will the method be available to others after completion of the project?

Reviewer 9:

Reviewer 12:
1. Determine what can be reasonably accomplished given transitions in project goals and personnel. 2. Reevaluate the timeline and project goals. Stating future plans of "Completion of all analytical work and geophysical data processing" provides no time/budget/personnel basis for deciding on progress or continued funding.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1104
Presentation Title: Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada
Investigator: Zehner, Rick (Geothermal Technical Partners, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
The project has two elements. The presentation focused on one, testing an innovative technique; the other, possibly identifying a new geothermal resource, may be more important. The project plans to demonstrate the effectiveness of shallow-temperature measurements in early geothermal exploration. The 2-meter (2-m) probe tests will have limited impact as that method has been used for over 30 years, and recent realization that it might be very relatively more accurate in Basin and Range conditions, as well as improvements and examples, have been published for a number of sites. This project will more carefully evaluate the cost savings, and provide better sub-surface confirmation for that method. The hydroprobe method of evaluation is more innovative, and could lead to additional use of the method if it is successful. Because this might be a more complete case study of the shallow methods than earlier publications, and because it includes testing of a possible resource, the reviewer is rating this as good (but just barely!).

Reviewer 9:
If successful the project will contribute to both objectives of the Innovative Exploration Technology program; it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Reviewer 12:
Determining the cost-effectiveness of 2-m surveys and staged exploration programs is particularly relevant given the broad pronouncements about the efficacy of the methodology.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
The PI has a conceptual model, and is planning a phased sequence of temperature measurements at increasing depth to try to determine where to drill based on that model. That is a good strategy. However, several aspects of the work to date suggest that the PI is not considering the factors that limit the ability of shallow probes to determine meaningful temperatures in the field. Consequently, he draws conclusions about the efficacy of the different methods without evaluating what they can and cannot detect because of the impact of non-geothermal phenomena on shallow temperatures. These issues as they apply to Basin and Range exploration are discussed in detail in a GRC paper: "Compensation for Seasonal and Surface Affects [sic] of Shallow (Two-Meter) Temperature Measurements," Mark F. Coolbaugh, Chris Sladek, and Christopher Kratt, GRC Transactions, Vol 34. The PI cites this paper, but it does not appear that these issues are being considered in this project. Here are examples of the reviewer's concern: 1. The PI states that the 2m depth is "below the zone of most solar thermal variation." He is correct if he refers to the daily variation, but the annual variation could easily by +/- 5 degrees, and the difference between simultaneous measurements could be 4 to 6 degrees due to albedo, slope and diffusivity differences. When asked about uncertainties, the PI said measurement uncertainty was about 0.5 degrees, and did not allude to other issues. 2. The PI plots temperature measurements made at a range of depths from 2 meters (m) to 15 m and compares them directly and says they are consistent. That comparison might make sense right at a steam outflow zone, where temperatures might be isothermal with depth, but the comparison is not useful in areas of conductive vertical heat flow, like above the outflow zone. 3. The PI states that the 2-m probe did not detect an outflow zone, suggesting that result occurs because of "thermal masking by cold groundwater or opalitization." In fact, the resolution of the method is poor enough that a substantial outflow could exist and not be seen. If the temperature uncertainty due to diffusivity is 1 degree at 2 m depth, corresponding to a gradient of 500 degrees per km, a 250°C plume

could exist at 500 m and not be detectable. Temperature measurements shown on Slide 14 near the Hole M&B 10 site where the gradient is perhaps 70°C/147 m support this contention, as they are similar to the mid-basin temperatures. 4. Was an effort made to avoid periods of rain during the 2-m probe collection? The reviewer assumes that was easy in Nevada! The author identifies the low cost of 2-m probes. The reviewer encourages the author to be explicit about the uncertainty caused by non-geothermal factors when he assesses the value of the 2-m probes. The reviewer thinks he will decide that the 2-m probe measurements are good for locating the "steam-heated zone" shown on his Slide No. 9, but that more accurate measurements are needed downhill from there to find drilling targets. A similar analysis must be done to estimate the uncertainties in the Hydroprobe temperature measurements. The next step is to drill 200-m TG holes. The reviewer is surprised there are no TG holes in the hanging wall adjacent to the hottest area along the range front. Based on Slide 11, that is where the ultimate target is expected to be.

Reviewer 9:

Reviewer 12:
Existing TGH data (not presented) has the potential to evaluate the 2-m results without additional drilling. Existing TGH sites are not even plotted on isotherm maps but apparent "high temperatures" correspond to TGH sites selected several decades earlier without benefit of 2-m or direct push data. How then are these methods improving exploration technology?

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
The project is moving ahead at a reasonable schedule. A lot of data has been obtained and examined.

Reviewer 9:

Reviewer 12:
The project is 20% complete. TGH MT confirmation drilling is still pending.

Comments Regarding Project Management/Coordination
Reviewer 28:
The project is a one- to two-person effort, making management simple. The PI has obtained data from other sources, and modified plans to include additional measurements (MT) because of them, increasing the value of the effort. The reviewer cannot assess whether the permitting issues will delay the project further than indicated. More data needs to be collected before decision point is reached.

Reviewer 9:

Reviewer 12:

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:
This focus of this program is on evaluating cost-effective early-stage thermal exploration methods that can improve exploration techniques. Two methods are involved. The first is shallow 2-m temperature holes, an old method that has generated some new interest recently, and may be especially well-suited to exploration in arid alluvial deposits as are seen in the Basin and Range. The second is intermediate-depth temperature holes using an inexpensive, direct-push technology to get measurements at up to 50 m depth, but, in practice, much shallower, because of the cobble nature of alluvial fans.

The data have been collected and presented, and the techniques will be evaluated by drilling a few deeper thermal gradient holes. Based on all this data, if a target is identified, two slim holes will be drilled to confirm it and add to the known resource base for geothermal systems.

Reviewer 9:

Reviewer 12:
The project is 20% complete. Existing TGH data could confirm utility of the methodology but was not presented. In combination with other DOE-funded projects, this exploration program offers the opportunity to again evaluate the effectiveness of shallow temperature probe holes. The sooner this can be done, the better.

Comments Regarding Strengths
Reviewer 28:
Strengths include adding Dave Blackwell to help interpret the thermal data.

Reviewer 9:

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 28:
The PI gives the impression that he is not aware of the limitations of the 2-m probe method due to uncertainties caused by factors such as albedo and diffusivity influences on the annual temperature variations at 2 m depth. See comments under technical issues. The reviewer is concerned that data is focused on "steam outflow zone". How will drilling be directed toward a target that is to the right of this zone in the conceptual model slides? Would examining case studies from other similar Basin and Range Systems help with the siting?

Reviewer 9:

Reviewer 12:
No interim evaluation was made of the validity of the 2-m probe methodology. Older TGH data is reportedly available for comparison but not provided in either the written summary or presentation. Project continuation is dependent on funding that is not currently available.

Suggestions for Improvement
Reviewer 28:
The reviewer suggests incorporating more knowledge of the limitations of shallow probe temperature measurements into interpretation. Be aware of what cannot be measured with this technique. Don't just plot temperatures on a map, particularly if they come from different depths. The data collected to date put some limits on the depth and temperature an outflow zone. Don't just say "didn't see one." Say "if it is 100°C it has to be deeper than ____ m." The reviewer thinks that getting Dave Blackwell involved would be a large help here. Can the PI state before he collects the TG data how he will compare them to the 2-m probe data? Will he calculate gradients from the 2-m probe? Will he cross-plot 2 m depth vs. temperature gradient and look for a correlation? How will he do this if the temperature-depth results in the TG holes are curved? Would this program benefit from a review committee that could help with the geologic model and well siting as it moves to the next phase?

Reviewer 9:

Reviewer 12:
1. Determine whether this project is worth pursuing. 2. If so, determine what can be reasonably accomplished given limitations in matching funding. 3. Reevaluate the timeline and project goals. State a time/budget/personnel basis for deciding on progress or continued funding.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1105
Presentation Title: Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss
Investigator: Lear, John (El Paso County)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
This project has fair to good relevance/impact of research. This project could lead to a small increase in geothermal capacity, and it might encourage additional exploration in similar environment at other sites, if they exist. In addition, a demonstration of the efficacy of helicopter-based thermal gradient drilling could demonstrate a technique that will provide greater access to thermal gradient data. The presentation (but not the project summary) also indicates that chemostratigraphy is an innovative method being tested. In the United States there is not much exploration for geothermal in limestone environments, so the reviewer cannot assess the impact of developing new approaches to chemostratigraphy on geothermal exploration.

Reviewer 9:
The project will contribute to the goal of increasing the geothermal resource base.

Reviewer 12:
Low-temperature resource exploration is of limited relevance.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
This project is good to fair regarding scientific/technical approach. The overall scientific approach does not seem to be guided by a model of the target. The PI did not communicate why the particular measurements were chosen and what questions they might answer about the drilling target. A "cartoon" model was presented, but no indication was given as to what data constrained it or what was learned from the measurements to date. On the other hand, the team has been careful about uncovering previous work before inadvertently duplicating efforts, and that has paid off. There appear to be plans to use a lot of information from the wells to be drilled, which is good. The temperature data look pretty extensive and appear to define targets, although in areas with lateral flow, the hottest locations may not be below the near-surface thermal anomaly. It is not clear to the reviewer at this time what innovative methods will be applied to cuttings from the drillholes. The EGI collaborators will be in charge of that, and they have a good track record for learning from samples.

Reviewer 9:

Reviewer 12:
Where is the innovation? Literature search, field surveys and remote sensing are very common practice in any diligent exploration program and have been the hallmarks of geothermal exploration for more than six decades.

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
This project has made significant progress towards the Phase I goals, has located previously-drilled slimholes that reduce their anticipated drilling costs, and has identified a site for a production-sized well. Costs to date have been high, about $2M before any drilling, including thermal gradient wells. Based on the information the reviewer has, it is difficult to identify what that money was spent on. Most of the data reported is from previous work—only the DEM analysis and the ASTER data are newly collected. Without more information about what has been done, the reviewer considers the progress on this project adequate for the resources expended.

Reviewer 9:
The project has made important advances, due in good measure to the thoroughness shown in the task of recovering and analyzing preexisting information.

Reviewer 12:
The project team has conducted rapid evaluation of previously unknown data identified through diligent record review and field surveys.

Comments Regarding Project Management/Coordination
Reviewer 28:
This project is good to fair regarding project management/coordination. The project spent effort to identify previous work in the area, and uncovered a lot of useful information that moved the project ahead. The project has had some difficulties with collaborators moving to new companies and having to be replaced—it is not yet clear if that will have any impact on the project. The PI did not have a strong grasp of all the technical elements of the project. It might be useful to specify the group of people who are responsible for compiling models and integrating them into the decision process.

Reviewer 9:
Project management has been excellent.

Reviewer 12:
The project is ahead of schedule. Timeline reporting and milestones have been noted.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:
This project is testing two innovative exploration methods, helicopter-transported drilling for thermal gradient holes and chemical- and chrono-stratigraphy to evaluate a low-temperature resource in an under-utilized geothermal environment. The project budgeted a fairly high amount of money for the initial exploration phase, and has collected data as well as learning that slim holes were available for testing. The scope of work has been modified based on these discoveries, and the project is proceeding towards the testing of slim holes. Neither innovative exploration method has been applied to date.

Reviewer 9:

Reviewer 12:
Project reporting is slim on results and detail. For example, data from newly rediscovered slim holes are cursory or incomplete. Critical interpretive information such as well stratigraphy, downhole temperature surveys, water levels, temperature/depth profiles, conductivity/heat flow determinations in various lithologies are provided to allow evaluation of whether the interpreted isotherms are valid and how local/regional hydrology might be affecting temperature distribution. Proposing a conceptual model is important but detailing how that model was derived is equally important.

Comments Regarding Strengths
Reviewer 28:
None noted.

Reviewer 9:

Reviewer 12:

Comments Regarding Weaknesses

Reviewer 28:

Based on web searches, it is not clear what the current status is for Aerospect, LLC, the provider of the Heli-Lite drilling system that is being tested. The company does not have a web page that the reviewer could find, and listed collaborator, Mark Burdge, is currently with another company. The reviewer encourages the PI to clarify to DOE who is currently involved with the project.

Reviewer 9:

Reviewer 12:

"Interpretation of faults in unmapped terrain..." based on remote sensing data alone is a dubious practice and without field confirmation or additional geophysics remains speculative. Extrapolating shallow (233 ft) temperatures is dubious based on the long history of exploration disappointments within the Great Basin and Rio Grande Rift. No justification is provided for determining "...that flows of at least 2,000-3,000 GPM were likely..." or to define what the term "likely" means. Projected generation of 2-6 MW of electrical generation potential is unjustified and unsubstantiated by any information on generation technology for a low-temperature resource.

Suggestions for Improvement

Reviewer 28:

The reviewer hopes the Heli-Lite tests are documented well so that others can assess the costs and efficacy of this approach. Be more explicit about who has the responsibility for integrating the data into a model that informs decisions in the project.

Reviewer 9:

Reviewer 12:

More detail required to fill abundant data gaps.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1106
Presentation Title: New River Geothermal Research Project, Imperial County, CA
Investigator: Johnson, Stuart (Ram Power, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
The reviewer rates this project between good and excellent regarding relevance/impact of research. Exploration approach is not innovative, but it will illustrate the value of a conceptual model. Data will be shared and the application here and at other parts of the Imperial Valley could lead to a significant increase in known geothermal capacity.

Reviewer 40:
Potential exists for impact and testing of multiple geophysical methods for geothermal prospects in layered sedimentary rocks. A successful find in this area, which is rich in geothermal, would lead to production.

Reviewer 9:
If successful, the project will contribute to the goal of increasing the geothermal resource base.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
Overall approach is sound, and the pull-apart model should be a good basis for interpreting data. The reviewer cannot evaluate the quality of the data collection or of its interpretation. Two questions: Red line in seismic section is not based on much—what is its significance? Is the gravity interpretation based on an assumption of uniform density in the section? Other Imperial Valley systems have densification around them. If this one does not, then it might indicate there are more fields in the valley than were previously thought.

Reviewer 40:
This project has a clear, well-defined plan with a developed model. The objective is to develop a comprehensive model using all data; it is not too clear how the model will be developed. Basically, standard techniques were merged together to yield a 3D model. The level of innovation is relatively low but the quality of work appears high.

Reviewer 9:

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
The project team collected data efficiently and is moving toward a decision point.

Reviewer 40:
Productivity, in terms of DOE funds expended, is very good. The progress is fair to good towards target objectives.. Data from a wide range of surveys was collected but no clear model was presented or interpreted yet.

Reviewer 9:

Comments Regarding Project Management/Coordination
Reviewer 28:
This is a pretty focused program with few players, and therefore few management problems. The presenters are not explicit about how decisions will be made, but are moving toward the decision in a well-organized manner. Some type of

review panel or technical consultation might improve the model being developed.

Reviewer 40:
Mention is made of how two other DOE grants (Alum and Silver) will be linked. As the other two areas are spatially distant from the New River, it is not clear how this will be done other than financially.

Reviewer 9:

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:
The purpose of this project is to utilize up-to-date exploration methods coupled with a conceptual model to site wells at a new location in the Imperial Valley. The project will site and drill and test wells to confirm a moderate-sized resource. Experience gained integrating data into a 3D conceptually driven model will apply to other sites in the Imperial Valley, an area with a large resource.

Reviewer 40:
It would seem that at this stage an evaluation of the potential and review of the results of the exploration could be provided.

Reviewer 9:

Comments Regarding Strengths
Reviewer 28:
Although the innovation is only incremental, the project is in an area with a lot of data and a number of fields tied to "pull-apart" features, which are an important aspect of the conceptual model used to design and interpret the data. The developer is committed to move all the way to power production at this site, and the information gained will help development at other sites. The project team has progressed through the data collection phase quickly.

Reviewer 40:
The project has a well-organized and clear plan.

Reviewer 9:

Comments Regarding Weaknesses
Reviewer 28:
It is not clear who is involved in assembling the 3D model and how decisions will be made. Although the PI has a good track record at understanding geothermal systems, it might be better to have a broader team review the model development.

Reviewer 40:
Given that permitting is still underway, will the schedule hold up?

Reviewer 9:

Suggestions for Improvement
Reviewer 28:

The reviewer suggest evaluating whether unmodeled density variations in the sediments might be adding error to the gravity interpretation.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1107
Presentation Title: Away from the Range Front: Intra-basin Geothermal Exploration
Investigator: Spinks, Karl (GeoGlobal Energy LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 28:
This project may add to known geothermal capacity and innovative methods may help in other Basin and Range areas.

Reviewer 40:
Some innovative techniques—over-coring, global positioning system (GPS), light detection and ranging (LIDAR)—are being applied in a novel setting. If successful, this could prove to be a new geothermal setting for Basin and Range.

Reviewer 9:
If successful, the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Comments Regarding Scientific/Technical Approach
Reviewer 28:
The approach seems sound, and technical issues are well defined in a one-slide summary. The technical capabilities to measure current deformation are relatively new, and there is much to learn about their value in exploration. This project will help with that learning. Beyond that, there is not much to judge on yet. The reviewer cannot tell if "model" is a conceptual description or a rock mechanical calculation where observations can be quantitatively evaluated. One element is the collection of "push cores" to 100 feet depth. Others have had limited penetration with push-cores because of cobbles and other material inhomogeneities. It would be interesting to know if that is less of a problem when exploring far from the range-front alluvial fans.

Reviewer 40:
In general, while a variety of techniques are being applied, it is not clear how useful they will be in defining an actual target. LIDAR seemed to work well but interpretation in terms of geology may be tricky. GPS rates will likely be small and non-unique in interpretation.

Reviewer 9:

Comments Regarding Accomplishments, Results and Progress
Reviewer 28:
There is not much to report yet, although progress has been limited by funding and permitting issues. Things should start moving fast now that some of these barriers are removed. Until then, the progress cannot be evaluated meaningfully.

Reviewer 40:
Given the short time span of funding, the results so far are reasonable.

Reviewer 9:

Comments Regarding Project Management/Coordination

Reviewer 28:

The reviewer rates this project between fair and good regarding project management/coordination. Delays could indicate concerns about the management, but they may have been outside the control of the management. However, some questions remain. How will the model be developed? Will there be a way to incorporate the talents of the technical team into that, or will data be handed to the PI who will do the integration? Why were environmental issues not included in the initial proposal? Was the project delayed by changes at GeoGlobal Energy (GGE)? Whatever the answers, the management will be easier to evaluate as the project gets moving.

Reviewer 40:

The lack of adequate time and budget for the environmental assessment is a bit disturbing as this should have been foreseeable. Otherwise, project management/coordination seems adequate.

Reviewer 9:

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 28:

The project will integrate contemporary deformation measurements with LIDAR, a few stress measurements and shallow thermal measurements to locate favorably oriented fractures away from the range front in a Basin and Range site. Identified targets will be drilled with two slim holes and tested. Successful tests will verify additional geothermal capacity, and, if the methods turn out to be useful, will improve exploration technologies for blind Basin and Range systems.

Reviewer 40:

The project seems to be high-risk. Given that the low-temperature area was previously outlined, the reviewer would guess that not much more will be learned until (if) a slimhole core is drilled. It would be very useful to obtain oil industry data (seismic and well logs) from nearby recent wells.

Reviewer 9:

Comments Regarding Strengths

Reviewer 28:

The techniques have appeared promising in some other studies, and could be useful for a large number of other sites. Testing models based on deformation data with slim holes is a good plan. The project has a team of academics and consultants who will provide a broad range of input into the developed model.

Reviewer 40:

This is an innovative use of new techniques in a challenging area.

Reviewer 9:

Comments Regarding Weaknesses

Reviewer 28:

the project is having trouble getting started, in part due to contracting issues. It is not known if permitting of deeper wells will be a problem.

Reviewer 40:
Not sure how well GPS and coring will resolve the strain field.

Reviewer 9:

Suggestions for Improvement

Reviewer 28:
None noted.

Reviewer 40:
The reviewer suggests trying to obtain oil company data as a priority. Of course, this may be difficult with the existing budget.

Reviewer 9:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1108
Presentation Title: Merging high resolution geophysical and geochemical surveys to reduce exploration risk at Glass Buttes, Oregon
Investigator: Walsh, Patrick (ORMAT Nevada Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 60:
Glass Buttes is a region of high potential to help the DOE Geothermal Technologies Program (GTP) address the goal of identifying 400MW of new resources. The project is relevant and up-to-date by including historical data (well gradient T's) and modern remote sensing and geophysical tools in cutting edge visualization software to provide 3D integrated views for resource interpretation.

Reviewer 28:
This project should provide a valuable case study of an underutilized geothermal environment, and may increase the available tools for studying that environment. If successful, it will lead to increased geothermal capacity.

Reviewer 9:
If successful, the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Comments Regarding Scientific/Technical Approach
Reviewer 60:
This project has a strong combination of techniques whose integration will likely yield the best possible synthesis to inform selection of potential drill sites. The team has an excellent history in similar types of analysis in other locations.

Reviewer 28:
This project is fair to good regarding scientific/technical approach. It is a good idea to collect a broad range of data, and to use a 3D model to integrate them in order to make drilling decisions. The presentation could be clearer about how these methods will be used to "define fault[s] with likely permeability." Is the working hypothesis that surface alteration will identify target faults that can be traced into the sub-surface with other methods? If so, state it clearly. The presentation also does not provide much indication of how these innovative methods are being tested. For example, the summary indicates that cost is one barrier to the use of these methods. The data collection and interpretation has cost about $500K to date. Is that too high a number for general use of these methods?

Reviewer 9:

Comments Regarding Accomplishments, Results and Progress
Reviewer 60:
Data are still in the process of being integrated and during the presentation hurdles involved with importing some types of data were noted. Historical data that are only written records are more difficult to integrate, but they also inform the selection of drill sites. Seventeen targets have been identified using preliminary analysis and were submitted for permitting of either slim or production wells. Permitting hurdles (submitted December 2009) have delayed implementation.

Reviewer 28:
This project has had good progress to date. It would be interesting to see the Phase I report in order to really evaluate the

progress.
Reviewer 9:

Comments Regarding Project Management/Coordination
Reviewer 60:
Management appears to be effective; contracting for data occurred and data sets have been acquired. Shared use of LeapFrog among several projects is cost-effective. It was smart to permit either slim- or production-size holes at each site—this may cause more up-front permitting delay, but given the desire for an eventual commercial development this knowledge early on will prevent future permitting issues from prohibiting development.

Reviewer 28:
Management is focused and is accomplishing things.

Reviewer 9:

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 60:
the project has a good approach and the presenter has a clear sense of goals and outcomes. Methods are sound, and the integration of multiple data sets and tools to do so are likely to benefit others. Individual approaches may not be novel, but application in a new location is important and crucial to identifying new resources. Permitting has delayed implementation, but this is true of all these projects. Use of LIDAR is to be commended; this new tool is proving to be exceptionally useful in identifying small structures that contribute to fluid pathways.

Reviewer 28:
This project is collecting and integrating a number of types of data to guide exploration and production drilling in an area of silicic volcanism in central Oregon. The methods include traditional geologic and geophysical methods as well as LIDAR and Hyperspectral imaging for petrology and alteration assemblages. The PI argues that these methods, presumably the latter two, have not been applied because they of "High costs and unknown applicability." A published case study of the use of the non-traditional methods would increase the exploration capabilities of others in this silicic environment.

Reviewer 9:

Comments Regarding Strengths
Reviewer 60:

Reviewer 28:
The PI's company has experience with the innovative methods.

Reviewer 9:

Comments Regarding Weaknesses
Reviewer 60:

Reviewer 28:
Data were presented for the traditional geological and geophysical data, but no information was presented bout the most

expensive and innovative method, hyperspectral imaging. Is that because the method is still in progress, or was it unsuccessful?

Reviewer 9:

Suggestions for Improvement

Reviewer 60:

Reviewer 28:

The reviewer would like some clarification on what they are looking for with the data that would influence their decision to go ahead with drilling. The reviewer presumes this is in the Phase I report, which is about to be released.

Reviewer 9:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1109
Presentation Title: Alum Innovative Exploration Project
Investigator: Ronne, Joel (Sierra Geothermal Power, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 60:
Alum is a known potential resource, yet slim hole temperatures appear to be moderate with low flow. Unless data from this project can be integrated and delivered to a broader audience, the project results will not inform other exploration efforts.

Reviewer 40:
New technologies are being used (coil tubing, geophysical technique) and a potentially commercial geothermal system was evaluated. Power purchase agreement is in place if the project if successful.

Reviewer 12:

Comments Regarding Scientific/Technical Approach

Reviewer 60:
Application and acquisition of multiple data sets appears buckshot rather than well thought out. Little to no synthesis was presented. Linkage between subsurface and surface data is unclear. There was no clear plan to evaluate ZTEM vs. other methods. The project summary was not provided, only the presentation.

Reviewer 40:
The project has innovative approaches although apparently not completely successful (coil tubing). The reviewer is not sure if seismic was completed.

Reviewer 12:
The project has staged exploration phases to constrain risk. What exactly is innovative? The presenter noted that nearly all of the techniques have been previously "tested" in the petroleum, minerals and geothermal industries. The presentation alluded to new slim hole data but provided no details, including a minimum of a temperature/depth profile.

Comments Regarding Accomplishments, Results and Progress

Reviewer 60:
This was very difficult to assess. The project was started under Sierra Geothermal Power, Inc. (SGP), transferred to Ram Power and is still apparently the responsibility of PI Stu Johnson. The presenter was not familiar with the project, the data that was acquired, and did not argue convincingly that the project was a priority for Ram Power as information other than —reports” did not appear to be available. The presenter admitted to —sifting through” information so there was no clear project transfer. GPH data appears to have been acquired; hyperspectral was mentioned but not shown and there is no evidence of synthesis and integration with geologic setting and lithology from wells.

Reviewer 40:
Surface and near surface mapping was mostly done but not completely. Exploration drilling was done.

Reviewer 12:
Schedule readjustments have delayed plan implementation.

Comments Regarding Project Management/Coordination
Reviewer 60:
The plan seemed haphazard from the start. Lack of oversight and lack of a clear plan for project and data transfer is obstructing further progress.

Reviewer 40:
There have been delays due to the merger of two companies and it appears that the handoff of all information is not as smooth as it could be.

Reviewer 12:
Timelines and milestone have been reported, but there is limited validity because of chaotic internal management.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 60:
This project has been poorly planned and coordinated, then lost in the company transition. It is clearly stalled and needs a dedicated manager to pull the pieces together to be delivered. It is unfortunate that drilling preceded the integration of surface exploration data sets, resulting in a large outlay of funds (~$5M spent by DOE and SGP) that may have little deliverable return. If the results from this project were integrated with the Silver Peak area and the Pearl area (occurring under the direction of partner, University of Kansas), it could be valuable to the community, as a type example. Detailed interpretation of the remote sensing and geophysical data sets could shed light on whether the drilling results are expected to be typical, or whether in the rush to implement drilling, higher priority sites were overlooked. Suggestions: before considering a no-cost extension, identify a dedicated project manager and technical support staff to pull together all existing data sets, generated reports, and historical information. Create a new plan for implementation and goals, milestones and metrics for synthesizing data from this property with neighboring regions and delivery to the GDR. Establish a new timeline for completion.

Reviewer 40:
This project is perhaps a reasonable prospect, but the transition between companies appears to have caused problems.

Reviewer 12:
This has had poor project management and attention to (ill-defined) project goals.

Comments Regarding Strengths
Reviewer 60:

Reviewer 40:
The project has an innovative use of technologies and is apparently a good prospect.

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 60:

Reviewer 40:
The transition between SGP and Ram seems to have been awkward. While the coil tubing was apparently unsuccessful, details are lacking.

Reviewer 12:
The project is thin on results. The presentation was entirely hearsay with little explanation or hard data. It should include detailed borehole data and expand the discussion of coiled tubing drilling and results. Based on the undocumented results of relatively low temperatures in newly completed slim holes, this prospect seems marginal at best.

Suggestions for Improvement
Reviewer 60:

Reviewer 40:
Evaluate all existing data and present results on the coil tubing and EM survey before moving on to the next stage.

Reviewer 12:
1. Determine whether this project is worth pursuing. 2. If so, determine what can be reasonably accomplished given transitions in corporate management and personnel. 3. Reevaluate timeline and project goals. State a time/budget/personnel basis for deciding on progress or continued funding.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1110
Presentation Title: Silver Peak Innovative Exploration Project
Investigator: Ronne, Joel (Sierra Geothermal Power, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 60:
Silver Peak is a known potential resource, and shallow temperature maps shown in the presentation for the Alum project appear encouraging. However, wells drilled appear to be sub-economic (low temperature). Unless data from this project can be integrated and delivered to the GDR the project results will not inform other exploration efforts.

Reviewer 40:
This is an innovative use of technology and a possible commercial prospect.

Reviewer 12:
Management is chaotic. Extension was already requested with little to show for efforts to this point.

Comments Regarding Scientific/Technical Approach

Reviewer 60:
The approach is generally sound, however, there is a problem in the execution. The work as executed put the drilling ahead of a synthesis and understanding of the geophysical and geological data, i.e. the cart before the horse problem.

Reviewer 40:
This project includes an integration of geophysics, remote sensing, and temperature. Coiled tube was not implemented.

Reviewer 12:
These exploration techniques have already been applied in petroleum, minerals and geothermal industries for ~30 years. What, then, is innovative?

Comments Regarding Accomplishments, Results and Progress

Reviewer 60:
Not even initial data are shown so it is not clear what has really been accomplished. The project was started under Sierra Geothermal Power, Inc. (SGP), transferred to Ram Power, and still apparently the responsibility of PI Stu Johnson. The presenter was not familiar with the project or even the whereabouts of the data that was acquired. Hyperspectral is mentioned but not shown, wells were drilled but locations are not identified on any of the image maps in this or the Alum project presentation. A resistivity study was apparently completed but also not integrated with any other data sets.

Reviewer 40:
The prospect was thoroughly explored but a commercial prospect was not found.

Reviewer 12:
There is very little data or rational justification.

Comments Regarding Project Management/Coordination

Reviewer 60:
The summary cites that airborne hyperspectral data was collected, but not analyzed; thermal IR was not collected. There are multiple issues with executing contract deliverables and completion of sub tasks. It appears they did not have a well

thought out plan to implement from the beginning, nor a good sense of staffing availability and timeline for execution. Lack of oversight and a clear plan for project and data transfer is obstructing further progress.

Reviewer 40:
There was a delay due to the merger; no-cost extension requested. The hand-off from SGP to Ram Power has not been smooth.

Reviewer 12:
Timelines, management targets and milestones are meaningless because of internal management disruption.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 60:
The presenter had limited knowledge of the project, history, data sets or implementation. This speaks to an overall problem with implementation and transfer from SGP to Ram Power. It was difficult to assess the use of exploration tools as the drilling appeared to proceed independent of any geophysical or remote sensing data analysis. The temperature probe data appears disconnected and there did not appear to be a systematic and well thought out timeline for execution or future plans. Although a good potential site in a neighboring lease has been identified, the current team has not demonstrated it can effectively carry out this proposed project. Recommendation for DOE: This and Alum project should be combined. Before further funding is committed, Ram Power should be asked to provide a detailed project scope, work flow and present results from data already collected in order to proceed in the region. Both Silver Peak and Alum appear sub–economic; it is not clear that Pearl is a better resource. It is recommended that detailed integration of existing data from all sites occur and be evaluated as part of the go/no-go (or stage-gate) approval step before proceeding with any additional drilling.

Reviewer 40:
This is a well-thought exploration project but ultimately appears to be unsuccessful.

Reviewer 12:
This project is even thinner on data than the very slim data set for the adjacent Alum prospect. There is little to point to that is innovative.

Comments Regarding Strengths
Reviewer 60:

Reviewer 40:
Purchase agreement is in place. Ztrem method was effective.

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 60:

Reviewer 40:
The single test showed poor permeability at this (Silver Peak) site.

Reviewer 12:

What is innovative in this project? Why continue in an area where bottom-hole temperatures are 103°C at 1,649 meters? The area is hardly a geothermal prospect and, based on the limited (or lacking data), has little chance to be developed as a producing geothermal system.

Suggestions for Improvement

Reviewer 60:

Reviewer 40:
Write a clear report on results, turn in data, and move on.

Reviewer 12:
1. Determine whether this project is worth pursuing. 2. If so, determine what can be reasonably accomplished given transitions in corporate management and personnel. 3. Reevaluate timeline and project goals. State a time/budget/personnel basis for deciding on progress or continued funding.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1111
Presentation Title: Validation of Innovative Exploration Techniques Pilgrim Hot Springs, Alaska
Investigator: Holdmann, Gwen (University of Alaska Fairbanks)

Comments Regarding Relevance/Impact of Research

Reviewer 60:
This is a nice use of modern thermal imagery technology. Forward-looking IR (FLIR) cameras have the potential to search remote expanses for temperature anomalies, but have not yet been widely used in geothermal exploration. Daytime FLIR alone can be valuable in highly vegetated terrain with multiple springs and seeps. Results will inform the community of the utility of this approach in this type of terrain. The project overall is likely to benefit a small rural community with high fuel costs.

Reviewer 40:
This project may provide new methods of using remote sensing along with a potential new resource. Chances of the resource to be exploited seem low, but proof of the remote sensing may be useful. Vegetation index is interesting.

Reviewer 12:
This is relevant research in identifying a low-temperature resource by reevaluating an identified geothermal prospect in a remote area.

Comments Regarding Scientific/Technical Approach

Reviewer 60:
The approach is generally sound and airborne collects are optimal for this remote, rugged, and difficult location. The partnering of remote sensing data with shallow temperature measurements is complementary. Resistivity measurements to improve well site location are beneficial.

Reviewer 40:
This is well designed with a clear objective. It could provide a new way to map geothermal. What is the overall geologic model?

Reviewer 12:
Assessing low-cost platforms (UAVs) can have a reasonable impact in determining how to complete rapid reconnaissance data over large areas but is yet to be applied.

Comments Regarding Accomplishments, Results and Progress

Reviewer 60:
Satellite data analysis and two airborne flights have been completed. The project is on schedule and there are solid results for the funding spent to date.

Reviewer 40:
Results so far appear encouraging in terms of usefulness of infrared remote sensing.

Reviewer 12:
The project is 25% complete, and 12% of the budget has been expended—slow progress.

Comments Regarding Project Management/Coordination

Reviewer 60:
Well thought out approach and timeline. Good execution of plan to date.

Reviewer 40:
Project is on schedule and moving forward as planned with a few problems. Good linkage and communication with other organizations.

Reviewer 12:
Thank you for including a timeline and milestone account.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 60:
This is a tightly focused project with a limited set of tools that should be useable and beneficial in this remote, difficult to access location. There is an opportunity to impact a small rural community and inform our understanding of Alaskan systems in general. The reviewer did not have the chance to ask about spring geothermometry but some geochemical sampling could also help identify whether an electricity-grade resource exists at some depth.

Reviewer 40:
Interesting results so far but prospects for large-scale development seem low, due to the distance from potential market. The primary result of drilling would appear to be validation of the method rather than a new commercial resource.

Reviewer 12:
Progress is slow.

Comments Regarding Strengths
Reviewer 60:

Reviewer 40:
Good communication with community and stakeholders. Solid understanding of technique.

Reviewer 12:

Comments Regarding Weaknesses
Reviewer 60:

Reviewer 40:
Likelihood of commercial prospect at this site seems low, other than local use. It would be useful to add more about conceptual model and other data sets. Will additional drilling improve assessment significantly?

Reviewer 12:
Results are "tentative." Hot springs were mapped but hasn't this be done by conventional geologist-on-the-ground methods (see Hutterer, 2002)? Integration with previous geophysics and temperature gradient drilling is lagging.

Suggestions for Improvement
Reviewer 60:

Reviewer 40:

Reviewer 12:
Integrate with existing data.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1112
Presentation Title: Blind Geothermal System Exploration in Active Volcanic Environments; Multi-phase Geophysical and Geochemical Surveys in Overt and Subtle Volcanic Systems, Hawaii and Maui
Investigator: Martini, Brigette (ORMAT Nevada Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 41:
This project primarily addresses the discovery of blind systems within young basaltic terrains which are somewhat limited within the United States but are still important. Very little is known in these environments with only one other system having been developed. However, this can only substantially broaden our understanding of exploration technologies for all types of geothermal environments.

Reviewer 60:
This project seeks to model the potential of a dormant, but young, basaltic system on Maui by incorporating elements from the Puna geothermal production site on Hawaii. The site incorporates modern geophysical exploration tools in a region with limited surface expression. Methods may be useful to other, young basaltic hot spot volcanic sites, and relevant to identification and development of new resources in an area with high potential.

Reviewer 9:
If successful the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Reviewer 4:
The potential for baseload energy generation for Maui is significant. The team also makes the case that the approach could extend to other dormant volcanic systems.

Comments Regarding Scientific/Technical Approach

Reviewer 41:
The approach to exploration is new and different. Joint modeling of magnetic and gravity data has been done before but is not common in the geothermal industry. Heli-mag seems to be by far the most useful in this type of setting. Would like to see this completed in other projects in the United States.

Reviewer 60:
This project tests the hypothesis that magnetics won‘t work well in homogenous terrains and couples that with novel gas sampling methods known to work well in more active volcanic systems. Staged approach is well thought out and reprocessing older data to provide baseline for expectations is solid.

Reviewer 9:

Reviewer 4:
The approach of combining studies of a well-constrained site on Hawaii with a new prospect on Maui is excellent. Provided an opportunity to reprocess historical data for Puna, creating an up-to-date baseline for the reference case on Hawaii. The team used their geophysical approach (gravity, magnetics) to constrain targets for CO_2 flux surveys; this demonstrates the potential importance of the integrated techniques, at a minimum justifying the intent. The benefit of the comparative approach makes up for the lack of true innovation in techniques.

Comments Regarding Accomplishments, Results and Progress

Reviewer 41:

Progress has been slow, no doubt due to cultural issues, but there appears to be a need for some technique to site the wells. Other results seem to be of value other than the lack of reasonable success from C02 flux.

Reviewer 60:

The project team has successfully completed the initial phase of data acquisition and analysis. The older data has been reprocessed, and modern gravity and magnetic surveys are complete. Integration of geophysical data and analysis depends on subcontractor workload. Collection of well geochemical data was hampered in part by local resistance on private property and limited naturally occurring springs. The summary mentions the acquisition of hyperspectral data (results not shown) and preliminary analysis is complete, though cloud cover limits the utility of data in critical regions. Overall, reasonable progress for the limited funds spent.

Reviewer 9:

Reviewer 4:

While CO2 was determined unsuccessful for Maui, the team did a nice job of hypothesizing why this might be the case (groundwater scrubbing at Puna; low flux for dormant resource plus groundwater scrubbing and masking by biogenic sources on Maui) and still believes it could be a useful method that they may attempt at younger volcanic zones.

Comments Regarding Project Management/Coordination

Reviewer 41:

Expenditures to date indicate that it may be very difficult to achieve project completion by Q1-2 2012. There may be considerable delays especially when applications are submitted for drilling permits. Expenditures are consistent with work completed.

Reviewer 60:

Project appears to be making progress with only a few delays or schedule problems. It should be noted that Maui has no geothermal regulations and the PI and Ormat are helping to identify and create those.

Reviewer 9:

Some important activities have been delayed due to subcontract work falling behind. Corrective measures have been taken and the project now seems to be advancing satisfactorily.

Reviewer 4:

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:

NOTE: THE REVIEWER WAS ASKED TO PROVIDE A REVIEW AFTER THE PRESENTATION WAS COMPLETED. THE REVIEWER WAS AT THE PRESENTATION BUT DID NOT ASK QUESTIONS AS A REVIEWER. This is a great project—one of the few that has some innovation associated with an exploration program. The setting is somewhat atypical which creates a greater opportunity for innovation. The reviewer does not see a future activity that would lead to siting a well. CO2 flux could have provided that but does not appear to have been successful for that objective. It is difficult to think of other techniques that would be able to identify some sort of rift structure which is assumed to be the target. Would detailed age dating of flows help to more clearly define a magmatic source area? This is an interesting problem.

Reviewer 60:
The project has the possibility of identifying new resources in an area of strong potential. Combined use of geophysical and geochemical approaches can lead to new models in this type of terrain.

Reviewer 9:

Reviewer 4:
This is a well thought out and extremely well presented study. The potential to compare data from a well-constrained site on Hawaii with the new prospect on Maui is excellent. While the techniques themselves are not particularly novel, the targeting of geochemical investigations based on geophysical guidance is thoughtful and the comparative approach is what adds novelty. The team also has plans to investigate other dormant sites on Hawaii that are even better analogues to Maui. This is highly encouraged. While the particular study is not a complete success (difficulty with CO_2 measurements providing useful input), it was made clear that the scientific approach and lessons learned will benefit future efforts.

Comments Regarding Strengths

Reviewer 41:
This is a good team with good innovative thinking. Using Puna as a model and testing techniques there first is an excellent way to develop applicable technologies.

Reviewer 60:

Reviewer 9:

Reviewer 4:

Comments Regarding Weaknesses

Reviewer 41:
If CO_2 flux is not working then there need to be other techniques that will identify specific targets.

Reviewer 60:

Reviewer 9:

Reviewer 4:

Suggestions for Improvement

Reviewer 41:

Reviewer 60:

Reviewer 9:

Reviewer 4:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1113
Presentation Title: Use Remote Sensing Data (selected visible and infrared spectrums) to locate high temp ground anomalies in Colorado. Confirm heat flow potential w/ on-site temp surveys to drill deep resource wells
Investigator: Robinson, F. Lee (Flint Geothermal LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 41:

This is a relevant project and is particularly useful in areas where 1) only minimal exploration has been completed and public data is limited (such as Washington State), 2) there are geothermal settings that are marginal (such as Colorado), or 3) large areas with geothermal potential but no specific agency or administrative body that has taken the responsibility for providing a geothermal database. It will certainly assist in exploration and development of blind geothermal systems and this is its greatest asset.

Reviewer 60:

The reviewer sees nothing novel or innovative in the project team's approach. Landsat and ASTER data have long been used in geothermal exploration and the work as presented appears ignorant of the subtle processing methods needed to extract true thermal anomalies. The project seems disconnected from geothermal development in Colorado, as recently discussed at a workshop sponsored by the Colorado School of Mines. The presentation and summary do not cite specific methods, field approaches or goals, and use only generic terminology limiting applicability in the wider geothermal community. The current target resources (areas of ―relatively higher temperature") are likely not linked to sub-surface heat flow and hence are not relevant to identifying significant, new resources in the state.

Reviewer 9:

If successful, the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Comments Regarding Scientific/Technical Approach

Reviewer 41:

The technical approach is good but with some reservations. There was no indication or graphic as to what areas within Colorado have been covered by the Phase I activities. No explanation was made regarding the selection criteria used to identify the 29 AOIs and the 6 selected areas for further evaluation. The presenter indicated that no field work had been completed, but if to the team is going to select 6 areas out of 29 there should have been some field evaluation involved in that process (it need not be an exploration survey). Regarding the approach execution, a concern is that by limiting the evaluation to within 2 miles of a transmission line that large areas of geothermal potential are going undocumented. Most existing, developed geothermal systems have had to construct transmission lines in the 5 - 10 miles range, and in the case of Dixie Valley, it was much longer. Transmission lines, while they add to the cost of a project, are generally not a financial impediment to development. The project should be focusing on finding geothermal resources, where ever they exist, so that the technology can be demonstrated.

Reviewer 60:

The approach is simplistic and limited. The presentation does not convey a detailed knowledge of remote sensing principles or application of the data and their inherent utility. There is no real discussion of methodology and the areas of high heat flow are potentially artifacts of surface cover, slope, and thermal inertia differences rather than related to subsurface heat anomalies. The emphasis on ―identification of water features" is not relevant to the discovery of subsurface geothermal resources. There is no description of how the satellite imagery will be used to guide the field component and ultimately drill site selection. An integrated geographic information system (GIS) of the various data sets was not shown and does not appear to be guiding drill site selection. During the questions and answers (Q&A), the presenter suggested proximity to private land and power transmission were more important than the magnitude of the putative ―warm exposure" or the type of alteration mineralogy, or the geochemistry of warm springs. In the Q&A the presenter suggested the field study phase would include ―2-m temperature surveys, chemistry of water, MT, and shallow temperature gradient," yet it is not clear that either the PI or any of the listed collaborators have the skills needed to conduct and interpret these measurements.

Reviewer 9:
The nature and details of the electrical/magnetic surveys that will be applied in Phase II to the two selected sites will remain incompletely defined until those sites are identified. The success of the project depends heavily on those surveys. The reviewer suggest that the selection of the techniques to be applied and the detailed planning of the surveys become a matter for revision by DOE.

Comments Regarding Accomplishments, Results and Progress
Reviewer 41:
It is difficult to assess the quality of this project based on the data provided in the PowerPoint and summary; however, it seems to be good. There are no details of the future evaluation program planned for the six areas other than general statements on electric, gravity, and magnetic surveys. Productivity is average—from January 2010 (start date) to June 2011 is a long time to get Landsat/ASTER data evaluated and the database assembled. It could have been completed earlier and the data on the proposed field testing program could have been completed for this review meeting.

Reviewer 60:
A long list of data types are stated to be included, but this was not demonstrated in the presentation or in the subsequent discussion. What was shown was the product of a very brief analysis of seemingly very few images. The context within the state and Colorado's potential for geothermal exploration and development is lacking. The project is missing a concrete and specific plan for the next phase of exploration against which results and progress could be judged.

Reviewer 9:

Comments Regarding Project Management/Coordination
Reviewer 41:
It is difficult to assess but seems fine so far. There is concern over so little having been accomplished (which may be due to the contract) in the last 15 months—only 4% of the budget is spent. The serious problem is the schedule. For a thorough exploration program—sufficient to site slim holes which cost ~$1 million each, if not more—it would be virtually impossible to complete by the end of 2011, especially since six sites are to be evaluated. The end of 2012 for Phase II is more realistic if the exploration is completed to industry standards. Since these are blind systems they require more time than those with surface expressions. The team of collaborators is well thought out, particularly having an environmental consultant.

Reviewer 60:
The project does not have clearly articulated data products that should result from the collaborations. Many of the data types listed are regional-scale and there does not appear to be coordination on synthesis of varying data types. There is no plan or timeline for specific measurements to be made in the next phase of exploration and contractors able to do the type of work that was stated during the question and answer session are not identified.

Reviewer 9:

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:
This is a good project but with a number of concerns, mostly in that the individual Landsat and ASTER data HAVE been used fairly extensively so this is not an innovative technology and is not an innovative use of a combination of existing technologies. The reviewer does not think it will have a major impact on costs since a full exploration program will still be needed to site drilling targets. This aspect of the project is crucial and requires very detailed design which should be tailored to each individual site so that conceptual models can be generated and specific drilling targets be selected and then prioritized. The presenter indicated that a 2-meter survey would be part of the field program which the reviewer would not recommend. Far more important would be a ~500 ft temperature gradient program at each site, if warranted and if feasible. This would indicate whether the Landsat/ASTER data are a response to a deeper heat signature and not from shallow surface effects (such as diurnal variations and albedo). The reviewer would also not recommend leasing even temperature gradient wells for the early Phase II activities. Leasing should be considered only for slim holes. Access agreements should be sufficient.

Reviewer 60:
This project leaves the impression that the PI has limited experience with geothermal and the partners selected to contribute this expertise are only peripherally involved, if at all. Only organization titles were provided, not specific individuals. Given the extremely limited assessment and analysis to date, it is unlikely that this work has identified any high-potential electricity-scale resources and so is not likely to make a significant contribution to the Geothermal Technologies Program (GTP) goal of identifying 400 MW of new resources.

Reviewer 9:

Comments Regarding Strengths
Reviewer 41:

Reviewer 60:

Reviewer 9:

Comments Regarding Weaknesses
Reviewer 41:

Reviewer 60:

Reviewer 9:

Suggestions for Improvement
Reviewer 41:

Reviewer 60:

Reviewer 9:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1114
Presentation Title: Finding Large Aperature Fractures in Geothermal Resource Areas Using a Three-Component Long-Offset Surface Seismic Survey, PSInSAR and Structural Kinematic Analysis
Investigator: Teplow, William (U.S. Geothermal, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 41:

Reviewer 24:
Finding zones with the greatest volume of fluid flow is extremely important to improving the performance of geothermal fields and reducing the costs of development and operations.

Reviewer 4:
The potential impact of the combined geophysical approach seems strong, perhaps even outstanding. However, it‘s not clear to the reviewer what exactly the team has learned from the combined data that advances their confidence in their prospects beyond what some subset of techniques might provide. It would help to see why, for example, leaving out the interferometric synthetic aperture radar (InSAR) component would compromise the results.

Reviewer 51:
The investigators are searching for large aperture fractures (LAFs) using "a combination of three-component long-offset active source seismic surveying, permanent scatterer synthetic aperture radar interferometry (PSInSAR) and kinematic structural analysis as an integrated methodology for locating and 3D mapping of LAFs in a shallow to intermediate depth (600-4000 feet) geothermal system." LAFs are important because "highly productive wells that have encountered LAFs supply the bulk of the geofluid to the power plant while production wells in the same field that do not encounter LAFs are of marginal value." The project should be the first systematic approach for locating and mapping these specific LAF features within geothermal prospects and fields. "LAFs are important to the economic viability of many geothermal projects because wells drilled into LAFs typically exhibit very high productivity and low pressure drawdown." A successful outcome would "reduce number of dry holes, … reduce the number of production wells required for a given wellfield power output and reduce parasitic loads for production well pumping." The project has made notable progress and impact on DOE‘s Geothermal Technologies Program missions and goals. The project has demonstrated significant advancement in addressing knowledge gaps and barriers. The project has considerable impact on factors in geothermal energy development.

Comments Regarding Scientific/Technical Approach
Reviewer 41:

Reviewer 24:
The research team has conducted various studies to help them ascertain the structure of the field and locate the possible fluid pathways. Although the methods can find possible fluid pathways, it is not clear that any of the methods will discern the actual fluid flow or permeability. The authors state the seismic was able to differentiate tight and permeable faults, but this was not obvious to the reviewer. Drilling is still necessary to validate whether fluid flow exists.

Reviewer 4:
The project‘s scientific/technical approach is good, though investigator comments on struggles with cost and spatial coverage for seismic and InSAR efforts raise questions on whether the scope of the surveys was reasonably matched with

the budget.

Reviewer 51:
An interdisciplinary approach is appropriate, and the methods used are established. It is, however, unclear why 20 miles of seismic surveys were needed when the locations of some of the LAFs were already known. Using the known LAF locations, the techniques should have been calibrated. Although the cost of the seismic surveys is not provided, the seismic investigations were probably the most expensive component of Phase I. Whether the seismic survey errors are significant in the case of 15 cm targets is not discussed. In Figure 2, described with: "Known LAF zone exhibits well-defined, deeply penetrating velocity boundaries," there are more deeply penetrating velocity boundaries that are not classified as LAFs. A discussion of those zones is necessary. The figure does not have axis labels. It is unclear how deep these LAF features are and whether there are LAFs which are not resolved by the technique. It would be interesting to know how many reflection lines have been deployed and how many produced useful data. Since the drilling will be performed in "specific drilling targets, both along strike and down dip of known LAF's," it is not clear whether the investigators have found any new LAFs and whether the method has any chance to be actually validated.

Comments Regarding Accomplishments, Results and Progress
Reviewer 41:

Reviewer 24:
The researchers have accomplished their stated goals very close to the anticipated schedule. A drilling target has been identified for the go/no-go decision. It is unclear, though, that an innovative method has been developed to further the geothermal industry.

Reviewer 4:
The project team seems to have completed a usable combined geophysical survey under budget (90% expended) for Phase I. Exploration wells are targeted but success is yet to be seen.

Reviewer 51:
Task 1 was accomplished with good quality results. It is not clear from the "project scope" whether the current project is a method calibration or a search for new LAFs. If productivity is defined as finding new LAFs, the affirmation in slide 10, "In the Northern and Southern Exploration Areas high resolution datasets and strong cross-correlation yielded specific drilling targets, both along strike and down dip of known LAFs." does not show that new targets have been identified. The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for improvement.

Comments Regarding Project Management/Coordination
Reviewer 41:

Reviewer 24:
Phase I has been completed nearly on-time and on-budget. There is a clear decision point in place as to whether to proceed with Phase II. Phase III (Data Dissemination from Phase I) has been initiated. The necessary coordination of vendors and other items such as permits appears to be in place.

Reviewer 4:
A slight delay in completing Phase I doesn't seem as though it will impact the work, which is currently under budget. Again, the concern over investigator gripes with cost brings into question planning savvy.

Reviewer 51:
Management of this project has been effective and plans for future management are well structured and include all the

appropriate and logically placed management checks and controls, however, improvements are desirable.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:
NOTE: THE REVIEWER WAS ASKED TO PROVIDE A REVIEW AFTER THE PRESENTATION WAS COMPLETED. THE REVIEWER WAS AT THE PRESENTATION BUT DID NOT ASK QUESTIONS AS A REVIEWER. This is an excellent project—well thought out, innovative and completed by high quality scientists. Unfortunately much of the data was not presented so it is difficult to review without having been able to ask questions at the review.

Reviewer 24:
The project appears to be well run, on budget, and nearly on schedule. Drilling still needs to be completed to verify the existence of the LAF and fluid flow regardless of what the project geophysics indicate. This is not a change from the current process. The methods do not directly define whether the fault is high permeability. The geophysics appears to locate the main fault for this site, and it happens to have large voids. This will not necessarily translate to other geothermal sites.

Reviewer 4:
The intent to couple geophysical techniques is good. The use of PS InSAR to bolster seismic, gravity, and surface structural analysis seems promising. If the investigator clarified how surface velocities added to their interpretation, in particular by providing some quantitative analysis of correlations with known production operations, it would be easier to assess how meaningful the combined approach is. An empirical relationship between subsidence velocity and production history for San Emidio, for example, could be the start of a useful metric for U.S. Geothermal, Inc. and other developers.

Reviewer 51:
"LAFs are important to the economic viability of many geothermal projects because wells drilled into LAFs typically exhibit very high productivity and low pressure drawdown." An interdisciplinary approach to detect LAFs is appropriate.

Comments Regarding Strengths
Reviewer 41:

Reviewer 24:

Reviewer 4:

Reviewer 51:
The method seems to properly estimate LAF locations in at least some of the cases of known LAFs.

Comments Regarding Weaknesses
Reviewer 41:

Reviewer 24:
It is not clear whether the methods can truly highlight areas of high permeability. The project results correlate known zones of high permeability with observed geophysical values, but the relationship between the permeability and geophysical parameters is not defined.

Reviewer 4:

Reviewer 51:
A stepwise approach, with identification of the most probable LAF locations with cheaper geological and geophysical techniques, followed by expensive seismic surveys would have probably been more cost effective. Instead, "the project schedule required parallel data gathering and processing as much as possible so that vendors and PI would have sufficient time for interactive data interpretation. Preferred sequential work scheduling was sacrificed for this reason." It is unclear how this technique will be validated if the drilling is going to be performed at know LAF locations.

Suggestions for Improvement
Reviewer 41:

Reviewer 24:
Better define theoretical tie between the geophysical methods and large aperture fractures, if it exists. Without this tie, no innovative methods have been developed.

Reviewer 4:

Reviewer 51:
The method should not only be calibrated, but also validated through drilling. Statistical analysis of the correlations between different data sets could be conducted before drilling.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1115
Presentation Title: Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA
Investigator: Matlick, Skip (ORMAT Nevada Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 41:
The project objectives meet Program goals of additional geothermal development - aimed at 50 MWe. Three-dimensional/three-component (3D-3C)is a new technology which will have a significant impact if S-wave data can be effectively gathered. Regarding technology gaps, locating and identifying permeability has always been the main barrier to identifying resources prior to drilling;if this approach works it will go a long way in alleviating this problem, particularly in areas where seismic reflection data can effectively be used, such as the IV or Basin and Range. Elsewhere, the reviewer is not sure how it would work.

Reviewer 24:
Improving the drilling site selection through 3D seismic techniques has the potential to result in greatly improved field production and reduced cost. The goal of the project is to use converted phases (P-to-S) from structures to improve fault characterization. This has proven unsuccessful at this point.

Reviewer 4:
The team may have reduced exploration risk by applying a standard seismic approach to guide drilling, as opposed to blind prospecting based on surface features alone. This does not seem particularly innovative.

Reviewer 51:
The project‘s relevance/impact of research is fair. The project has made modest progress and impact on the DOE Geothermal Technologies Program‘s (GTP) missions and goals. The project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate to low impact on factors in geothermal energy development. The project has been funded to address an important geothermal program goal: "to reduce exploration risk by characterizing fault and fracture geometrics at Wister, CA, a blind geothermal resource." The Wister 12-27 well was supposed to be "the first geothermal exploration well located by using 3D seismic data in the Imperial Valley" and "the innovation of using 3D seismic data is new to the geothermal industry." To the reviewer‘s understanding understanding, the shear wave imaging method does not work, unless millions of dollars are spent on drilling a well to estimate the P/S velocity: "The processing of the converted shear wave 3D seismic data has yielded velocity ambiguities that cannot be readily resolved without other information." Since P-velocity model estimation methods are already developed, the project has made modest progress and impact on GTP‘s missions and goals.

Comments Regarding Scientific/Technical Approach

Reviewer 41:
Regarding technical approach, even though the converted shear wave program did not work, the program appeared well planned and competently executed, based on the minimal data available to the reviewers. The reviewer is not certain if the source and receiver spacings were too large and caused the lack of reflectivity definition. The separations were 1,320 and 880 feet, respectively, which in the reviewer‘s experience is large. Maybe this was to allow for greater area of coverage.

Reviewer 24:
The goal of the project, improved well siting through state-of-the-art seismic processing, was/is worthy of testing. P-to-S converted phases are not traditionally used in velocity model development or imaging in any industry. The primary goal of the project is to test whether converted phases can be used as a tool in geothermal fields. The work currently done has

indicated this likely not to be the case, but further work, possibly by another data processor, should be continued to further test the method.

Reviewer 4:
The approach may be sufficient for the target study, but more background research may have guided smarter seismic deployments (based on a large and growing body of regional work in the Imperial Valley) and/or suggested the need for additional expertise to ensure successful S-wave results. It‘s not clear what needs to be done to exploit this data in targeting the second well as stated, or if the investigators are prepared for the task.

Reviewer 51:
Some aspects of the project may lead to progress in achieving project objectives and overcoming barriers/knowledge gaps but the approach has significant weaknesses and noteworthy areas for improvement. It seems that drilling was started with insufficient information: "Although only time-sections were generated because the rock velocities were not known, the data clearly showed that two normal faults were dipping eastward beneath the Well 12-27 site," although the P-velocity model has been enough to predict the fault intersection depth,," "Processed and interpreted P-wave data September 2010; Delayed S-wave processing until after well was drilled to record dipole sonic log. Dipole S-wave velocities used for processing." The scientific method which was funded does not seem to produce results: "The processing of the converted shear wave 3D seismic data has yielded velocity ambiguities that cannot be readily resolved without other information. Independent S-wave velocity data are needed for converted shear wave data processing here."

Comments Regarding Accomplishments, Results and Progress

Reviewer 41:
Regarding project quality, accomplishments were acceptable considering the main objective and innovation (converted S-wave analysis) did not provide the necessary data to characterize the fault permeability. The well was tight but P-wave data from the sonic log showed the fault intersected by the well. It would have been useful to see the dipole sonic log.

Reviewer 24:
The project is well behind schedule. The work so far has used traditional P-wave seismic interpretation to drill a non-productive well. The converted shear phases proved unusable. Even though the method was not a success, the project to first-order obtained its goal of testing the method.

Reviewer 4:
The team targeted and drilled a well that appears to identify a viable resource, though it‘s not clear what can be inferred about progress towards the project goal of 50 MWe.

Reviewer 51:
Since the initial idea was to reduce, and not increase, the costs of finding new geothermal resources, the quality of the results is low. From the first phase investigations, it seems the method does not work, unless drilling is performed. This makes the project extremely expensive, and does not seem to reduce drilling risk. Before spending money to drill a well, all the possible investigations should have been conducted, including S-velocity analysis, old well data analysis and other geophysical investigations and combined with statistical analysis of the data. There is no plan outlined in the current report on what measures have been taken not to drill another unsuccessful well.

Comments Regarding Project Management/Coordination

Reviewer 41:
The timeline and budget look good. No other information was available.

Reviewer 24:
The project should have been completed by this date, but has just recently acquired of all the necessary information to

fully test the hypothesis of the project. The delay is in large part due to permitting issues which may or may not have been controllable by the project leadership. It is unclear to the reviewer why the velocity models were not obtained through less costly methods earlier in the project, as they are fundamental to achieving the project's goals. A go/no-go decision point has been set before drilling another well. Management should consider contracting a new vendor to process the converted shear wave data before abandoning the method completely.

Reviewer 4:
There were some permitting delays and trouble with S-wave processing. Not enough details are provided to assess how these hurdles were managed.

Reviewer 51:
The policy, schedule, business and staffing plans, and spend plan were carried out well, however, drilling a well without sufficient information was not a sound technical decision.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:
This is a good project undertaken by very competent people despite the lack of success in being able to use converted S-wave data. The problem was not restricted to this project as converted S-wave data was also not useable at the Soda Lake project. Maybe the reprocessing of S-wave data will provide additional insights to the permeability structure.

Reviewer 24:
To date all work has been completed with only traditional P-wave 3D seismic, including the drilling of a non-productive well. The project tested an innovative method to the geothermal industry, but it proved unsuccessful. Without further attempts to process the data, the project has become a case study on developing production at a new field. The field is definitely hot and capable of sustaining a geothermal field. If the permeability is too low to directly produce steam/hot water, an enhanced geothermal system (EGS) may be considered.

Reviewer 4:
This project appears to apply standard seismic techniques in a geographic setting where significant structural and seismic analyses already exist and are still underway. While the approach may meet the nominal goal of reducing exploration risk, it does not seem innovative. More background work may have streamlined the effort and led to even more successful survey results.

Reviewer 51:
The project may produce acceptable results using the velocity constraints resulting from drilling. However, the method does not seem to work for cases when geothermal companies do not have $3 million to spend in advance, to acquire initial velocity models. 48.7 full-time, year-long jobs have been created to date.

Comments Regarding Strengths
Reviewer 41:

Reviewer 24:
The project aimed to test a non-traditional method for reducing the drilling risk associated with geothermal development. Unfortunately, the method so far has turned out not to work.

Reviewer 4:

Reviewer 51:
48.7 full-time, year-long jobs have been created to date. The well location has been estimated correctly based on the P-velocity information. The fact that the method does not seem to work for shear waves is valuable information.

Comments Regarding Weaknesses
Reviewer 41:
Only minimal data was presented. No details on the dipole sonic log and how velocities compared with those used for P-wave analysis.

Reviewer 24:
A large amount of time and money has been spent, yet work on the designed goal of the project was completed late and ultimately proved unsuccessful. Seismic reflection methods often do a poor job defining vertical or near-vertical structures, such as faults transmitting geothermal fluids.

Reviewer 4:

Reviewer 51:
The first phase was unsuccessful; it does not seem that the 3D P/S method works: 1. "Weak P-wave and converted shear wave reflectivity." 2. The decision to drill was made before having all the necessary information: "Unknown shear wave velocity field prior to survey and drilling." 3. The money was spent on drilling unsuccessfully: "Since lost circulation did not occur and the cuttings lacked indications of open fractures, it appeared that the wellbore did not have "commercial" permeability…. This test shows only 1.5 BPM of water could be injected into the well at 600 psig which clearly indicates the wellbore had little if any permeability." However, the PI writes: "P-wave 3D seismic data on the Wister project area has been used to map faults and fracture zones. Seismic imaging of the subsurface structure has provided excellent targets for exploration drilling." The presentation was low quality; most of the graphs do not have axis labels. The project summary has not been put together carefully; part of it has been copied from the proposal: "The proposed Wister 12-27 well is in the southeastern part of the 3D survey. The location has been selected to drill into an east-dipping fault zone. The proposed well will be a vertical hole with a planned measured depth of approximately 6500 feet." And later in the text: "Ormat Nevada Inc. (Ormat) drilled Wister Well 12-27 between October 26, 2010 and December 17, 2010 using GeoDrill Rig #1."

Suggestions for Improvement
Reviewer 41:

Reviewer 24:
At this stage, it is difficult to make improvements. The data has been analyzed and it is time to decide whether to drill the second well. If the data indicates confidence in the ability to successfully site a new well, an existing permitted drill location should be used if possible in conjunction with directional drilling to reduce further permitting delays and costs. Having another vendor attempt to process S-wave data would be worthwhile since the goal of the project is to test an innovative method. Different processing software or methods may be required.

Reviewer 4:

Reviewer 51:
Drilling at a new site should be continued after proof of comprehensive preliminary investigations with all possible

methods have been provided. Supplementary geophysical information should be analyzed before drilling.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1116
Presentation Title: A 3D-3C Reflection Seismic Survey and Data Integration to Identify the Seismic Response of Fractures and Permeable Zones over a Known Geothermal Resource: Soda Lake, Churchill County, Nevada
Investigator: Benoit, Dick (Magma Energy Corp.)

Comments Regarding Relevance/Impact of Research
Reviewer 41:

Reviewer 24:
The project is designed to improve the performance and/or return the field to its original performance through the use of new and/or high-resolution geophysical methods. These methods appear not to have worked, but traditional methods have identified possible zones for further production.

Reviewer 4:
It's not clear how the DOE Geothermal Technologies Program (GTP) will benefit from this project beyond perhaps improving the yield of one resource. There's no clear plan for technology transfer as required by the funding opportunity announcement (FOA), even to other potential Magma Energy Corp. sites.

Reviewer 51:
The project is important in identifying "new prospects, better understanding of geothermal potential of Carson Sink" by applying "…three-dimensional/three-component (3D-3C) reflection seismic technology" and other geophysical techniques, "to define transmissive geothermal structures at the Soda Lake Geothermal area, Churchill County, NV." Applying a set of 3D-3C methods (gravity, MT, seismic) integrated into a geographic information system (GIS) database has the potential to provide better images of the geothermal field and provide new drilling targets. This is a high-cost, however, high-precision exploration method. The method has been used to identify drilling targets, however, was not yet validated (project completion ~14%, expenses $1.4 million). The project also demonstrates that the 3D shear-velocity model estimation methods chosen are not suitable for this type of experiment, due to poor performance.

Comments Regarding Scientific/Technical Approach
Reviewer 41:

Reviewer 24:
Although the 3D seismic did not prove as useful as hoped, the researchers have made good use of the other data sets such as gravity. The detailed studies have ultimately resulted in possible new drilling targets. As with other projects in this "innovative methods" track, testing and analysis of new methods should not be discontinued just because the first attempt failed.

Reviewer 4:
A standard set of survey techniques was used, but the team did a nice job of presenting the value of their 3D GIS integration of data for developing a new conceptual model of the site.

Reviewer 51:
The project is well organized and was well executed; the work stages are logical. The approach is well thought out and effective in achieving the project's objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has minor room for improvement. Statistical analysis should be applied to assess the correlation between different datasets, leading to

more rigorous arguments for the chosen drilling areas. Using a set of established methods is smart, however, these methods are not cost-effective or innovative. According to the authors "at this writing, the converted-wave processing has not been successful. The combination of the acquisition parameters, 220‘ receivers, 550‘ receiver lines and tandem, 770‘ shot lines, and an unexpectedly high Vp/Vs ratio created conditions where the up-going shear-wave ray-paths were nearly vertical. As a result, the shear-wave wavefield was severely under-sampled. After six months of testing asymptotic conversion point and depth-variant, common conversion point binning algorithms, the shallow data could not be imaged." The authors are still trying other approaches, which is a positive action, within reason, however, it is not clear whether this method will work.

Comments Regarding Accomplishments, Results and Progress
Reviewer 41:

Reviewer 24:
A large volume of data has been retrieved/acquired/analyzed and a new model of Soda Lake has been developed. It would appear that the project is well on the way to meeting its goals, even if an innovative method wasn't proven useful for the program.

Reviewer 4:
Progress seems sufficient, though P-S processing was unsuccessful and it‘s not clear if there is a need or plans to revisit this component.

Reviewer 51:
The accomplishments, results, and outcomes have been good in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for slight improvement. The main accomplishments are that a new conceptual model of the area and drilling targets have been estimated using integrated results from a variety of exploration techniques. One of the seismic techniques (converted shear wave processing) has been so far proven as not applicable and not efficient, after six months of data processing. The results are of good quality and show progress in accord to the project spending. New drilling targets have been identified, which expresses good project productivity.

Comments Regarding Project Management/Coordination
Reviewer 41:

Reviewer 24:
It would appear that the project is on schedule and budget. There were no go/no-go decision points presented.

Reviewer 4:
Permitting delays seemed to be utilized for more in-depth analyses. It was stated that results led to a revision of the statement of project objectives (SOPO) and budget, but insufficient information is provided to evaluate these changes or how they were managed.

Reviewer 51:
Management of this project has been effective, however minor improvements are desirable. For example, is should not take more than six months of work to decide that the converted wave processing is not useful, thus no more time should be spent trying to retrieve a shear-velocity model. Other seismic techniques could be used for estimation of a shear velocity model.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:

Reviewer 24:
This project appears to have made significant progress at improving the understanding of the Soda Lake geothermal field. Although the seismic data collection was hampered by permitting delays and ultimately did not provide as much useful information as hoped, the project has been able to make use of various other geophysical methods to make good progress.

Reviewer 4:
The approach may reduce exploration risk for the site in question, but it‘s not clear if/how this will translate into broader impact on the industry beyond Soda Lake. The techniques are not particularly novel, but the value of GIS integration and visualization for exploiting joint datasets is good.

Reviewer 51:
Despite difficulties related to project delays, and seismic method problems, the project is expensive; however, it is well organized, and has produced results. The number of jobs created is 7.28 FTE.

Comments Regarding Strengths
Reviewer 41:

Reviewer 24:
The project team utilized multiple geophysical techniques to overcome poor results of just one method. This is critical to the successful development of any field.

Reviewer 4:

Reviewer 51:
The preliminary survey for seismic velocity analysis ensured good results for the P-velocity model. Good project management has been demonstrated. The conceptual model is verifiable. The main strengths of the project are the approach—"Geothermal exploration requires a multi-discipline approach integrating surface and downhole geophysics, geology, temperature data and regional tectonics. A 3D GIS database can integrate disparate data sets unifying different units of measurement, geographic projections, sampling intervals, grid density, etc. to provide a seamless platform for 3D visualization"—and the newly identified drilling sites.

Comments Regarding Weaknesses
Reviewer 41:

Reviewer 24:

Reviewer 4:

Reviewer 51:
The weaknesses of the project are: 1) the high costs, 2) use of conventional methods (lack of innovation) of which some do not produce good results (shear waves), and 3) the lack of a sound statistical analysis of geophysical dataset correlation.

Suggestions for Improvement
Reviewer 41:

Reviewer 24:
Converted seismic phase analysis does not appear to have worked for any project in this track, likely because reflection seismic does not image near-vertical structures well. A recommendation for the program as a whole, and not exclusively for this project, would be to conduct a study on seismic methods to determine which are applicable to the geothermal industry. Why do methods that have worked successfully elsewhere not work in the geothermal field? How can they be improved or adapted?

Reviewer 4:

Reviewer 51:
A review of other seismic methods to estimate S-wave velocity could help estimate the needed S-wave information. For example, shear velocity can be estimated from Rayleigh wave dispersion, from ambient noise analysis. Other seismic methods such as refraction microtremor (ReMi) and/or attenuation analysis could be of use in 3D shear-velocity model and geothermal reservoir characteristics estimation.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1117
Presentation Title: Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System (An Alternative to Grid-Drilling for Geothermal Exploration): McCoy, Churchill County, Nevada
Investigator: Benoit, Dick (Magma Energy Corp.)

Comments Regarding Relevance/Impact of Research

Reviewer 41:
The project objectivescomply with DOE Program goals to find additional, blind resources. There are not many new technologies being used. This project would have a significant impact if a resource were identified for this unusually large thermal anomaly.

Reviewer 24:
The project attempts to combine multiple geophysical techniques to improve the chances of drilling an economic well. Reducing the number of wells necessary to make the field productive will reduce the operating costs and improve the overall performance. There are no actual innovative methods being employed. The only advancement for the geothermal community will be if McCoy becomes a productive field.

Reviewer 4:
The project motivations state an inferred potential in the project area and the need to better constrain the actual resource ―using a new strategy” to ensure ―the future of geothermal in the Great Basin.” The team ―is utilizing a suite of modern geophysical techniques” to try to pinpoint a deep geothermal source at the project site and has significant amounts of data (still to be archived at NGDS), but it‘s not clear that they have a unique strategy or plan to translate results into broader impact beyond the state-of-the-art at other sites.

Reviewer 51:
The outcome of the project is important to verify a new structural geologic concept for blind geothermal resource assessments. A previous DOE-sponsored exploration project in the area, from 1977-1982, resulted in over 50 thermal gradient holes drilled "that identified four thermal anomalies which were in turn tested with five wells between 1,000 ft and 2,500 ft, none recording a temperature greater than 101°C. At the time, geothermal exploration was driven by surface manifestations and serendipity." Blind geothermal resources are difficult to characterize without using "a full suite of modern geophysical and geochemical tools, use of slant-hole drilling" and other existing information. "In the absence of hot springs or fumaroles, a chance encounter with hot water or abnormally high temperature gradients and subsurface temperatures, either through mining exploration or water well drilling, was required to initiate a broader exploration effort." Costs may be reduced by better location of the drilling sites; however, the reviewer did not find strong arguments that the temperature of the fluids will reach the optimal values. The project demonstrates the use of a combination of datasets. "Using modern geophysical and geochemical methods and a new geohydrologic model, our goal is to identify areas of potential upflow of hydrothermal fluids by combining independent data sets in a novel approach."

Comments Regarding Scientific/Technical Approach

Reviewer 41:
The technical approach being used for this project is not particularly innovative. Magnetotellurics (MT) and controlled source audio magnetotellurics (CSAMT) are industry standards; soil multi-gas is less common but not unusual. Gravity, ground magnetics and mapping are all standard tools.

Reviewer 24:
The synergy of multiple geophysical techniques is a robust way of improving the information known prior to expensive

drilling. It would have been helpful to see more of the data results to fully judge the technical approach. There were no new exploration technologies. The new drilling targets determined are broad areas. No seismic data was collected to identify specific features for drilling to intersect.

Reviewer 4:
No great flaws are apparent and a number of potentially useful techniques are employed, but it‘s unclear why the particular approach is most appropriate to the locale. Is a particular component of the approach providing the greatest insight (e.g., MT)? How have the techniques been combined in an innovative way to learn something that a single method would not impart?

Reviewer 51:
The approach is well thought and mostly effective in achieving the project‘s objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has room for improvement. For example, a strong case should be made, before drilling, that the expected temperature of the fluids will be large enough.

Comments Regarding Accomplishments, Results and Progress
Reviewer 41:
Project accomplishments seem to be reasonable based on the surveys completed to date and the problems with acquiring permits. The reviewer is unsure of the value for ground magnetics but no data was presented to illustrate its relevance. Buried in the summary was a comment on the hydrogeologic characterization of outflow zones and tracing that back to possible upflow—that would have been data worth presenting with more detailed discussion. There was no real discussion of exploration results and how they are used to site the angled temperature gradient wells.

Reviewer 24:
All targets have been met to this point. At least two possible general drilling targets have been identified. There was no discussion of go/no-go decision points. The project has not brought any innovative methods to the program. Two broad targets are identified, but no specific drilling targets which is a bit troubling.

Reviewer 4:
The MT results appear to reveal a promising connectivity structure. None of the existing wells penetrate this zone and it will serve as a target for exploration wells. There are real concerns about the outlook for completing the project due to permitting difficulties.

Reviewer 51:
The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for improvement. There are high quality accomplishments to date. Technical targets were met. The productivity can be assessed if the estimated models have predicted useful drilling sites.

Comments Regarding Project Management/Coordination
Reviewer 41:
The project does not seem able to be completed by January 2012, the project end date. However, it is reasonable that the schedule would slip due to permitting issues. The budget seems reasonable for the work completed to date. No other information on project management was presented.

Reviewer 24:
Permitting delays and improvements to the field such as new roads will delay completion of the project. Very little money has been spent, but the drilling program has not been initiated. Rather than focus on the authorization/permitting

challenges, the project leader should focus on what can be done in the meantime to improve the chances of drilling successful wells.

Reviewer 4:
The PI is clearly frustrated by permitting delays, but there isn‘t enough information to discern whether a strong strategy is in place to move past this hurdle. Without further details this seems like a significant risk to the ultimate success of the project.

Reviewer 51:
Management of this project has been very effective and/or plans for future management are well-structured and include all the appropriate and logically placed management checks and controls, however, minor improvements are desirable. For example, planning a statistical study to assess the probability of successful drilling, based on quantitative and qualitative integration of all datasets, would improve the chance of success. Any variance from the original plans/schedule resulted in a minor impact on the overall project.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:
This is a good project for DOE funding and is being completed by very experienced personnel. However, it is difficult to assess because no substantial data has been presented. While the reviewer appreciates the difficulties in acquiring permits and getting environmental documents approved, time may well have been better spent in presenting more detailed technical data that could be assessed. Most presentation slides had multiple maps that were not legible and certainly not sufficiently detailed. Summary slides such as Slide 4 were of little use in providing insights. The reviewer ended with no significant understanding of where any of the surveys had been completed or any sense of how the datasets had been jointly interpreted (with the exception of the CSAMT/MT which had a good graphic but again no detail)

Reviewer 24:
The project is far behind schedule but on budget, although the drilling portion has not been started. Work has been completed on the data collection and data analysis is being completed. The next stage is drilling of the two possible targets. A go/no-go decision was not discussed. No specific drilling target is defined. Only slim holes should be drilled at this point.

Reviewer 4:
Based on the project summary document, it appears that the MT survey has provided the investigators with new subsurface constraints that may reduce exploration risk and lead to knowledge of a more viable local resource. However, as presented, this seems like the result of an ad hoc application of several general geophysical techniques. If the project were presented as a case study for a suite of techniques, with clear conclusions about which approaches are most fruitful, it might make for a stronger case about reducing exploration risks at the project site and beyond.

Reviewer 51:
As the authors mention "McCoy is a high risk, high potential prospect." The exploration activities have identified drilling targets, however, before drilling, the reviewer thinks the authors should make a strong case for the existence of useful fluid temperatures.

Comments Regarding Strengths
Reviewer 41:
Overall the program looks like it was completed skillfully and with people that knew what they were doing. The new

geologic mapping looks good with good overall graphic presenting the CSAMT/MT data.

Reviewer 24:
The project combines multiple methods in an attempt to improve production results. Even if one method proves unproductive, other methods will hopefully provide the desired result.

Reviewer 4:

Reviewer 51:
Combining independent data sets is a novel approach. "Gravity and surface mapping provide the structural framework. CSAMT has mapped the shallow thermal aquifer in great detail, showing conformance to topography and the hydrological gradient. A forty-station MT survey on a 1-km grid identified multiple deep conductive structures feeding thermal fluids into the shallow aquifer. Several structures are identified as potential fluid conduits. Results from the soil gas survey may provide orientation of transmissive structures." The activities resulted in potential drilling targets being identified. "All on-the-ground exploration activities are complete. Data integration will continue. Three areas are identified as potential upflow zones and should yield at least two drillable targets, with two wells planned per anomaly."

Comments Regarding Weaknesses
Reviewer 41:
Lack of data that constrained the review included: no information on why temperature gradient wells were to be angled (assume some type of environmental constraints on access?); no indication of depths or well plans for the temperature gradient wells or how and where they will be drilled; no gravity data presented; no data from the multi-gas survey, the only innovative survey completed; and no legible data from the MT/CSAMT.

Reviewer 24:
Although not part of the project plan, it would likely have improved confidence and future drilling success to collect small 3D seismic profiles focused on the drilling targets to identify specific targets.

Reviewer 4:

Reviewer 51:
Is not clear from the materials presented at the meeting whether the expected temperature at the proposed drilling sites is expected to be over 200°C. This should be shown on page 6 in the presentation, however, the figures in the presentation are barely visible and have no axes labels or legends, which makes the evaluation very difficult.

Suggestions for Improvement
Reviewer 41:
Present more detailed data.

Reviewer 24:
If money is available, perform small seismic studies over the targets, or some other method, to focus the drilling.

Reviewer 4:

Reviewer 51:
Statistical analysis of the correlations between datasets should be performed to strengthen the arguments for potentially successful drilling sites.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1118
Presentation Title: Advanced Seismic Data Analysis Program ('Hot Pot Project') - Alytical Techniques of Coherency First Arrival Data Processing and Full Waveform Inversion Velocity Model and Validation by Drilling Wells
Investigator: Moore, Shuman (OSKI Energy LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 24:
The project is designed to reduce drilling risk by more accurately understanding the structures at depth prior to drilling. This is an important goal for the geothermal industry as it may result in improved performance and reduced operating cost and risk.

Reviewer 4:
Applying advanced data processing methods to enable the exploitation of data acquired using techniques common to the oil and gas industry is a very good contribution. However, in this case, lithology and exploration well control were still needed to calibrate reprocessing of the data. This tempers the impact of the method, in the sense that a priori subsurface knowledge will still be needed to produce valid seismic results.

Reviewer 51:
The project objective is of importance, since improving geothermal well target selection and reducing drilling risks are requirements for efficient geothermal energy production. Even if expensive, a high-resolution seismic survey in the right place can reduce the drilling costs. The problem, not addressed by the study, is finding the right place to investigate. An undetermined number of jobs have been supported: "No permanent jobs have been created to date. However, multiple temporary jobs have been provided to environmental, permitting, and geologic contracted service providers." The project is a classical, expensive approach to geothermal exploration, and it does not change any factor in geothermal energy development, except for being applied in a new area.

Comments Regarding Scientific/Technical Approach

Reviewer 24:
The project is using seismic processing to improve imaging of complex structures. Adjusting the velocity model to improve image resolution is not an innovative method. More information on the methods that are innovative would have been helpful. Combining gravity data to help constrain the potential target is a beneficial task.

Reviewer 4:
This is an unusually well-focused effort with the potential to further usability of seismic reflection data with broad applicability.

Reviewer 51:
The project uses indeed advanced analytical methods for interpreting seismic surveys, however, the novel aspect of this approach is questionable, and so is the cost-effectiveness. The seismic approach is in use and has been commercialized for at least 10 years with good results, thus is not new. The technical approach is sound, because an established method has been chosen, and more information than seismic has been used. This type of advanced reflection line analysis method has been applied successfully in other geothermal areas in Dixie Valley (DOE/ID/13465-T), thus the claim to innovation probably mostly refers to applying the method in a new area. The approach is well thought out and effective in achieving the project‘s objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has room for improvement. For

example, deployment and analysis of 25 miles of seismic surveys is not cost-effective. There is no mention of a method used to limit the amount of seismic analysis only to areas of interest.

Comments Regarding Accomplishments, Results and Progress

Reviewer 24:
The seismic processing resulted in improved resolution of the subsurface structure and helped identify faults as possible drilling targets. The project is behind schedule but should meet its goals.

Reviewer 4:
Seismic cross sections appear significantly improved over results from standard methods, but more details on interpretation and preliminary drilling plans would help clarify the potential contribution. Exploration wells are then needed to confirm the validity of the approach.

Reviewer 51:
The accomplishments, results, and outcomes have been good in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for improvement. Optim is a company known for professionalism, thus the quality of their data analysis is very good. However, they deploy their lines in locations most probably chosen by the client, and the client chose to deploy 25 miles of reflection lines "located primarily on the basis of shallow (500‘) temperature gradient results; 5-line survey grid was oriented for most probable fault directions based on (limited) published data." Using seismic and geological data was useful, as expected. However, the value of accomplishments is high, at high cost.

Comments Regarding Project Management/Coordination

Reviewer 24:
The project was delayed up to 8 months due to data processing and permitting issues. It appears to be on budget. Project leadership is applying the necessary steps, even if it results in a project delay, to properly process the data and get the best results. No discussion of go/no-go decision making. Management has begun addressing data sharing tasks.

Reviewer 4:
The project team made use of permitting delays to obtain additional constraints from private mineral exploration sources that proved critical to successful seismic processing. The team seems poised to provide data to the Geothermal Data Repository upon approval of Phase I.

Reviewer 51:
Management of this project has been very effective and/or plans for future management are well-structured and include all the appropriate and logically placed management checks and controls, however improvements are desirable. For example, decisions one where to survey should be made based on more geophysical information. There was a 6-month delay from original plans/schedule which was not corrected early, however, resulted in minor impact on the overall project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 24:
The project is attempting to improve subsurface imaging through the use of advanced seismic methods. It was not clear to the reviewer how innovative processing methods were used to improve the resolution beyond what traditional methods can do.

Reviewer 4:

This is a tightly focused effort that, if successful, would demonstrate a technique that is readily transferable to other sites. The team summarizes a key concern regarding the potential reach of the technique when they say that —advanced seismic data analysis – when calibrated with geologic input – successfully obtained interpretable data in an area of complex structure and variable lithology." That input included well control, so a priori subsurface information (drilling) will still be needed in each case to validate the method. So, it‘s not clear just how much risk is avoided.

Reviewer 51:
This is a classical exploration project, which has the potential of achieving good results, however at high cost.

Comments Regarding Strengths
Reviewer 24:
The project does combine gravity data with the seismic to help constrain the potential drilling targets.

Reviewer 4:

Reviewer 51:
The main strength is the use of Optim advanced seismic data analysis, which," when calibrated with geologic input - successfully obtained interpretable data in an area of complex structure and variable lithology."

Comments Regarding Weaknesses
Reviewer 24:

Reviewer 4:

Reviewer 51:
The reviewer does not understand why a well-established seismic exploration method is presented as a new analysis technique. The method is high cost, high resolution. The results still need to be validated by drilling.

Suggestions for Improvement
Reviewer 24:
If other geophysical data sets have been previously collected over the field, include those to improve confidence at minimal cost.

Reviewer 4:

Reviewer 51:
Take more precautions to limit the amount of funds spent for seismic surveys.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1119
Presentation Title: Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation
Investigator: Noel, Donna (Pyramid Lake Paiute Tribe)

Comments Regarding Relevance/Impact of Research

Reviewer 41:
This project is designed to evaluate the geothermal resource potential of the Astor Pass area. Evaluation of all potential geothermal areas is an important goal under the DOE Geothermal Technologies Program, and, as such, this was a viable project.

Reviewer 24:
The project aims to verify the usefulness of various innovative methods and improve reservoir characterization. This is a very important task for improving exploration capabilities and reducing risk and cost.

Reviewer 4:
It seems like a large list of techniques have been employed but it‘s not clear what the take-home message is or might be. Did one particular technique yield perceived strong constraints, or did an integration of specific techniques allow for interpretation that would not have been possible with a smaller subset of approaches? What was learned that will benefit future endeavors? It seems like there is potential for this to be teased out through iteration between the observational and modeling components of the study, so this could be outstanding if realized.

Reviewer 51:
The project has made modest progress and impact on the DOE Geothermal Technologies Program‘s (GTP) missions and goals. The project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate impact on factors in geothermal energy development. The project is designed to "provide guidance and cost-benefit of various exploration techniques to assess geothermal resource potential…and provide data to the DOE Geothermal Data Repository." The project addresses "site specific estimate geothermal power production and associated uncertainty" using a combination of geophysical methods. However, it is not clear that the whole study was even necessary because of the results of the project—drilling two very close wells within 100-300 meters of an old well and not being able to estimate whether the temperature of the fluids will be adequate for energy production. Using a set of conventional exploration methods increases the cost, however, assures better performance in drill site identification.

Comments Regarding Scientific/Technical Approach

Reviewer 41:
The technical approach to this project has some very serious problems. There was no discussion of the Phase 1 exploration results from a shallow temperature survey, very little data on the seismic survey and the fracture analysis has not yet been completed even though two wells have been drilled. There is no data from any previous exploration including a 1,500-foot well, other than a difficult-to-distinguish temperature profile. Most of the innovative technologies listed in slide 6 of the presentation have either not been completed or have not been reported. There is almost no data on the two +4,000 foot wells drilled—the borehole geophysics data is not legible so cannot be reviewed. There is no presented rationale as to why the wells were drilled where they were and specifically why they were drilled so close together. Where data has been presented, e.g., MT, it is illegible so that contour values, depths, and line profile numbers are known.

Reviewer 24:

The project team performed a number of non-traditional techniques for the geothermal industry. The presenter stated that an interdisciplinary team is critical to good success, which is very true. At the end of the project, discussing the benefits received from each method will be useful for the Geothermal Technologies Program as a whole.

Reviewer 4:
The approach, though not clearly focused, does qualitatively appear to have yielded rather clean results that are easily interpretable. How the team approaches the iterative modeling component will be telling of the ultimate impact of the project.

Reviewer 51:
Some aspects of the project may lead to progress in achieving project objectives and overcoming barriers/knowledge gaps but the approach has significant weaknesses and noteworthy areas for improvement. It is not clear if all the geophysical data collected was used to decide where to drill the wells: "Although well placement decisions had to be made using a preliminary geologic conceptual model, we feel that we have intersected key structural features within the Astor Pass geothermal reservoir." Thus, the next question is: if only the existing models have been used, what was the purpose of all the supplementary surveys? It is also not clear why the authors feel that well testing will improve the results: "Static fluid temperatures are approximately 10°C less than expected; we feel that fluid temperatures will exceed 100°C following well testing."

Comments Regarding Accomplishments, Results and Progress
Reviewer 41:
A significant amount of work appears to have been accomplished on this project but there still is a question as to whether a viable resource exists at Aster Pass. Regarding quality, the project team is certainly sufficiently qualified to complete the tasks, however, there appears to be a lack of understanding as to what is needed for a viable geothermal system. The exploration surveys seem to be disjointed and there is a lack of any overall consistent approach.

Reviewer 24:
No more go/no-go decision points are needed as the wells have been drilled. The remaining work is to finalize a conceptual model and begin well testing. The project is progressing well.

Reviewer 4:
Exploration wells seems to have hit their target, though temperatures are 10°C less than expected. The viability of the resource should be attainable from planned well testing and reservoir modeling.

Reviewer 51:
The accomplishments, results, and outcomes have been marginal in relation to the resources expended and progress towards project objectives and technical targets/goals. There is significant room for improvement. The project does not seem to be successful so far. Although the work has been done, the accomplishments are minimal when compared to the costs. There is no doubt that the quality of the scientific research per geophysical method is very good, however, the reason for performing the research is not clear. The novelty of the project consists in using multiple established techniques only—all the technologies mentioned on Slide 6 are already in use. There is no statistical analysis mentioned to assess the correlation between the results of different types of investigations and to help validate the set of methods. Actually, the results show low geothermal potential, and thus the question of whether the old well fluid temperature could have indicated this problem from the start. It is not clear how the method, if validated, will be useful to detect viable geothermal reservoirs if the results are not good so far.

Comments Regarding Project Management/Coordination
Reviewer 41:

Reviewer 24:
Stakeholders are being invited to the site to observe and ask questions. The project appears to be well run. The project is on schedule and on budget.
Reviewer 4:
This is a strong presentation of project management/broader impacts efforts, including planning an on-site media day, contributing data to another GTP project, and including data in the DOE Geothermal Data Repository and a project-wide database at UNR.

Reviewer 51:
Plans for future management are not well-structured and lack the appropriate and logically placed management checks and controls; improvements are required. Since the results of the project are not good so far, the PI should present a well-documented case to argue for further spending.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:
This project, using the data provided in the presentation, the summary report and statements from the presenters relating to data not presented, has not been successful unless a direct use project is envisaged at the site. Location of the two 4,000 foot wells, only 400 feet apart, is difficult to comprehend. The justification was that a monitoring well was needed for the flow test. If this well had not encountered reservoir temperatures (and there is not a temperature log to TD to demonstrate that it did) then the second well should have tested a different target on the project lands. There is nearly $1.8 million left in the budget and the use of those funds on tasks identified in Slide 16 of the presentation should be reevaluated. Continuing the well test for 60 days is UNJUSTIFIED for a ~100°C resource which is definitely not commercial or practical for power generation. Direct use projects do not justify such high budgets for well testing or fracture stress modeling. If this is to be a direct use project then that money could be much better used for other project activities. The approximate $850,000 in budget for 3D modeling and reporting is also not justified at this stage based on the reported temperature data. This urgently needs review and reprioritizing.

Reviewer 24:
The project aims to improve geothermal exploration and reduce risk and cost of development through examining innovative technologies. The reviewer does not feel that any of the methods are innovative or new.

Reviewer 4:
The project seems well managed and on track to determine the viability of the Astor Pass resource. It's not clear if/how the approach could be successfully replicated at other sites. The team expresses budding plans to iterate between data and models to begin quantifying uncertainties in particular methods that could ultimately translate into cost-benefit guidance. If some quantitative constraints result that future investigators can use to streamline their geophysical exploration approaches, this would be a valuable contribution. Careful thought about this component is encouraged.

Reviewer 51:
The project has required a large amount of funds, however, the materials presented at the review show minimal results in terms of the broader geothermal program mission and goals.

Comments Regarding Strengths
Reviewer 41:
This is a project team of competent individuals.

Reviewer 24:
The project is combining multiple methods to improve reservoir imaging. The combination of multiple methods will greatly help to reduce the potential risk from misinterpretation from a single method.

Reviewer 4:

Reviewer 51:
A strength of this project is the use of a variety of established geophysical exploration methods to characterize a geothermal reservoir.

Comments Regarding Weaknesses

Reviewer 41:
It is difficult for the reviewer to understand why three wells (2 x 4,000+ feet) should all be drilled so close together and close to an existing 1,500 foot well. Why are there no temperature surveys presented for any of these wells to TD. The presenter stated the temperature profiles in the presentation were to 500 meters (Slide 12). However, closer inspection with a magnifying glass shows the depths to be 500 feet. This needs to be clarified.

Reviewer 24:
The reviewer is unsure of the usefulness of the shallow 2 meter temperature holes. It has been used previously, but this method seems fraught with potential errors as shallow ground water flow, or other phenomenon, could distort the results. Utilizing multiple methods will help validate or contradict this method.

Reviewer 4:

Reviewer 51:
The innovative aspect of the project seems to be limited to an interdisciplinary approach, using commercial software or existing exploration methods. The reviewer wonders whether previously existing information would have been appropriate to assess that there is not enough geothermal potential in this region and whether an assessment was performed before the start of the project. It is not clear how the various pieces of geophysical information have been combined to estimate drilling sites and fluid temperature and how well testing would improve the results.

Suggestions for Improvement

Reviewer 41:
The reviewer suggests limiting the flow test on the existing well to no longer than 30 days—cease all other work and then reassess where this project is going so that future activities can be prioritized.

Reviewer 24:
Local EQ moment tensors are being used to understand the stress field, but installing a small seismic array to record induced seismicity is a low-cost method of measuring the stress in the field, while also obtaining other important information about the field.

Reviewer 4:

Reviewer 51:
Before proceeding with the rest of the project, a documented statement of why the authors think the well testing will improve the results should be required.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1120
Presentation Title: Application of 2D VSP Imaging Technology to the Targeting of Exploration and Development Wells in a Basin and Range Geothermal System, Humboldt House-Rye Patch Geothermal Area, Pershing County, Nevada
Investigator: Ellis, Richard (Presco Energy, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 41:
This is very relevant research used extensively in the oil & gas environment but less so in geothermal. Well cooling is a critical factor.

Reviewer 24:
The project is attempting to more thoroughly explore a previously studied field using techniques relatively new to the geothermal community. All methods have been used extensively in other fields. The seismic imaging methods did not produce clean/clear structural imaging in this case, but may show improved results in other fields. This project may result in improved knowledge of the structure at the field and may ultimately result in increased production and/or reduced cost.

Reviewer 4:
The study presents a qualitatively pleasing conceptual model with some constraints derived from seismic, gravity, and aeromagnetic surveys. The geologic setting is a common one and so improved interpretations could have a broad impact.

Reviewer 51:
The relevance and impact of this project are less than good. The project has made progress and impact on the DOE Geothermal Technologies Program's (GTP) mission and goals. The project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate impact on factors in geothermal energy development. Using a combination of classical geophysical exploration methods is the only innovative aspect of this project. Drilling cost reduction remains to be demonstrated. The project seeks to identify high-value drilling targets identified using a synergistic approach. No job creation information is available.

Comments Regarding Scientific/Technical Approach
Reviewer 41:
This project has a sound technical approach by people who know what they are doing.

Reviewer 24:
The team has thoroughly examined the seismic in addition to combining aeromagnetic and gravity data to help validate the prospect. Since the field has been heavily studied in the past, other geophysical methods may have already been well documented. The reviewer would encourage the researchers to include as many methods/data sets as possible in their interpretations.

Reviewer 4:
The techniques seems rather standard but the tying together of data into a nice conceptual model is encouraging. The models are qualitatively attractive but what are the associated uncertainties?

Reviewer 51:
The approach is well thought out and effective in achieving the project's objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has room for improvement; for example, low quality seismic data was used (there is no visible

fault in Slides 11-12) and the data is not statistically related to temperature.

Comments Regarding Accomplishments, Results and Progress

Reviewer 41:

The primary objective of the cooling well was not achieved due to the reheat capacity of the well—this will always be the primary barrier to any downhole geophone deployment. Rye Patch is not the hottest of systems that could benefit from VSP so there is a need for equipment redesign for such temperatures. The project circumvented this problem and came up with results that still significantly improved the understanding of the system.

Reviewer 24:

The project appears to be on budget and have progressed quite far toward reaching its goals, but from the presentation it wasn't clear whether they are on schedule. All go-no/go decision points have passed. The quality of the work is good.

Reviewer 4:

Reviewer 51:

The accomplishments, results, and outcomes have been good in relation to the resources expended and progress toward project objectives and technical targets/goals. There is room for improvement. High quality results were obtained, however, it is not clear, considering the low quality of the seismic data, what the errors are of the method.

Comments Regarding Project Management/Coordination

Reviewer 41:

There is an excellent summary of the budget and schedule on Slide 2. This incorporates the original statement of project objectives (SOPO) schedule so a comparison could be made. The reviewer suggests that all budgets and schedules can be put onto to one graphic—use this as a template. There was little indication of contractors, collaborators and how they contributed to the project. More information than that shown in the schedule would have been useful.

Reviewer 24:

This topic wasn't well addressed in the presentation. The slide on this was unreadable. Based on the progress of the project, the reviewer is inferring that it is being managed well.

Reviewer 4:

The project seems to be moving on a successful track.

Reviewer 51:

Management of this project seems to have been effective and plans for future management include all the appropriate and logically placed management checks and controls. There is not enough information to assess whether any variance from original plans/schedule were corrected early and resulted in minor impact on the overall project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 41:

Even though the presentation did not follow the prescribed format, in the reviewer's opinion this is by far the best presentation seen at the DOE Review and would recommend it to be used as a template for the future. There are excellent, clear graphics that allow the reviewer to understand what has been done, very high quality technical work by people that know what they are doing and very valuable results for understanding the structural controls on the system, even though not all of the research goals could be achieved (wellbore cooling).

Reviewer 24:
The project goal is to better define the possible resource at Humboldt-House Rye Patch geothermal field using various seismic methods. The project has developed a new conceptual model and identified possible new drilling targets. The reviewer believes the project is progressing well and has excellent potential for improved production. Even though the presentation did not follow the prescribed format and it was difficult to judge the schedule, budget, and management, the reviewer liked having more scientific information provided. This made judging the technical merits of the project easier.

Reviewer 4:
This is a seemingly strong integration of standard geophysical techniques to produce an above-average conceptual model of a common geothermal resource setting. This seems good, but it would help to see how data were tied together and what lessons can be applied elsewhere. The project is fairly advanced in its timeline but it's not clear what plans are in place for data sharing.

Reviewer 51:
The project has produced a reinterpreted conceptual model and drilling locations have been identified, however, not yet validated. The error margins in the conceptual model need to be estimated. The use of a variety of geophysical techniques is the only innovative aspect of this project.

Comments Regarding Strengths
Reviewer 41:
The primary strength of the project appears to be the integration of multiple datasets producing a comprehensive interpretation and understanding of reservoir structure. Since this is a proven resource with existing production wells, there were more opportunities to interpret the data than may exist in a green field setting. However, there were substantial improvements made to the structural interpretation that could significantly improve the risk associated with additional drilling.

Reviewer 24:

Reviewer 4:

Reviewer 51:
Seismic sensors are configured as a vertical array. A synergistic approach is used to identify high value targets resulting in a new conceptual model for the area.

Comments Regarding Weaknesses
Reviewer 41:
No major weaknesses noted.

Reviewer 24:
Relying so extensively on the seismic data, especially when the results were not completely clear, may have introduced some interpretation difficulties and reduced confidence in the drilling potential.

Reviewer 4:

Reviewer 51:
The seismic survey does not provide proper fault imaging, and the wells do not show fault evidence, thus the interpretation may be questionable.

Suggestions for Improvement

Reviewer 41:

A mechanism is still needed for cooling wells for geophone deployment.

Reviewer 24:

Include all available geophysical and other data in the development of the potential drilling targets and conceptual model.

Reviewer 4:

Reviewer 51:

Better seismic survey processing would probably improve the interpretation. A presentation following the DOE guidelines would be useful for the next review process.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1121
Presentation Title: The Snake River Geothermal Drilling Project: Innovative Approaches to Geothermal Exploration
Investigator: Shervais, John (Utah State University)

Comments Regarding Relevance/Impact of Research
Reviewer 32:
This project demonstrates good geothermal/conceptual model research objectives in basaltic terrain but the resource temperature is likely too low.

Reviewer 24:
Although the project's innovative methods likely won't improve geothermal exploration, the project is very important as its goal is to identify new/blind geothermal fields in the Snake River Plain. Being able to produce geothermal energy from this very large, moderate-temperature region would go a long way to meeting future geothermal energy goals even if some sources can only be used for direct heating.

Reviewer 4:
The potential for better characterizing a new resource type in a broad area of high heat flow seems like the best early-stage development the Geothermal Technologies Program (GTP) could hope for.

Reviewer 51:
The project has made notable progress and impact on GTP‘s mission and goals. The project has demonstrated significant advancement in addressing knowledge gaps and barriers. The project has considerable impact on factors in geothermal energy development, however, it seems defocused because it has a lot of objectives, and it is not clear how the different techniques are integrated. A positive outcome of this project would help "understand the distribution of elevated heat flow in the Snake River volcanic province and its relationship to the volcanic history and stratigraphy; document the presence of previously unrecognized thermal anomalies in a greenfield geothermal district; and …document the application of seismic, magnetic, and gravity surveys to discovering these blind geothermal anomalies within the province." "Southern Idaho is a region of vast untapped potential in a setting that is not currently being investigated by industry…" with "…blind or previously unrecognized geothermal resources in a region with documented heat flow amongst the highest in the continental United States." The project documents "innovative new ways of finding blind or previously unrecognized geothermal resources in a region with documented heat flow amongst the highest in the continental United States."

Comments Regarding Scientific/Technical Approach
Reviewer 32:
This is a highly qualified team, gathering almost all of the right data. More justification is needed of why this terrain might work. Previous Snake River Plain deep wells suffered from low permeability due to diagenesis plugging porosity and lack of deviatoric tress to support or induce fracture flow. One possible hypothesis that might be useful in supporting a fracture flow at depth argument is the convergence of stress fields in this area related to the intersection of the thermal (SRP) and tectonic and thermal (WRP) subsidence stresses. It might be possible to estimate critically stressed volumes and geometries at geothermal depths using these assumptions.

Reviewer 24:
The team appears to have applied a full suite of relevant technical methodologies in attempting to answer many questions. They identified a number of potential targets based on sound research and hypotheses.

Reviewer 4:
The innovative techniques appear to hinge on downhole capabilities (bottom hole temperature tool, acoustic televiewer, VSP). Existing geologic and geophysical data are used to define drilling targets. More details on how the test well locations were chosen would help.

Reviewer 51:
The approach is good, however, it has plenty of room for improvement. For example, it is not clear whether a rigorous statistical approach will be used to derive a baseline model and how all the available geophysical data sets will be integrated with the heat flow data, and related to geothermal exploration requirements.

Comments Regarding Accomplishments, Results and Progress
Reviewer 32:
There are some good data with good quality coming out that will be useful in generating and testing conceptual models and perhaps leading to a resource elsewhere in this type of terrain.

Reviewer 24:
The project appears to be very close to on schedule and on time. All go/no-go decision points have been met. The project is in the later stages and drilling is being completed. Once this is done, it will be determined whether the SRP has potential as a geothermal resource and whether blind fields could be identified. The overall success of the project will not be known until the well analysis is completed, but it appears that all goals will be met.

Reviewer 4:

Reviewer 51:
The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress toward project objectives and technical targets/goals. There is room for improvement. It is unclear what the success measures are on this project. The drilling is presented as a successful operation, however, there is no discussion of the utility of the drilling results. The high quality accomplishments are also at high cost.

Comments Regarding Project Management/Coordination
Reviewer 32:
There has been good coordination given the scientific nature of the work and academic predisposition to wander off.

Reviewer 24:
The project appears to be very well run and organized with participating organizations. Delays were encountered, but management made adjustments to maintain the schedule.

Reviewer 4:
This is a large and complex project, but it seems well managed, e/g., management software, dedicated management support at DOSECC, daily site reports, weekly conference calls, coordination with Boise State and SMU, and data uploaded into ICDP Drilling Information System (DIS), which is captured by NGDS.

Reviewer 51:
Management of this project has been effective, however, improvements are desirable. For example, a detailed analysis of the utility of data from each drill hole for the project goals should be assembled and presented before proceeding with more drilling.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative.

Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 32:

Reviewer 24:
The project goal is to identify new/blind geothermal fields in the Snake River Plain, which has not received extensive past exploitation. Being able to produce geothermal energy from this very large region would go a long way to meeting future geothermal energy goals. The project is well on its way to meeting its goals of defining the SRP potential.

Reviewer 4:
This project clearly strives to present the potential for a large impact on the geothermal sector, going beyond characterization and/or development of a specific, localized resource–one of the best early-stage developments the GTP could hope for. The collaboration joins a large group of highly qualified investigators whose contributions appear to be well integrated. It would be interesting to see a conservative estimate of the potential resource yield, and to know more details about the potential for development in the face of any land use or other possible regulatory issues.

Reviewer 51:
This is a project of high interest. Understanding the relationship between heat flow and other geophysical parameters is important for identification of geothermal prospects.

Comments Regarding Strengths

Reviewer 32:

Reviewer 24:
The project has a diverse set of highly skilled team members, and a broad range of geophysical methods were used.

Reviewer 4:

Reviewer 51:
The use of a combination of geophysical exploration techniques is innovative. Although effectiveness of these methods is not discussed in the report, they may be effective in new geothermal anomaly identification. Jobs created: 5 full-time graduate students,6 full-time Staff Geologists, 3 part-time Staff Geologists,1 administrative assistant, 3 undergraduate technicians,11 Drillers, and 1 FTE supervisor (3 positions).

Comments Regarding Weaknesses

Reviewer 32:

Reviewer 24:

Reviewer 4:

Reviewer 51:
The project area seems quite large: 200 by 150 km for a detailed investigation. It is not clear whether the fluid temperature in the test wells was successful and if the results are interpreted in terms of heat flow and geothermal potential.

Suggestions for Improvement

Reviewer 32:

Reviewer 24:

The SRP is a unique feature, but it is very large and could potentially host a large number of geothermal sources. Developing a thorough conceptual model explaining which features hold the most potential will be very important to the future development of the SRP.

Reviewer 4:

Reviewer 51:

The current approach seems defocused because it is not clear how the different techniques are integrated to accomplish the several objectives of the study. A report stating how the project is addressing each of the many objectives should be provided to the sponsor.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1122
Presentation Title: We propose to explore and commercially develop ―blind" (no surface evidence) convective hydrothermal systems associated with a young silicic pluton on the flanks of Newberry Volcano, Oregon.
Investigator: Waibel, Albert (Newberry Geothermal Holdings, LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 24:
The goal of the project is to detect potential blind geothermal fields through the combination of traditional and novel geophysical methods. The methods are being tested at Newberry Volcano, Oregon. If the combination of methods proves successful, it will allow geothermal production from a large area that has a very high-temperature heat source, yet has not been successfully developed to this point.

Reviewer 9:
If successful, the project will contribute to both objectives of the Innovative Exploration Technology program—it will develop/test innovative technologies and it will contribute to increase the geothermal resource base.

Reviewer 4:
This project has good intent to test repeatable techniques for low-risk characterization of a novel geothermal resource type with potential broad applicability.

Reviewer 51:
To date, the project has made modest progress. Identification of geothermal resources with no surface manifestation is important. The project provides "an exploration methodology for identifying hot plutons with no surface expression and their associated geothermal systems." Addressed challenges are "blind resource areas (no surface features such as hot springs, fumaroles, faults, surface geochemical sampling targets) and a deep water table." The method is useful for testing "a reliable combination of exploration techniques to identify and develop blind hot plutons and geothermal resources in young volcanic terrains" and for identification of "… the best series of exploration tools that can expeditiously and economically locate blind hot plutons and associated geothermal convections cells."

Comments Regarding Scientific/Technical Approach

Reviewer 24:
Although none of the individual reservoir characterization techniques will likely prove revolutionary for the geothermal industry, finding a way to combine such a large and diverse set of methods for reservoir characterization will be important for reducing drilling risk and possibly field development costs. The reviewer finds no fault in the research approach/plan.

Reviewer 9:
This project builds upon a substantial amount of pre-existing information. In order to fully appreciate the value of the novel techniques that are being applied, a point should be made that in the final report it be clearly defined how the old information guided the application of the new techniques, and how these helped filling the information gaps and helped complete the system's 3D model.

Reviewer 4:
The geophysical toolbox employed includes standard as well as lesser-used techniques (i.e., Light Detection And Ranging (LIDAR), advanced geochemistry). Some examples to gauge expectations would help, as will clear reporting about the relevance of particular approaches upon completion of the project.

Reviewer 51:
The approach is well thought out and effective in achieving the project's objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good so far, however the project started one year ago and is only 10% completed.

Comments Regarding Accomplishments, Results and Progress
Reviewer 24:
The project was delayed one field season due to a late budget release (according to the presenter). It is in early stages and it is too early to rate the quality of the results. The progress appears good, although somewhat behind schedule.

Reviewer 9:

Reviewer 4:
LIDAR has enabled tying together a number of aspects. Progress has been delayed and results don't really enable saying much about the potential for success of technology transfer at this time.

Reviewer 51:
The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress toward project objectives and technical targets/goals. There is room for improvement. Very little research has been conducted; it is hard to comment.

Comments Regarding Project Management/Coordination
Reviewer 24:
There have been delays due to budget issues, permitting, and weather. Final verification well drilling may be a year behind original schedule. It is still early in the project and drilling, but it appears to be on budget. The team seems to be making a concerted effort to include all parties in the planning/progress.

Reviewer 9:

Reviewer 4:
Permitting successes, coordination with the ongoing enhanced geothermal system (EGS) demonstration project, and internet conferences, public meetings, and newsletters all suggest sound management. Delays have led to postponing many of the geophysical analyses.

Reviewer 51:
Management of this project has not been effective, and it is not clear why the scheduling issues, permitting delays and drilling delays could not be solved in one year. Although plans for future management are well structured and include all the appropriate and logically placed management checks and controls, improvements are desirable. Variances from original plans/schedule were not corrected early, however, resulted in minor impact on the project mission.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 24:
The project's goal is to combine eight methods of reservoir characterization to locate and produce from Newberry Volcano. Regardless of the success of this project, the final result should provide important information on the potential success of each method, and more importantly, the potential of combining the various characterization methods.

Reviewer 9:

Reviewer 4:
There is good intent here to improve methodology for characterizing young volcanic geothermal resources, with application to many other settings. The practical nature of the Newberry case study (location of shallow hot rocks is known, accessible to infrastructure such as transmission and roads, location is legislatively designated for geothermal exploration) is an additional strength for the local effort. More details on what was learned from which (combinations of) geophysical techniques will improve the potential for technology transfer beyond Newberry. For example, if the team learns that LIDAR or gravity or another particular technique(s) (as opposed to a blanket application of an arbitrary suite of methods) are capabilities worth applying at other similar locations, that could be broadly beneficial.

Reviewer 51:
Although one year into the project, the work is just starting, thus an appropriate project result evaluation cannot be made at this time. The intentions are good and feasible, as it was probably already decided by the proposal reviewers.

Comments Regarding Strengths
Reviewer 24:
Combining an array of exploration methods generally results in improved results and reduced risk. The combination of methods is being tested at a well-known site with enormous geothermal potential.

Reviewer 9:

Reviewer 4:

Reviewer 51:
This is a well-structured scientific study.

Comments Regarding Weaknesses
Reviewer 24:
A microseismic array is shown in the Powerpoint presentation, but not covered in the talk. The array design should be carefully evaluated to determine if it will provide the necessary information. If a single array is used, it should be installed near the depth of the expected seismicity. If high temperatures prevent this, a carefully designed surface seismic array should be employed.

Reviewer 9:

Reviewer 4:

Reviewer 51:
There have been significant project delays.

Suggestions for Improvement
Reviewer 24:
A goal of the project, regardless of its outcome, should be to thoroughly document the interplay of the various geophysical techniques. Which were most technically effective and which were the most cost effective? Which the least? Is there a specific combination of methods that provides the most relevant information?

Reviewer 9:

Reviewer 4:

Reviewer 51:
This project could perhaps use better management.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1123
Presentation Title: Crump Geyser: High Precision Geophysics & Detailed Structural Exploration and Slim Well Drilling
Investigator: Casteel, John (Newberry Geothermal Holdings, LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 24:
The benefits of the Flowing Differential Self Potential (FDSP) method will be determined during the upcoming Phase II. This tool may be better able to identify fluid pathways, which could result in improved production, although a well must be drilled for the tool to be used. The final result of the project could be the development of a new geothermal field along with a new tool for reservoir characterization.

Reviewer 40:
This is a —new” resource with comprehensive geophysics. The project will test the use of an FDSP. This is a similar structure to other places in the region. There are well-integrated geophysics and potential for a resource (actually, the resource has been drilled before so not quite new).

Reviewer 4:
A lesser-used technique (FDSP) is discussed, but the benefits over the current state-of-the-art aren‘t yet clear. This could be a truly innovative method, and the team does make the case that if successful their approach would be applicable over large regions with similar geologic settings in Oregon and Nevada.

Reviewer 51:
If successful, the project would "demonstrate the application of high precision geophysics for well targeting" and would "demonstrate utility and benefits of sump-less drilling for a low environmental impact." The project aims to answer the challenge of reducing exploration costs.

Comments Regarding Scientific/Technical Approach

Reviewer 24:
The project team has applied traditional approaches to develop potential drilling sites. Detailed results of the high-resolution techniques were not well expanded on in the presentation, but they are appropriate for exploration of the field. The potential of the FDSP will not be known until the completion of Phase II.

Reviewer 40:
This project includes a comprehensive exploration plan with drilling as confirmation. It has good use of geophysics. Seismic interpretation looks odd; shows approximate position of faults rather than precise mapping. The seismic on the mountain side is poor quality and may be due to issues with statics as well.

Reviewer 4:
The approach couples known geophysical techniques with more unique methods (FDSP, sump-less drilling), but more details would be needed to evaluate how those additions benefit the project.

Reviewer 51:
The technical approach is correct, however, the results are not clearly presented.

Comments Regarding Accomplishments, Results and Progress

Reviewer 24:
All Phase I tasks have been completed including data interpretation, except for one data set. A comprehensive 3D model has been developed and two possible well sites have been located. The stage-gate review has passed and Phase II has begun. The progress is good and the project appears that it will meet its goals.

Reviewer 40:
The project has shown good progress with most to be spent on the upcoming drilling. It has useful discovery of previous data to save additional wells.

Reviewer 4:
Accomplishments seem impressive, including acquisition of most geophysical datasets and building of a 3D geologic model, saving money by finding an existing TG well and drilling an exploration well at no cost to DOE, and siting of slim wells. What was learned from the exploration well, and is there demonstrable need for slim wells to augment this? Is there any sense of whether the goal of finding 260°F and 300°F reservoirs can be met?

Reviewer 51:
The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for improvement. It is not clear, besides completing most of the surveys, what the accomplishments are in relation to the project goal of discovering "new 260°F and 300°F geothermal reservoirs in Oregon."

Comments Regarding Project Management/Coordination
Reviewer 24:
The project is possibly ahead of schedule and on budget. Management is running the project well. Go/no-go decision points are in place before drilling each well.

Reviewer 40:
The project is co-managed between Ormat and NGP; they seem to have a plan in place. The presenter did not mention any problems. The project team hasn‘t spent that much yet.

Reviewer 4:
Frequent meetings and use of existing software resources are good. The team appears prepared to adhere to data sharing requirements.

Reviewer 51:
Management of this project has been effective and plans for future management are well structured and include all the appropriate and logically placed management checks and controls.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 24:
The project aims to use high-resolution geophysical methods to reduce development cost and reduce risk at Crump Geyser, Oregon. Stage 1 has been completed and the drilling of two slimhole wells is set to begin to confirm the existence of high-temperature fluids. The project is likely to meet its goals of looking for high-temperature fluids near Crump Geyser.

Reviewer 40:

The project includes a fair amount of data and a conceptual model. It is worth going to the next step.

Reviewer 4:
The project seems to have good potential in applying well-tested and newer techniques to a setting that could be replicated more broadly across Oregon and Nevada. It will help to learn how the specific suite of methods chosen (in particular FDSP) influences the trajectory of the project.

Reviewer 51:
Except for the information that Phase I of the project was completed, there is no other indication that the project has accomplished the initial goals. No information on the results of well drilling is provided. More drilling is planned, probably in locations chosen based on a baseline model derived from existing information.

Comments Regarding Strengths
Reviewer 24:
The project has mainly been performed on private land, reducing the need for permitting, which has slowed the progress of many other projects.

Reviewer 40:
This project has demonstrated pretty good well control and a fair amount of geophysics.

Reviewer 4:

Reviewer 51:
The project uses a combination of multiple techniques to estimate well location. It has a good project plan, management, and some notable results.

Comments Regarding Weaknesses
Reviewer 24:

Reviewer 40:
Despite the well control, most are shallow and the model has some significant risk. Seismic interpretation (and or data) may be off. Isotherms are speculative.

Reviewer 4:

Reviewer 51:
Only 0.5 jobs were created. There is only qualitative analysis of data by overlying; no rigorous statistical analysis was conducted. The seismic data is of low quality. There is no information on exploration well success or method success. Only 0.61 jobs were created.

Suggestions for Improvement
Reviewer 24:
It is important for all projects in this track, including this one, to fully document the exploration methods used, how effective they are (both technically and cost-wise), and what pitfalls other exploration groups may encounter. Sharing this information with the geothermal community will be critical to improving the methods used and reducing future exploration costs.

Reviewer 40:

Reviewer 4:

Reviewer 51:
Improve seismic line interpretation and robust statistical analysis of the data.

Low Temperature, Co-Production, Geopressured Demonstration

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0800
Presentation Title: Beowawe Bottoming Binary Project
Investigator: McDonald, Dale (Beowawe Power, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 29:
This is not new territory for the industry; for example, there is a binary bottoming plant at Brady's Hot Springs. This is a new technology for TAS so that company benefits from DOE's support. Impacts on production well rate of temperature decline and injection well plugging would be good information for the industry. Heat exchanger fouling rate on spent brine is also good information.

Reviewer 20:
This project will likely accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 gigawatts (GW) of capacity by 2020. It produces additional power from an existing brine waste stream thus saving money over development of new geothermal sources and reduces risk. It is over budget with respect to cost of installation and the shipping cost of the unit but DOE contribution is unaffected; cost overrun could have a significant effect on transfer of technology to other similar operations. It provides a good test of scaling potential for similar brine in other operations, and it adds to the database of power generation from binary plants.

Reviewer 32:
There is really not a lot new but operating experience could be useful in justifying similar efforts at non-DOE supported plants. This would not be cost effective at this point without DOE support.

Reviewer 22:
Increasing plant efficiency is very important and the addition of a bottoming cycle is stated by the PI to do that. The PI states that "first-of-its-kind equipment design" will be used but no description of what makes this "first-of-its kind" actually different than a bottoming cycle using conventional ORC technology. From the material presented and the presentation, it appears that this equipment is a first for the vendor of the unit and not a new and novel development. There are several IRC bottoming cycles being used.

Comments Regarding Scientific/Technical Approach
Reviewer 29:
It would be important to not only track the decline of resource bottom hole temperature from the time the bottoming plant came on line, but to compare the decline rate to the decline rate prior to the bottoming plant beginning operation.

Reviewer 20:
The PI may have over-stated the uniqueness of the design as it is only unique to the particular manufacturer used; it is not a one of a kind binary unit. The overall technical approach is sound; the design was based on an analysis of the appropriate parameters—available brine and ambient conditions, required plant tie-ins, scaling potential, voltage level, makeup water, permitting, space requirements, and economic feasibility. A pre-injection brine analysis should also have been performed, but scaling has not proven to be a problem.

Reviewer 32:

Detailed, documented and publicly available operating experience may be useful but the presentation indicates that reporting may be "pro forma" and does not encompass all relevant and potentially useful data as seen from a scientific perspective.

Reviewer 22:
The drawing of the system shows a conventional ORC setup. No technical data is given to demonstrate how this system is better than any other ORC system. From the given data, the efficiency of 1.5 MW from 3,900 gallons per minute (gpm) is comparable to many bottoming systems. Since the system has been designed and fabricated, some up-front design analysis to support the efficiency increase statement would validate the scientific/technical approach.

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
Bringing the power plant on line is an outstanding accomplishment.

Reviewer 20:
Accomplishments, results, and outcomes have been good in relation to the resources expended. The project has only been in operation for 3 months of the expected 2-year performance period, however, it is generating power above expectations—1.8 MW vs. 1.5 MW expected. The total power output from the operation has increased by 20%. The reduced injection temperature has not resulted in any scaling problems; a minimal amount of makeup water was required.

Reviewer 32:
The lack of high-quality injection well and plant efficiency monitoring data details are causes for concern.

Reviewer 22:
99% of the project is stated to be completed and no results are presented. Presentation of design analysis, facility layouts, or any supporting data would assist in determining accountability. The 99% must be the percent of the budget, not of the work, since over a year remains on the project. This final year is probably of the most value since it will include the operational data if it is not held under the proprietary banner.

Comments Regarding Project Management/Coordination
Reviewer 29:
Congratulations on getting the plant on line ahead of schedule!

Reviewer 20:
Project management has been exceptionally effective. The significant budget overrun was absorbed without a slip in the schedule. The management plan was solid. Phase III reporting is now set to commence and the reporting plan (type of data and frequency) appears appropriate. Collaboration has gone smoothly. The project has created the equivalent of 24 FTE jobs. .

Reviewer 32:
the project was well run from an economic/management perspective and the commitment to completion in spite of increased costs are to be commended, but given the level of DOE support and known objectives, more and better reporting could have been done.

Reviewer 22:
The project appears to be on schedule which gives credibility to the project management team and their coordination.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative.

Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
It is outstanding that a power plant was actually brought on line, and it is important to follow this up with complete reporting on heat exchanger fouling plus impacts on production and injection wells.

Reviewer 20:
This project will likely accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 GW capacity by 2020.

Reviewer 32:
The apparent lack of commitment to recording and presenting monitoring data may be reflected in the fact that there are no publications or presentations associated with this project.

Reviewer 22:
The project appears to be on schedule to provide information to address the project objectives. The lack of supporting information on the uniqueness of the bottoming cycle leaves some question as to its place in filling in some of the knowledge gaps. Hopefully operational data will supply this information at a later date. Need to put in the final document the analytical data that supports the stated results. This is a first of its kind for TAS, not the industry. It appears that if no novel concept is being developed, then the project is just a development program for a private company under which a lot of the valuable information generated may remain under the proprietary banner.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
The project is generating power above expectations—1.8 MW vs. 1.5 MW expected; total power output from the operation has increased by 20%. The reduced injection temperature has not resulted in any scaling problems. Project management has been exceptionally effective.

Reviewer 32:
This is a committed management team able to overcome engineering and economic challenges.

Reviewer 22:
The three areas of project strengths are the project team, the maintenance to the schedule and the presence of a significant resource.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
Cost overrun with respect to the cost of installation and the shipping cost of the unit could have a significant effect on transfer of technology to other similar operations. Presentation may have over-stated the uniqueness of the design as it is only unique to the particular manufacturer used.

Reviewer 32:
There is not enough engagement or lack of commitment to record depth and breadth of monitoring data that would most benefit DOE.

Reviewer 22:
There do not appear to be any new developments in the equipment area.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
A pre-injection brine analysis should also have been performed, but scaling has not proven to be a problem.

Reviewer 32:
Present more monitoring results such that other operators could assess economics and DOE could evaluate for future research.

Reviewer 22:
The project is over 2 years into the schedule and the budget is nearly spent, so there is little room for improvements. More robust reporting on the "first-of-its-kind-equipment," even in general terms, would add significantly to the value from this project. From the presentation, this is a vendor's first, not the industry's. Separating the efficiency of the main plant from the bottoming cycle would add credibility to the worth of the "first-of-its-kind-equipment." The real point is the increase in efficiency from the bottoming cycle compared to other bottoming cycles, not the overall plant efficiency. Full disclosure of the equipment would add credibility to the claims (appears to already have patent protection).

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0801
Presentation Title: Dixie Valley Bottoming Binary Project
Investigator: McDonald, Dale (Terra-Gen Sierra Holdings, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 29:
This is about the same as Beowawe, so there is little added benefit from the power plant except to equipment providers. Impacts on production well rate of temperature decline and injection well plugging would be good information for the industry. Heat exchanger fouling rate on spent brine is also good information.

Reviewer 20:
This will likely accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 gigawatts (GW) of capacity by 2020. The project produces additional power from an existing brine waste stream thus saving money over development of new geothermal sources and reducing risk. It provides a good test of scaling potential for similar brine in other operations, and adds to the database of power generation from binary plants.

Reviewer 32:
"Much was learned from the Beowawe project." What exactly was learned and how much did it impact cost and technology development? Is this likely to be $3 million per megawatt (MW)as well?

Reviewer 22:
The project goals, if completed, may advance the DOE Geothermal Technologies Program (GTP) mission and goals but it is too early in the project to quantify this impact.

Comments Regarding Scientific/Technical Approach
Reviewer 29:
The real benefit will come from data regarding production well decline, injection well plugging, and heat exchanger fouling. If instrumentation needs to be added to track these closely, then the instrumentation should be added prior to the plant being brought on line. Data on the power plant design and operation will be of limited value to the industry, although since DOE funded the project that data should be made available as well.

Reviewer 20:
The presentation may have overstated the uniqueness of the design as it is only unique to the particular manufacturer used; it is not a one-of-a-kind binary unit. The overall technical approach is sound. The design was based on an analysis of the appropriate parameters—available brine and ambient conditions, required plant tie-ins, scaling potential, voltage level, makeup water, permitting, space requirements, and economic feasibility. A pre-injection brine analysis should also have been performed; For a 5 megawatt (MW) plant, , which will be air-cooled, a greater seasonality swing in performance must be expected vs. the Beowawe project.

Reviewer 32:
Given the integration of potential lessons learned from Beowawe, it was surprising that these lessons were not highlighted as showing ability to meet DOE objectives.

Reviewer 22:
The goal of the demonstration a "first-of-its-kind equipment" to produce 5 MW from 8,500 gpm is a good target. The areas where the contractor is to focus some analysis (brine, voltage, economics, etc.) will contribute knowledge to the

geothermal community, if all results are shared. This project appears to be a size extension of the Beowawe project conducted by the same team and also funded by DOE/GTP. What new scientific/technical developments and information is to be developed that is not to be developed in the other project?

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
Progress seems to be proceeding on track.

Reviewer 20:
Accomplishments, results, and outcomes have been adequate in relation to the resources expended. Engineering design is complete, permits have been obtained, however, construction only began in April 2011.

Reviewer 32:
The project is only 30% complete. The context with respect to Beowawe‘s estimate of $3 million per MW is essential but not detailed in the presentation.

Reviewer 22:
Accomplishments that are stated would be significant if there were some supporting data given. It is understood that no operational data is available, but there should be something from the engineering task that could be presented to show encouragement that this new system will provide an efficiency increase over other bottoming cycles. See scientific/technical comment above for comparison with Beowawe project.

Comments Regarding Project Management/Coordination
Reviewer 29:
Terra-Gen has performed well with a good team.

Reviewer 20:
Project management has been exceptionally effective. The significant budget overrun was absorbed without a slip in the schedule. The management plan was solid. The reporting plan, including the type of data and frequency, appears appropriate. Collaboration has gone smoothly to date at the onset of construction. There is a solid plan to make tie-ins to the existing plant during the October 2011 outage.

Reviewer 32:
Detailed lessons learned from Beowawe would have been a scoring opportunity. A plan for how the lessons learned from Beowawe and detailed discussion on technical data use for economic improvements for other plants would be useful or even essential with respect to DOE‘s mission.

Reviewer 22:
The tasks presented in the proposed schedule appear to be being accomplished on a timely basis. This reflects on the positive execution of a good management plan and the coordination within the project team.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
Doing this project in addition to Beowawe is of limited value other than impact on production well decline, injection well plugging, and heat exchanger fouling. It is important that this data be complete and clearly presented.

Reviewer 20:
This project will likely accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 GW capacity by 2020.

Reviewer 32:
Most comments on Beowawe bottoming (0800) apply here as well, especially the lack of detail and depth of monitoring data except that only 30% has been completed.

Reviewer 22:
The management of the project is on track and if it progresses as it has, it should provide input to some of the gaps in the present geothermal knowledge base. It is very hard to give anything but a fair to good rating to the project to date because there is no supporting data given from the feasibility and engineering studies that have been completed. This project appears to be just another verification test for the system developed for the Beowawe project.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
Project management has been exceptionally effective.

Reviewer 32:

Reviewer 22:
The areas of strength are the project management team, the realistic schedule and the significant size of the resource to test.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
The presentation may have overstated the uniqueness of the design as it is only unique to the particular manufacturer used.

Reviewer 32:

Reviewer 22:
Since this team is the same as the one doing the Beowawe project, how does the "first-of-its-kind equipment" in the two projects differ? From the presentation, there are no differences except for the size and temperature. There are no real advancements over the prior funded Beowawe project.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
Although scaling has not proven to be a problem at Beowawe, a pre-injection brine analysis should be performed since this plant has a different brine with more silica. The plant will be air-cooled, thus a greater seasonality swing in performance must be expected vs. the Beowawe project—something to be aware of.

Reviewer 32:

Reviewer 22:
The presentation in the project reports and information to the Geothermal Data Center on the "first-of-its-kind equipment" would allow other operators the chance to evaluate the system for their use; it appears to be patent protected. The project is more about the efficiency of the bottoming cycle and not the overall plant efficiency. To show the value of this project, the efficiency of the bottoming cycle compared to other systems should be in the forefront. Check the effect of the higher initial temperature—does this account for the better heat utilization? The reviewer suggests a presentation of geochemical data on brine cooling thus scaling. Check instrumentation to make sure all pertinent data is being taken.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0802
Presentation Title: Rural Cooperative Geothermal Development Electric and Agriculture
Investigator: Silveria, Daniel (Surprise Valley Electrification Corporation)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
This project has good value in identifying if there is a high-temperature resource that caused the two-hour run with the higher-temperature brine—geochemistry supports this concept. It could provide good value to other resources. It could provide a good example for co-ops to counter the bad situation at Rye Patch when a co-op, Mt. Wheeler Power, bought the power plant then had to sell due to drilling problems.

Reviewer 20:
This project will only minimally accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 gigawatts (GW) of capacity by 2020. It proposes to produce power from a shallow (720 ft) geologic formation that is being charged with anomalously high-temperature water (235° and higher). Outside of the immediate area of the project there are not many similar situations to transfer the technology. Simply demonstrating that local entities can work together to develop small geothermal electric plants falls short of attaining DOE goals. Financing seems to be a problem. The project does add to the database of power generation from binary plants.

Reviewer 32:
If "successful" (however that is defined, usually economics), word will spread and more rural communities will be more enthusiastic about geothermal development. The resource seems to be there and there are likely many more (albeit lower quality), such as resources that the agriculture community is aware of but has not had the positive experience and informal discussions necessary to motivate rural use.

Reviewer 22:
Positive results from development of a small, low-temperature resource will definitely provide a model to others as to the cost and work necessary for combined use of such a resource.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
Geochemistry at 280°F or higher makes this project really interesting. If the new well can encounter 300°F or higher it would be a significant find.

Reviewer 20:
Although the temperatures are high, the water production well is still drilling after 25 days—an inordinate amount of time for such a shallow well—bringing into question the selection of the driller. A binary plant is being designed based on the flowing temperature that is expected. There is good use of fault mapping, gravity survey, reservoir modeling, and a 2-meter survey, however, the team is still not able to clearly determine the source of the hot water and its observed temperature variations/fluctuations.

Reviewer 32:
From the reviewer‘s perspective, the project specifics are poorly documented with respect to geothermal exploration geology. The gravity data are arguably useful for structural delineation but other methods must also be used to adequately characterize the resource and develop a defensible and useful (with respect to meeting DOE objectives) conceptual model.

Reviewer 22:
Since it is early in the project and the data on the production and injection wells are not available, it is hard to evaluate the cost and technical effectiveness of the low-cost resource identification techniques.

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
It is good that the new well should be complete in about a month.

Reviewer 20:
Accomplishments, results, and outcomes have been marginal in relation to the resources expended and progress toward project objectives and technical targets/goals. A small percentage of funds have been expended to date. No information was provided or available regarding the size, working fluid, etc. of the binary plant. The water source well is being drilled now but that effort may be encountering problems since it is taking a rather long tome to drill. No information was presented on the injection well that will be required.

Reviewer 32:
For the applied geothermal intellectual infrastructure, adequate progress has been made, but for DOE utility, a more "academic" approach needs to be taken to improve the utility, adequacy and defensibility of the evolution of the conceptual model. Given the short time and long-term remaining resources, the project has a great opportunity to improve resource characterization and integration with other DOE efforts.

Reviewer 22:
Some results have been obtained from the resource mapping exercises but the overall value of these combined methods cannot be fully evaluated until the process wells are completed. The project is still in its first phase of finding a resource; the real accomplishments are still to come.

Comments Regarding Project Management/Coordination
Reviewer 29:
It is outstanding that the co-op is putting in so much money relative to DOE's portion. There has been good involvement from universities.

Reviewer 20:
Project management does not appear to be very effective. Permitting was completed but took longer than expected. The water source well is taking exceptionally long to drill. The binary plant design is not completed. There are limited prospects for technology transfer. The management plan is solid for the timing of the go/no-go decision. The plan to upgrade the transmission system is appropriate and the reporting plan (type of data and frequency) appears appropriate, and there is little doubt that data will be made available to DOE and the public. Collaboration has not gone smoothly, but the PI is working hard at it. The project has created the equivalent of 12 FTE jobs.

Reviewer 32:
The local commitment is outstanding and should be given significant weight in assessing this project. Positive DOE cooperation (and proactive DOE support for additional exploration data and conceptual model development) and reputation will go a long way toward ensuring the development of geothermal in agricultural areas.

Reviewer 22:
Two issues in the project management/coordination area impact this area. First is the problem of reworking existing well(s) because of issues with the State. Weren't the state rules and regulations checked before proposing to rework the wells? Second is the modification of the project schedule by 1.5 years. What was the cause and what is the overall impact to the project?

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
This could be beneficial to the industry in two important areas. It could show that with higher temperatures indicated by geochemistry, a high-temperature resource could be identified and drilled out. It could also provide an excellent example for co-ops to counter the bad situation at Rye Patch when a co-op, Mt. Wheeler Power, bought the power plant, and then had to sell due to drilling problems.

Reviewer 20:
The project will only minimally accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 GW capacity by 2020.

Reviewer 32:
A potentially significant resource and agricultural community context (where word will "get around" very quickly and emphatically) are real potential benefits. The potential for job creation in other agricultural communities is also a big potential winner but there should be a "driller education" component so as to minimize surprises and ensure proper well completion.

Reviewer 22:
The project, regardless of success, should provide to new parties in geothermal development valuable information on the problems and unpredictable nature of development of small, low-temperature resources. The project team has already looked at the plant design and requested preliminary bids from vendors without full knowledge of the actual resource flow and temperature. When available, the actual data will be used to order the equipment; this effort will actually decrease equipment lead time requirements.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
The project team is making some progress despite minimal expenditure of funding. A near-surface high-temperature water resource is available.

Reviewer 32:

Reviewer 22:
The only perceived strengths are noted in the above Overall statement as well as, if successful, the use of low-cost techniques to identify a geothermal resource. Additional strengths include willingness to share data on a realistic time basis, such as the progress with the drilling of the well(s). The enthusiasm of the project team is shown in backing the increased cost of the well development.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
Outside of the immediate area of the project there are not many similar situations to transfer the technology. No information was provided or available regarding the size, working fluid, or other specifications of the binary plant. The

water source well is being drilled now but that effort may be encountering problems since it is taking a rather long tome to drill.

Reviewer 32:

Reviewer 22:
Even with the above statement, the failure to follow contractual requirements in reporting, i.e., lateness in providing peer review material, should be avoided. It looks bad for the overall management of the project.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
Bring in another partner to the project that has some experience in such operations (either from the geothermal or oil and gas industries). The Rural Coop can exchange an equity share in the project for project management and technical expertise needed to make this project work.

Reviewer 32:

Reviewer 22:
None at this time.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0803
Presentation Title: Low Temperature Geothermal at Klamath Falls
Investigator: Brown, Brian (City of Klamath Falls)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
UTC (Pratt & Whitney) equipment has already been well proven at Chena Hot Springs and elsewhere, so there is limited new information to be gained.

Reviewer 20:
No cost-competitive technology was developed in this project as the City turned down the project due to its economics. It did not add to the DOE goal for 3 gigawatts (GW) by 2020. A technology was identified (variable flow/variable speed turbine) during the project but was not developed. There is the potential to add to the database of power generation from binary plants and develop a process to economically acquire and dispose of the cooling water in an urban area.

Reviewer 32:

Reviewer 22:
The overall goal of the project to integrate power production and direct use of a low-temperature resource is a valuable undertaking. Results from this study should assist other communities or owners of low-temperature resources in evaluating a similar combined application. It should also provide a better understanding of what barriers still exist for the application of combined use.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
Little new technical information would be gained with a UTC power module. A direct drive TG set could provide a new technical option, but that was not pursued.

Reviewer 20:
The presenter seemed to readily identify the limitations of the project yet proceeded since thermodynamic analysis (perhaps faulty modeling) looked promising. The project did identify the need for a variable flow/variable speed turbine which does not yet exist. The high-speed, direct-drive turbine generator appeared technically attractive but proved to be uneconomic for the Klamath geothermal district heating operation, thus an off-the-shelf power plant will not work for the situation. There is limited cash flow for the City of Klamath Falls.

Reviewer 32:

Reviewer 22:
The approach taken by the project team was appropriate for this project with only one concern. The incorporation of a "design for advanced high-speed, direct drive turbine-generator system" did not really add to the project even though it did identify that such a system is not presently available. This type of design/development should be and equipment development issue, not an application issue.

Comments Regarding Accomplishments, Results and Progress

Reviewer 29:
The no-go decision by the city is not a good result.

Reviewer 20:
Accomplishments, results, and outcomes have been adequate in relation to the resources expended—only a small amount of DOE funding was spent prior to the no-go decision. Some progress towards project objectives and technical targets/goals was made as technical feasibility was confirmed. The team identified the need to develop a variable-geometry turbine to match capabilities of the magnetic-bearing generator.

Reviewer 32:

Reviewer 22:
Sufficient data was presented to support the conclusion stated. Hopefully sufficient documentation is submitted to the Geothermal Data System to provide other potential users of a combined power generation and direct use system a solid basis with which to evaluate their resource.

Comments Regarding Project Management/Coordination
Reviewer 29:
The project had a good team despite the city's no-go decision.

Reviewer 20:
project management has been very effective. The management plan was solid and the reporting plan (type of data and frequency) appears appropriate if the project had continued. The study report will be distributed. Collaboration has gone smoothly, however, the project was a little hamstrung from the outset by the uncertain or indeterminate financial objectives of the City.

Reviewer 32:
The honesty and objective of the go/no-go decision process is useful. This is likely a political problem rather than a real technical or economic problem.

Reviewer 22:
The results of the project demonstrates that there was good project management and coordination between team members. The only perceived negative in this area is the involvement of the city—it is not clear if they were they on board originally and later decided to withdraw.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
This was a no-go decision so this project is now over (as it apparently should be based on the presenter agreeing with the city's decision).

Reviewer 20:
This project did not add to the DOE goal for 3 gigawatts (GW) by 2020

Reviewer 32:
This might be a case study in how water issues will impact geothermal development. Cooling water was a key cost/political driver.

Reviewer 22:

The project is nearing completion and should provide good information for others to follow in evaluating the combination of power generation and direct use of a low-temperature resource. The critical item now is the dissemination of the results to the geothermal community.

Comments Regarding Strengths

Reviewer 29:

The presenter had the strength to agree with the city's decision not to move forward. Good for him!

Reviewer 20:

The project team identified the need to develop a variable-geometry turbine to match capabilities of the magnetic-bearing generator.

Reviewer 32:

Reviewer 22:

The strength of this project will come from the information produced to evaluate the integration of a power production system into a direct use system, including the problems and the merits.

Comments Regarding Weaknesses

Reviewer 29:

Reviewer 20:

No cost-competitive technology was developed in this project as the City turned down the project due to its economics. A technology was identified (variable flow/variable speed turbine) during the project but was not developed. The project team seemed to readily identify the limitations of the project yet proceeded since thermodynamic analysis (perhaps faulty modeling) looked promising.

Reviewer 32:

Reviewer 22:

The one area that takes away from the overall project is the incorporation of the development and evaluation of a non-developed hybrid power system. This development and evaluation of a non-developed hybrid power system would be a worthwhile endeavor but was really beyond the size and scope of this project. This was both a cost and effort distraction, unless enough data is presented to encourage further development of such a system.

Suggestions for Improvement

Reviewer 29:

Reviewer 20:

Needed to determine Klamath Falls economic thresholds with much more certainty prior to developing the project.

Reviewer 32:

Reviewer 22:

The project is too near completion for incorporation of any improvements except for the encouragement that there is good distribution and documentation of the results. Data should be available to show other heating districts that incorporation of a small-scale power plant would be economical at a higher price for electricity to the grid.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0804
Presentation Title: Novel Energy Conversion Equipment for Low Temperature Geothermal Resources
Investigator: Minor, Eric (Johnson Controls, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
If the project team can truly get a 20% improvement in efficiency it will be substantial; is it truly 20% better than what could be obtained by technologies other than Pure Cycle?

Reviewer 20:
This project may accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 gigawatts (GW) of capacity by 2020. The objective of the project—to develop equipment that generates power from geothermal resources at a cost of 20% less than current technologies—is in complete alignment with DOE goals. A 1.5 megawatt (MW) power plant is under consideration but no information on it was presented.

Reviewer 32:
Apparently, significant progress has been made to justify DOE‘s go decision. The 20% cost decrease goal is reasonable but on the edge of credibility.

Reviewer 22:
The reduction in the cost of producing power from a low-temperature resource or any other geothermal resource is a very relevant and worthwhile endeavor if new systems or applications are incorporated. With cost reduction as the overall objective, it provides a wide area in which to work.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
The basis of 20% improvement over Pure Cycle does not mean it will be 20% better than other technologies. The concept appears to be good, but there was not much detail provided. Will the final result be that Johnson Controls will claim that it can make more power than Pure Cycle, but not share details that can benefit the industry?

Reviewer 20:
The 20% efficiency improvement vs. the existing PureCycle generator on site is claimed but difficult to confirm in the material presented. This project modifies off-the-shelf commercial chiller equipment as minimally as necessary to reduce the life-cycle cost of the equipment—a recuperator was added, a novel counterflow configuration was designed and a patent application has been filed but the presenter was reluctant to discuss details.

Reviewer 32:
The data sharing was not discussed in enough detail.

Reviewer 22:
Improving the performance of the power producing system by limiting change to the modifications of existing equipment may be too restrictive in reducing the LCCOE. The resource for testing the new system is proposed to be the geothermal resource at OIT. The commitment of OIT to the project and the supplying of the resource was not really evident.

Comments Regarding Accomplishments, Results and Progress

Reviewer 29:

Seems to be decent progress, although not a lot of detail was presented. A patented "black box" design where process conditions are secret is hard to evaluate.

Reviewer 20:
The claimed accomplishments, results, and outcomes have been adequate in relation to the resources expended, and progress toward project objectives and technical targets/goals has been stated, but is difficult to confirm.

Reviewer 32:
Not enough money has been spent to really assess this criterion but getting positive OIT and DOE decisions is good.

Reviewer 22:
A fair rating was based on the lack of supporting or definite statements as to the design and performance expectations of the selected demonstration unit (only a generalized concept drawing is shown). The only definite statement was that the Kalina Cycle was eliminated. Is it water or air cooled, what type of generation systems were selected, what type of heat exchangers, etc? If a patent has been applied for, there should be sufficient protection of their developments that this information can be shared. The statement was made that the "20% improvement at no additional cost" was accomplished in the design of the demonstration unit. Is the 20% improvement in efficiency or reduction in cost? These are not the same.

Comments Regarding Project Management/Coordination
Reviewer 29:

Reviewer 20:
Management of the project is exceptionally effective. There is excellent communication between research team participants, but the peer review presentation lacked details and facts. The installation schedule has slipped by a few months but the impact is negligible. Local mechanical and electrical contractors are now part of the team. The plan for data sharing and reporting is appropriate.

Reviewer 32:
Getting OIT and DOE to a positive position is a notable accomplishment.

Reviewer 22:
How has the incorporation of local mechanical and electrical contractors improved the project team? Is this just an educational effort (which is commendable) or do they add to the knowledge base of designing a system? The installation deadline has been moved back by 6 months, so if as stated "data will mostly be generated once ...running," has the project timeline been extended to provide the length of demonstration time that was originally proposed?

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
If DOE funds a project in which the investigator develops a process then patents it, how does that benefit the industry? Did DOE just fund the investigator's research that will benefit only the investigator?

Reviewer 20:
This project may accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 GW capacity by 2020. A 1.5 MW power plant is under consideration but no information on it was presented.

Reviewer 32:
The reviewer is concerned that the Johnson Controls effort is primarily directed at obtaining a patent and that data gathering and sharing will suffer accordingly. DOE must make technology transfer clear.

Reviewer 22:
The development of a low-temperature power generation system that will reduce the LCCOE will be very beneficial to the geothermal industry. Since installation and testing of the prototype is over a year away, the contribution to the knowledge gap is projected to be positive but will have to wait to be proven.

Comments Regarding Strengths
Reviewer 29:
The presenter feels strongly that Johnson Controls will develop a better power plant in that size range.

Reviewer 20:
The objective of project—to develop equipment that generates power from geothermal resources at a cost of 20% less than current technologies—is in complete alignment with DOE goals. It has focused on modification of off-the-shelf commercial chiller equipment as minimally as necessary to reduce the life-cycle cost of the equipment. A novel counterflow configuration was designed and a patent application has been filed but the presenter was reluctant to discuss the details.

Reviewer 32:

Reviewer 22:
The project team is the main strength of this project at this time.

Comments Regarding Weaknesses
Reviewer 29:
Benefits to the general industry seem to be much less than the benefits to Johnson Controls.

Reviewer 20:
The presentation made claims but lacked supporting detail; the presenter was reluctant to discuss project detail.

Reviewer 32:

Reviewer 22:
The limiting change to the modifications of existing equipment for improving the performance of the power generation system may be too restrictive even if it is/was done to limit the cost of the system.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
Provide detail that supports claimed accomplishments.

Reviewer 32:

Reviewer 22:
At this time, the only improvement would be in the open reporting of results of the engineering and design efforts. If all of this is being protected by patent applications, will it still be held as proprietary? If so, then the distribution of the

performance data is very critical. Is the test unit being highly instrumented so that the efficiency improvement can be determined in detail?

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0805
Presentation Title: Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas
Investigator: Luchini, Chris (Universal GeoPower LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 29:
This would be a first on coproduced hot water (Pleasant Bayou was similar but there is a difference between geopressured resources and coproduced fluids).

Reviewer 20:
This project may accelerate the use of geothermal resources and aid in attaining the goal of enabling 3 gigawatts (GW) of capacity by 2020 by providing an immediate path forward to 300 to 1,000 megawatts (MW) of geothermal power generation in Texas alone. No funding partner has been located to date, basically discontinuing any progress on project development.

Reviewer 32:
There is nothing different from DOE geopressured program results.

Reviewer 22:
Demonstration of the value/economics of the geothermal/geopressure resource available in shut-in wells will have a positive contribution to expanding the development of geothermal power production. The size of this shut-in resource makes it a potential supplier of desired green energy. Also, the incorporation into the project of the associated natural gas is a very positive aspect of this project. The presenter was also candid in the fact that if there were no gas then the project would have no economic reasons to move forward, a very good point.

Comments Regarding Scientific/Technical Approach
Reviewer 29:
It is impressive that the company admitted the first well site was inadequate and moved to another. There are not a lot of technical issues to be resolved.

Reviewer 20:
The project team identified that the reworked gas wells must produce enough natural gas to support the infrastructure supporting the ORC power plant (associated gas will provide the majority of revenue for the project). A power plant has been designed by Pratt and Whitney. The well selection process seems to be a little more involved than anticipated as both economic and technical parameters must be considered (this will reduce the expectation of 300 to 1,000 MW of geothermal power generation in Texas). The team recognizes that water temperatures may exceed 340°F requiring an alternative to the PureCycle power plant that has been designed.

Reviewer 32:
No detailed data were presented.

Reviewer 22:
The scientific/technical approach is good and should provide positive results and these results should be as important as the economic factors. It is understood that economics is the driving factor and cannot be ignored, but even if economics turn out to be the limiting factor, some valuable information should be gleaned from the technical efforts to that point. No new technical developments are expected on an application demonstration based on positive economic factors.

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
The project still needs a funding partner for the well rework. Project cost increased from $3.6 to $5.97 million but that includes doubling the power output.

Reviewer 20:
The partner that was identified to provide funding to workover the shut-in wells has backed away from the project; no other funding partner has been located primarily due to the fact that there is absolutely no demand for green energy in Texas—a huge problem for DOE meeting the 3 GW of geothermal power generation by 2020 goal. The project has developed geologic and economic models to rapidly evaluate potential project sites. Another site has been determined to be economically viable, however, the project is still unable to attract funding, making the economic viability of this alternate site questionable. The site plan is in place and approved.

Reviewer 32:
It is early in the project, but a partner is needed. The ability to assess and change wells is positive but more detail regarding key variables is essential for DOE.

Reviewer 22:
The setback with the initial site being unsuitable has been addressed and the project appears to be moving on. The presentation of the evaluation of the two sites and comparison of the two sites would provide valuable knowledge for the geopressure resource development.

Comments Regarding Project Management/Coordination
Reviewer 29:
This is a strong team if it can bring in the funding.

Reviewer 20:
Management has been very effective and plans for future management are well-structured and include all the appropriate and logically placed management checks and controls. Even after the investors have been identified, a go/no-go decision will be made dependent on the temperature and volume of flow obtained from the well(s). The variance from the original plans/schedule were corrected early but the project is still on hold at this point. The reporting plan is appropriate. Collaboration between technical partners has been good.

Reviewer 32:
This project has good flexibility and awareness of key issues, yet to be determined if mitigation of these issues will be successful.

Reviewer 22:
The project management appears to have handled the problems with the initial site selection and is addressing the changes in the economic factors associated with green energy development.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative.

Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
This is a good project that can hopefully move forward. Lack of green energy incentives is something that DOE needs to have an impact on if there is any chance for the industry to meet DOE's stated goal of 3 GW by 2020 from low-temperature resources.

Reviewer 20:
No funding partner has been located to date, basically discontinuing any progress on project development and negatively impacting DOE's goal of use of geothermal resources to provide 3 GW of capacity by 2020.

Reviewer 32:

Reviewer 22:
The project appears to be advancing in a very positive manner and problems and barriers are being address in a realistic (economic) fashion. The probability of this project proceeding (based on economic limitations) needs to be determined soon to limit expenditures of Geothermal Technologies Program (GTP) funds on a project that will not be accomplished.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
The project team identified the potential for 300 to 1,000 MW of geothermal power generation in Texas alone.

Reviewer 32:

Reviewer 22:
The PI has a good understanding of the business aspects of developing the resource and with the associated team members there is the technical basis for a good project.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
No funding partner has been located to date, basically discontinuing any progress on project development. Another site has been determined to be economically viable by the PI, however, the project is still unable to attract funding making the economic viability of this alternate site questionable. Water temperatures may exceed 340°F, requiring an alternative to the PureCycle power plant that has been designed. There is no market for geothermal, or any green energy generation, in the state of Texas.

Reviewer 32:

Reviewer 22:
The statement that "there are no 'Technical' discoveries that will be addressed in this project, only economic ones" makes the worth of this project in addressing knowledge gaps very limiting. The technical discoveries will be in the results of the evaluation of the resource and the design and operation of the power system(s). Economics is the driving factor but the project team should not lose sight of the supporting technical issues/results.

Suggestions for Improvement

Reviewer 29:

Reviewer 20:
A firm commitment from the funding provider should have been a requirement to obtaining DOE support of the project. Perhaps DOE could assist in locating an investor through its Loan Guarantee Program.

Reviewer 32:

Reviewer 22:
The presentation of supporting data/information for claims of accomplishments is the only validation of progress. To withhold everything to date as proprietary stifles the evaluation of the project as a worthwhile investment by GTP. There should be an extension executed for this project that would be the length of time that will be required for securing funding so that the operational and economic data development will have sufficient time to be developed.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0806
Presentation Title: Electric Power Generation from Co-Produced Fluids from Oil and Gas Wells
Investigator: Gosnold, William (University of North Dakota)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
It is valuable to gather and present data on operation on a North Dakota oil and gas field.

Reviewer 20:
This project has excellent alignment with DOE's goal to accelerate the use of geothermal resources and enabling 3 gigawatts (GW) of capacity by 2020. It evaluates power generation of three different commercial power conversion systems—ORC, Kalina, and Thermal Hydraulic Engine. It will demonstrate that the technology can be successful at a wide range of physical parameters and varying operating conditions. The results will be widely disseminated facilitating technology transfer of the technology. Successful demonstration of an economically viable system will provide abundant geothermal electricity generation as there are a significant amount of oil wells producing hot water in the Williston Basin.

Reviewer 32:
The project is revisiting some of the previous geopressured ideas but is much more broad ranging in acquiring, assessing and utilizing data for technology transfer and economic analyses (both upstream resource and downstream turbine selection). It is tempting to argue that this resource is unlikely to be economic but it is significantly different enough (in resource characteristics and project team quality) that it is worth continued and robust support.

Reviewer 22:
The fully executed project will provide added information to the knowledge gaps for the integration of low-temperature power generation for the existing oil and gas produced water resource. The added goal of providing an educational tool for the next generation of geothermal engineers/scientists is commendable.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
Good bid summary although the reviewer was surprised that cost comparisons were shown to the public. Bid prices are generally considered confidential. It is good that it went to multiple bidders. Data on operating parameters such as heat exchanger fouling will be valuable and should be tracked closely and presented clearly.

Reviewer 20:
The approach is well thought out and effective in achieving the project‘s objectives. The original site and partner were acquired by another company delaying commencement of the project, and communication problems forced the PI to locate a new partner which was successful. The new oil field demonstration site appears ideal for conducting the testing. It is a smart approach as power generation systems from six manufacturers were solicited and analyzed. The new field site may accommodate a water-cooled unit which was not part of the solicitation to manufacturers and may affect the selection of the optimum unit to install. The selected ORC unit (550 kilowatts or kW from Calnetix) was based on assumed water availability of 850 gallons per minute (gpm)—this may not have the same economics if only 400 gpm water is available or if infrastructure has to be expanded to get all the water from the oil wells to a single location.

Reviewer 32:
Although early in the project, the data presentation was indicative of likely future utility with respect to meeting all aspects of DOE objectives for this type of work. The technical and scientific staff are adequate and even impressive in

number and quality.

Reviewer 22:
The approach for this project is well planned and the adaptability of the project (changing from the original project site and the change back to the site) to overcome unforeseen barriers speaks well to its future success. The technical issues being addressed will assist in filling in the knowledge gap for low-temperature/coproduced fluid power generation.

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
The project seems to be off to a good start although only 3.64% of the budget has been spent.

Reviewer 20:
The accomplishments, results, and outcomes have been good in relation to the resources expended and progress toward project objectives and technical targets/goals. Data has been analyzed, a site and testing partner have been secured, and a power generation system has been selected. Securing the partner was a stumbling block that caused a slight delay in the project.

Reviewer 32:
It is very early in the project but the presentation indicated an ability to effectively leverage resources into useful data. The quality of the involved personnel and institutions will likely lead to broad and defensible communication of results as indicated by previous presentations and publication records.

Reviewer 22:
The stated accomplishments to date with supporting data for both resource evaluation and equipment selection shows the project to be of high quality and producing definite results.

Comments Regarding Project Management/Coordination
Reviewer 29:
It is good that the project team was able to convince the company that acquired the well owner to move forward with the project.

Reviewer 20:
Project management has been very effective. The management plan is solid and the reporting plan (type of data and frequency) appears appropriate. A slip in the schedule has occurred as the original partner was acquired by another company, but is now on track for installation of the ORC unit at the end of 2011—this may be a little optimistic as it is only 6 months away; it ill reduce the actual pilot testing and may affect long-term reliability and performance data. Collaborations have generally been successful although one partner had to be dismissed from the project for failing to provide the feasibility study.

Reviewer 32:
It is too early to really tell but good management seems to be present.

Reviewer 22:
The project team is large but it appears that each area has a dedicated leader and that there is good coordination between team members. The incorporation of graduate and undergraduate students into the project team helps to provide for continuity in advancing geothermal activities. A positive aspect of the program was the success that the team had in replacing two original team members (Berrendo and Encore) and redistributing the workload to keep the project on schedule. A timeline with go/no-go decision points would have been nice.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
It would be good to produce power from this North Dakota field. The schedule for being online winter 2011 seems too optimistic, but hopefully the project moves forward.

Reviewer 20:
This project has shown excellent alignment with DOE's goal to accelerate the use of geothermal resources and enable 3 GW of capacity by 2020.

Reviewer 32:
This is a good look at a previously "neglected" and low-temperature resource.

Reviewer 22:
This project appears to be on track to produce excellent data that will assist in the penetration of the oil and gas industry to incorporated geothermal power production in their operations.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
The project evaluates power generation of three different commercial power conversion systems—ORC, Kalina, and Thermal Hydraulic Engine. It will demonstrate that the technology can be successful at a wide range of physical parameters and varying operating conditions. Progress to date has been good—data has been analyzed, a site and testing partner have been secured, and a power generation system has been selected. Successful demonstration of an economically viable system will provide abundant geothermal electricity generation as there are a significant amount of oil wells producing hot water in the Williston Basin.

Reviewer 32:
This project is likely to produce a good combination of science, engineering and economic data and cost data, and has a good project team.

Reviewer 22:
The strength in this project is the leadership shown by the management team in overcoming early obstacles (mainly a non-functional team member and initial withdrawal of the resource) to keep the project on track. The evaluation of the potential power generation systems appears to be very complete and informational. The incorporation into the project of graduate and undergraduate students speaks well for the future of the project and the geothermal industry. The project team has already been very progressive in getting the developed information to the public.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
The original site and partner were acquired by another company delaying commencement of the project, and communication problems forced the PI to locate a new partner. Solicitation from manufacturers should have specified consideration of a water-cooled unit. The selection of the ORC unit (550 kW from Calnetix) was based on assumed water availability of 850 gpm—this may not have the same economics if only 400 gpm water is available or if infrastructure has

to be expanded to get all the water from the oil wells to a single location.

Reviewer 32:
Can they stay on schedule and get access to wells? The long-term injection for these formations is not well known.

Reviewer 22:
None noted at this time.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
The PI could request that Calnetix relook at its proposal and consider incorporating a water-cooled ORC unit, and then perform the appropriate economic analysis on that unit.

Reviewer 32:

Reviewer 22:
Make sure that the power units are fully instrumented so that the fouling and performance of all components of the system can be accomplished. This is very important to provide valuable information to the National Geothermal Data System. This is a good project that is well defined; the reviewer has no further suggestions for improvements.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0807
Presentation Title: Electric Power Generation from Low to Intermediate Temperature Resources
Investigator: Gosnold, William (University of North Dakota)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
It would be good if the project could demonstrate economic power generation from a heat source at only 99°C.

Reviewer 20:
This project has excellent alignment with DOE's goal to accelerate the use of geothermal resources and enabling 3 gigawatts (GW) of capacity by 2020. It evaluates power generation of three different commercial power conversion systems—ORC, Kalina, and Thermal Hydraulic Engine. It will demonstrate that the technology can be successful at a wide range of physical parameters and varying operating conditions. The results will be widely disseminated facilitating technology transfer of the technology. Successful demonstration of an economically viable system will provide abundant geothermal electricity generation as there are a significant amount of oil wells producing hot water in the Williston Basin.

Reviewer 32:

Reviewer 22:
The objectives of the project should provide information that can be used to fill in the knowledge gap in low-temperature power generation and address issues related to overcoming barriers in the application of the technology. A timeline with decision points would assist in tracking the project.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
There was a good bid summary although the reviewer was surprised that cost comparisons were shown to the public. Bid prices are generally considered confidential. It is good that it went to multiple bidders. Data on operating parameters such as heat exchanger fouling will be valuable and should be tracked closely and presented clearly.

Reviewer 20:
This outstanding approach is highly effective in achieving the project‘s objectives. The oil field waterflood demonstration site appears ideal to conduct the testing. It is a smart approach as power generation systems from six manufacturers were solicited and analyzed. Selection of the ORC unit (550 kilowatts or kW from Calnetix) was based on definite water availability of 850 gallons per minute (gpm). The source water for the project is all available at a single location. In addition to generating power, the waterflood project will experience a cost-savings as the water will not have to be cooled as much prior to injection.

Reviewer 32:

Reviewer 22:
The presented technical approach for the project and the preliminary results for some of the early tasks indicate that if future efforts stay on course, the project will provide significant data for low-temperature power generation.

Comments Regarding Accomplishments, Results and Progress

Reviewer 29:
This is a good start although it is still early in the project. Power plant installation by winter 2011 seems optimistic.

Reviewer 20:
The accomplishments, results, and outcomes have been good in relation to the resources expended and progress toward project objectives and technical targets/goals. Data has been analyzed, a site and testing partner have been secured, and a power generation system has been selected.

Reviewer 32:

Reviewer 22:
The accomplishments to date supported by the preliminary data indicate that the project is providing good results and progressing toward a successful project.

Comments Regarding Project Management/Coordination
Reviewer 29:
It is good that the project team dropped a non-performing partner early in the project and kept moving forward.

Reviewer 20:
Project management has been extremely effective. The management plan is solid and the reporting plan (type of data and frequency) appears appropriate. Many presentations regarding the project have been made. No variances in the schedule have occurred; it is on track for installation of the ORC unit at the end of 2011. Collaborations have generally been successful although one partner had to be dismissed from the project for failing to provide the feasibility study.

Reviewer 32:

Reviewer 22:
The project team is structured with PIs in key areas and it appears that there is good coordination between the individuals. The project team lost an original collaborator but successfully replaced the member by redistributing the workload among the other members and the selected power system vendor. A timeline with go/no-go decision points would have been useful in deciding management success in keeping the project on schedule.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
Getting a power plant on line in North Dakota, on that wellfield, and on such a low-temperature heat source should provide valuable information to the industry.

Reviewer 20:
This project has excellent alignment with DOE's goal to accelerate the use of geothermal resources and enabling 3 GW capacity by 2020.

Reviewer 32:

Reviewer 22:
Overall the project appears to be on schedule to provide information that will be very useful in furthering the use of low-temperature geothermal resources as a source of electrical power.

Comments Regarding Strengths

Reviewer 29:

Reviewer 20:
The project evaluates power generation of three different commercial power conversion systems—ORC, Kalina, and Thermal Hydraulic Engine. It will demonstrate that the technology can be successful at a wide range of physical parameters and varying operating conditions. Progress to date has been good—data has been analyzed, a site and testing partner have been secured, and a power generation system has been selected. Successful demonstration of an economically viable system will provide abundant geothermal electricity generation as there are a significant amount of waterflood operations inolving hot water in the Williston Basin.

Reviewer 32:

Reviewer 22:
The project has a solid management team that has shown adaptability in overcoming some early obstacles. Use of the project as a teaching tool by incorporating graduate and undergraduate student is addressing the future personnel demand for the geothermal industry. Significant effort has already been done to get the project plans and results to the public.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
The solicitation from the manufacturers should have specified consideration of a water-cooled unit.

Reviewer 32:

Reviewer 22:
None to include.

Suggestions for Improvement
Reviewer 29:

Reviewer 20:
The PI could request that Calnetix relook at its proposal and consider incorporating a water-cooled ORC unit, and then perform the appropriate economic analysis on that unit.

Reviewer 32:

Reviewer 22:
Because of the similarities and the use of the same data and results, has the combining of this project with the project "Electric Power Generation from Co-Produced Fluids from Oil and Gas Wells" been considered and proposed to the Geothermal Technologies Program (GTP)? This may simplify tasks for both the contractor and DOE/GTP. Make sure that the power units are fully instrumented so that the fouling and performance of all components of the system can be accomplished. This is very important to provide valuable information to the National Geothermal Data System. This is a well-defined project for which the reviewer has no further suggestions for improvements.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0808
Presentation Title: Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources
Investigator: McGinnis, Robert (Oasys Water)

Comments Regarding Relevance/Impact of Research

Reviewer 29:
It would be good if there could be an economic method of generating power from low-temperature resources. It is also good to look at non-traditional systems.

Reviewer 20:
This project has excellent alignment with DOE's goal to accelerate the use of geothermal resources and enable 3 gigawatts (GW) of capacity by 2020. It produces power from extremely low-grade (as low as 40°C) geothermal resources by utilizing an Osmotic Heat Engine (OHE) for electricity production. The project is unique as Oasys is thinking out of the box with this process. The ability to generate power from lower-temperature resources will enable use of much shallower wells, reduce risk, and greatly expand the geographical range of geothermal energy production. Such an economically viable system will provide abundant sustainable electricity generation.

Reviewer 32:
This is a unique approach that definitely wins points for innovation.

Reviewer 22:
The proposed development of a system that will use very low-temperature fluids to produce electrical power is very relevant to the Geothermal Technologies Program (GTP) mission and goals. Such a system would also expand the application of the technology to a wider range of resources than are now being considered. Success in this project would definitely impact the development of geothermal power systems.

Comments Regarding Scientific/Technical Approach

Reviewer 29:
On the positive side, there appears to be some good thinking with a new technology. Fundamental questions such as parasitic loads, turbine efficiencies, and brine utilization (kilowatt hours per pound or kWh/lb brine) compared to competing technologies need to be well understood. Perhaps if the principal investigator had been at the review those answers would have been known.

Reviewer 20:
The OHE is a unique approach to the problem. Many knowledge gaps are being addressed in the project development. Power yield will be low, but potential resources will be greater. The process will theoretically eliminate the risk of mineral scaling. The PI was unable to answer some basic questions—the efficiency of the turbine, parasitic power drain, pressure tolerances, and reliability are not yet known. The advisory panel does not appear to yet be fully engaged in the project. There is much work to be done but Oasys appears to be on the right path and is addressing the issues that need to be answered. The project is on track for a go/no-go decision by the end of 2011.

Reviewer 32:
The presentation assumed this project to be "resource independent." The reviewer would like to see more support for this assertion. A detailed comparison with conventional binary is required.

Reviewer 22:

The technical approach presented to develop and test the new system is logical with a step-by-step development program. The incorporation of prior knowledge from similar applications done by the contractor gives a strong assurance to the technical development.

Comments Regarding Accomplishments, Results and Progress
Reviewer 29:
It is still early so need to review again after more work is complete.

Reviewer 20:
The accomplishments, results, and outcomes have been good in relation to the resources expended. Project milestones are clearly identified and progress towards each has been steady—stripper and absorption optimization, membrane development, module development, and integration into existing recovery systems are all estimated to be above 75% complete although this percentage is a bit difficult to independently verify.

Reviewer 32:
Given the number and quality of the advisers, the reviewer was surprised at the low level of detail and defensibility of the presentation. /this level of engagement on scientific technical defensibility does not bode well for the utility of the results for meeting DOE objectives.

Reviewer 22:
Stated accomplishments are very encouraging toward a successful project. The lack of supporting data of any form tempers the enthusiasm. Stated progress and percent of budget spent appears to be in line.

Comments Regarding Project Management/Coordination
Reviewer 29:
This appears to be a good team with smart scientists/engineers coupled with an experienced team at Alta Rock.

Reviewer 20:
Project management has been very effective. The management plan is solid and the reporting plan (type of data and frequency) appears appropriate. Collaboration has generally gone smoothly. A slip in the schedule has occurred—construction has been delayed to focus on membrane and module pressure tolerance development; it is now on track for a go/no-go decision by the end of 2011 which will reduce the actual pilot testing to less than one year and may affect long-term reliability and performance data. Collaborations have been successful.

Reviewer 32:
There is obviously poor coordination between advisers and engineers.

Reviewer 22:
The project management to date has kept the project progressing at a satisfactory rate and the future plans do not indicate anything different. The supporting advisory board should provide excellent oversight of the project and help to produce good results. The lack of information on the selection of a geothermal site for final testing is definitely an issue that needs to be addressed. A good site is as important as a good piece of equipment for validation purposes.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 29:
This project has interesting promise and should continue to completion of the current work. By then the questions that

were not answered at the peer review should be answered.

Reviewer 20:
This project has excellent alignment with DOE's goal to accelerate the use of geothermal resources and enable 3 GW capacity by 2020. It produces power from extremely low-grade (as low as 40°C) geothermal resources by utilizing an OHE for electricity production. The OHE is a unique approach to the problem. Many knowledge gaps are being addressed in the project development.

Reviewer 32:

Reviewer 22:
The project appears to be progressing in the right direction and on an acceptable schedule to provide information for future low-temperature geothermal power generation. The critical element in this being a successful project is the future operation of the new system on a trouble-free and economic basis. The development of a system totally different than the conventional ORC-type system would be a great advancement.

Comments Regarding Strengths
Reviewer 29:

Reviewer 20:
The ability to generate power from lower-temperature resources will enable the use of much shallower wells, reduce risk, and greatly expand the geographical range of geothermal energy production. Such an economically viable system will provide abundant sustainable electricity generation. The OHE is a unique approach to the problem and many knowledge gaps are being addressed in the project development.

Reviewer 32:

Reviewer 22:
The project strengths reside in the background and knowledge of the project team and their commitment to developing a new and viable power generation system.

Comments Regarding Weaknesses
Reviewer 29:

Reviewer 20:
The PI was unable to answer some basic questions—the efficiency of the turbine, parasitic power drain, pressure tolerances, and reliability are not yet known. The advisory panel does not appear to yet be fully engaged in project. A slip in the schedule has occurred—construction has been delayed to focus on membrane and module pressure tolerance development—but is now on track for a go/no-go decision by the end of 2011 which will reduce the actual pilot testing to less than one year and may affect long-term reliability and performance data.

Reviewer 32:

Reviewer 22:
What, where, and what is the temperature of the geothermal resource to test the prototype on? The presentation stated that AltaRock would supply the resource so this information should be available. The temperature should be near the lower limits of the proposed operating range to show its true value at lowering the range for low-temperature power generation.

Suggestions for Improvement

Reviewer 29:

Reviewer 20:
Provide a clear, complete schematic of the process by the time of the go/no-go decision.

Reviewer 32:

Reviewer 22:
An effort should be made by the PI to follow the contractual requirements in reporting, i.e., providing peer review material in a timely and requested manner. With the revised schedule will there be sufficient time to provide analysis of the membrane fouling and system performance? The presentation was made by an individual that had not been with the project for very long, thus limiting the ability to address technical questions on a good project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0809
Presentation Title: Demonstrating the Commercial Feasibility of Geopressured-Geothermal Power Development at the Sweet Lake Field, Cameron Parish, Louisiana
Investigator: Jordan, Steven (Louisiana Tank, Inc.)

Comments Regarding Relevance/Impact of Research
Reviewer 32:

Comments Regarding Scientific/Technical Approach
Reviewer 32:

Comments Regarding Accomplishments, Results and Progress
Reviewer 32:

Comments Regarding Project Management/Coordination
Reviewer 32:

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 32:
No presentation?

Comments Regarding Strengths
Reviewer 32:

Comments Regarding Weaknesses
Reviewer 32:

Suggestions for Improvement
Reviewer 32:

Power Conversion Technology

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0200
Presentation Title: High Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants
Investigator: Klockow, Helge (GE Global Research)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
The reviewer did not see how this research was new. Every company that has designed a geothermal power cycle had to go through a process to choose a fluid. This process may have been new to GE, but it is not new to the industry. Trends such as choosing a fluid with a higher critical temperature for an ORC with a higher-resource temperature are well known. Only the work done on examining new fluids might be of importance to the community.

Reviewer 7:
This research seeks to determine whether investment in "drilling" or power plant improvements gives the best return on investment. How would one know that? Drilling costs cannot be predicted with a very high level of confidence. Even further, it is difficult to know what another 200 feet of drilling might determine, so the notion of comparing power plant investments to drilling investments seems to be trying to split hairs we cannot even see. The first part of the research compares working fluids and makes claims that seem unreasonable, such as 100% improvement in net output. This first portion of the research seems to be a repeat of research work already done. It is already known that higher temperatures (critical) will produce more efficient cycles at higher temperatures.

Comments Regarding Scientific/Technical Approach
Reviewer 21:
From the information in the presentation and answers to questions there is nothing original. There are no references to previous work in this field so it is not possible to assess if the poor results are due to lack of assessment of previous work or duplication.

Reviewer 34:
The project is well organized and has established a method to evaluate a large number of fluids. However, the procedure seemed to concentrate on output power, and ignored things like costs, corrosion, thermal breakdown, flammability, toxicity, global warming potential, etc. These other criteria need to be included in a selection process.

Reviewer 7:
The information presented makes claims that are difficult to believe. For example, 100% improvements over current operating systems is huge and the reviewer did not see any data that would convince him to invest in this research.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
It is well known that one of the criteria of fluid choice is the resource temperature, therefore comparing (Fig. 1) different fluids to a given fluid is misleading. The increase of output is obviously outside the optimum temperature for which the fluid used as benchmark was chosen.

Reviewer 34:
It was impossible to fully evaluate the accomplishments of this project due to the lack of details provided. Evaluation was also difficult due to the way their results were presented. They compared their optimal fluid and cycle to a baseline cycle for a wide variety of temperatures. Their baseline used a single fluid in a subcooled ORC over a wide range in temperatures. The output metric was the ratio of the optimal cycle power to the baseline power as a function of resource temperature. Thus, their stated gain in output power is likely due to the poor performance of the baseline in conditions where it should not be used, and not to exceptional performance of their optimal cycles. It was unbelievable that they could produce a cycle that had double the output as current cycles used.

Reviewer 7:
Progress is being made in regards to the published schedule.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
The project seemed to be well run.

Reviewer 7:
The lack of interaction early on with determining drilling costs limits the appropriateness of this research.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
The claim of 30% to 50% improvement in efficiency is unsubstantiated

Reviewer 34:
The reviewer feels that this project did little to advance the art. Since much of the results will apparently not be shared with the geothermal community, it is of little value to companies other than GE.

Reviewer 7:

Comments Regarding Strengths
Reviewer 21:
A large amount of fluids were screened.

Reviewer 34:
The program seems to be well organized and is providing GE with data that will help it compete in the geothermal arena.

Reviewer 7:

Comments Regarding Weaknesses
Reviewer 21:
Based on the information in the presentation and answers to questions there is nothing original. There are no references to previous work in this field so it is not possible to assess if the poor results are due to lack of assessment of previous work or duplication.

Reviewer 34:
This work is not presented in a way to help the general geothermal community. Even for internal use, the project can be improved by investigating other criterion instead of output power. Output power is not a good criteria to rate geothermal systems since the fuel is free. Investment in geothermal is based on levelized cost of electricity (LCOE). In an LCOE calculation, the output power has no direct impact. Doubling the output power was presented as a possible outcome of this work. That large of an improvement is very hard to believe, even without any cost limitations.

Reviewer 7:

Suggestions for Improvement
Reviewer 21:

Reviewer 34:
The results should be presented in another format. It might be more interesting to use a Carnot efficiency as the baseline. In that format one can more clearly see how good their designs are instead of how bad the baseline performs. Since their plots showed minimal improvement at a single temperature, it can be implied that the baseline is pretty good when comparisons are made at the optimal temperature of the fluid used as the baseline.

Reviewer 7:
The reviewer struggles to understand how this research helps the geothermal community. Maybe it helps keep a couple of jobs at GE, but most of the work being done under this study has already been done.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0201
Presentation Title: Tailored Working Fluids for Enhanced Binary Geothermal Power Plants
Investigator: Mahmoud, Ahmad (United Technologies Research Center)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
The reviewer did not see how this research was new. Every person who has designed a geothermal power cycle has to go through a process to choose a fluid. This work may have been new to UTC, but it is not new to the industry. The presenter provided zero technical results (besides general comments that the project was going well) so it is difficult to evaluate this project. The written materials did not indicate that the project will evaluate costs, but this was verbally stated to be an important part of their procedure. All results are apparently proprietary, so it will be of little use to the geothermal community other than UTC. The evaluation on mixed fluids might be of more current interest, and should be a larger part of the program. Their inclusion of trilateral cycles in their analysis is interesting since they have little experience in that cycle and therefore it is difficult to justify a choice of an isentropic efficiency for the expander of that cycle. They used an isentropic efficiency of 50% for a positive displacement expander, which is much smaller than the value used by Energent in their presentation for a two-phase turbine. The use of a trilateral cycle is often hampered by temperature limits on lowering the brine temperature, and thus the theoretical benefits of a trilateral cycle are not often obtained.

Reviewer 7:
It would be outstanding to have a 40% increase in net output from low-temperature power plants.

Comments Regarding Scientific/Technical Approach
Reviewer 21:
This project presents nothing new: the trilateral cycle was well analyzed by Ian Smith in the 1980s (www.city.ac.uk/rvsj.376). The supercritical cycle has been demonstrated and used commercially since the late 1980s. (Ron DiPippo. Geothermal Power Plants. P. 191).

Reviewer 34:
The comparison of various fluids for geothermal applications is a subject that is well studied. It is unclear what additional insights this study has uncovered since essentially no results were presented. The project also investigated heat exchanger designs and fluid property evaluation. Results on these items were also not presented. It seemed that the approach was the different portions of the project were well coordinated, but that was difficult to evaluate due to the lack of information.

Reviewer 7:
The researcher is taking an all-of-the-above approach and not focusing on a single issue. The research appears too scattered to yield any important data. For example, it is already known that more heat transfer, fluids that have less friction, pumps that are more efficient, and fluids that extract more energy from the brine, etc., are needed The focus should be on individual issues that yield solutions.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
From the information in the presentation and answers to questions there is nothing original. There are no references to previous work in this field so it is not possible to assess if the poor results are due to lack of assessment of previous work or duplication.

Reviewer 34:
Due to the fact that no accomplishments were presented, it was impossible to rate the accomplishments. The project seemed focused on improvements on cycle power levels, yet, the evaluation of a geothermal project relies upon the levelized cost of electricity (LCOE). The project did not seem to include toxicity, thermal breakdown, corrosion potential, flammability, or many other important parameters in the determination of an optimal working fluid.

Reviewer 7:
The speaker showed a lot of enthusiasm, but there are no results to speak of.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
It is difficult to evaluate the project management of this program. DOE put up the majority of the funds, and all of the benefit goes directly to UTC and not to the geothermal community in general.

Reviewer 7:
Although the presenter talked about coordination and work, the reviewer did not see evidence of output.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
From the information in the presentation and answers to questions, the claim of 40% improvement in efficiency is unsubstantiated.

Reviewer 34:
This work is not conducted in a way to help the general geothermal community since results were withheld. Even for internal use, the project can be improved by investigating other criteria instead of cycle power. Investment in geothermal is based on LCOE. An increase in power may not be beneficial if the costs also rise significantly.

Reviewer 7:
The reviewer doubts the "take a look at everything approach" will yield any specific data that can be used to make improvements. The reviewer suggests a more focused approach on a single issue or maybe two. This scattered type of approach makes accountability difficult and almost impossible to pin things down.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:

Reviewer 7:

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
The claim of a 40% improvement in power per gallon of extracted fluid is difficult to believe (especially when details are withheld). Likely the result is due to poor baseline performance in a non-optimal condition. It will be very difficult to provide this improvement in most applications.

Reviewer 7:

Suggestions for Improvement
Reviewer 21:

Reviewer 34:
The project should consider how to include different fluid properties into its selection criteria such as toxicity, thermal breakdown, etc. The project should include other criteria in the evaluation of the benefit a fluid instead of just examining cycle power levels.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0202
Presentation Title: Working Fluids and their Effect on Geothermal Turbines
Investigator: Sabau, Adrian (Oak Ridge National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project was designed to identify new mixtures of fluids to be used in a geothermal system. The scope of the project was cut (likely due to a reduction in funding). However, it is difficult to understand why only two CO2 mixtures were examined. The project goal is to measure thermodynamic properties of mixtures since the assumption of ideal mixtures often yields significant errors. Even though the scope of the project seemed limited, the quality of the work presented was very good.

Reviewer 7:
This research seeks to solve a problem that the reviewer is not sure is at a critical need. The reviewer‘s understanding was that the research is to identify more properties of working fluids and how the working fluids might interact with turbines. The reviewer is not aware that turbines are failing because of working fluid interaction. In general, geothermal turbines operate at much lower pressures and temperatures and the failures are not related to stress or chemical degradation (at least not from binary fluids).

Comments Regarding Scientific/Technical Approach
Reviewer 21:
Using SF6 as one of the fluids is not practical as its global warming potential is 22,800(one of the highest)! Other mixtures may be more practical but as there are always some leaks they present the difficulty of maintaining a constant proportion.

Reviewer 34:
The approach seemed very reasonable. Their goal of developing a low-cost, high-efficiency cycle is great. However, none of the presentation seemed to be related to cost.

Reviewer 7:
The researchers‘ approach is to generate numbers from a computer code. The reviewer is not sure even after the research is finished that it will command the confidence of manufacturers. What is being attempted has to be backed up with real data.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
No practical application for the fluid was presented. Other mixtures may be more practical.

Reviewer 34:
The reviewer really appreciated that they investigated contamination of the fluid with water, for water additions can yield significant corrosion of the equipment. However, there were no investigations into how their chosen fluid may be contaminated with lubrication oils, and how the CO2 mixtures compare to other fluids in terms of toxicity, thermal stability, etc. A concern of using mixtures of coolants is the ability to maintain that mixture. It is possible that one component will leak out of the system faster than another and leave the system at a non-optimal mixture. Upcoming

experimental tests of the concept will help confirm the ability of the fluid to be used in a real system.

Reviewer 7:
The reviewer did not see a lot of results that could be applied to producing better turbines.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
The reviewer was concerned that this project seemed to investigate only two fluid mixtures. USF examined other fluid mixtures, but this portion of the project did not seem to be well integrated into the other work. The USF work seemed to only be modeling, and thus the stated goal of the project (to validate thermodynamic properties of mixtures instead of using ideal mixture correlations) is not achieved. Inclusion of testing of the system in a real loop will help validate the chosen fluid as a viable solution.

Reviewer 7:
Research is on track.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
There may be a limited value of the method for future study of mixtures.

Reviewer 34:
Cost is the major obstacle to development of geothermal energy. The thermal power is essentially free, and thus the only impediment to geothermal energy resources is the various forms of costs. This program did not address this in their presentation. CO2 cycles tend to be quite small, and this offers a potential cost savings. This should have been quantified at least briefly in this study.

Reviewer 7:
If the reviewer understood the research correctly, it is to identify working fluid properties and characteristics that can be used to extend equipment life. Turbines have a long life expectancy, especially for binary plants.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
This program will include actual testing of their fluids in an actual flow loop. This will enable them to determine the usability of the fluid especially if the loop is run for a significant amount of time.

Reviewer 7:

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
The project seems to have concentrated efforts on two CO2 mixtures without a demonstration that this is the optimal

choice, or that these investigations will be applicable to other mixtures. The project stated that molecular dynamics would be used to determine transport properties. However, there was no program to validate these properties.

Reviewer 7:

Suggestions for Improvement

Reviewer 21:

Reviewer 34:

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0203
Presentation Title: Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems
Investigator: McGrail, Peter (Pacific Northwest National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project desires to incorporate nanoparticles into the working fluid of a geothermal power cycle. The project has demonstrated that the particles will flow through a boiler without plating out of the heated surfaces when the flow is of a reasonable velocity. The concept offers an improvement in the cycle efficiency of the power cycle. However, use of such a novel concept may result in unanticipated problems.

Reviewer 7:
Use of nanoparticles could contribute to increased output from existing power conversion machines.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
This project is developing fluids for future applications of geothermal energy power plants. The project develops nanoparticles that have the desired properties by design and testing. This seems appropriate considering the current state of the art.

Reviewer 7:
Research is progressing on a logical path, e.g., adding particles and then measuring changes.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
Although in a very early stage of research, with further development these fluids may have application as a heat transfer fluid. Fluids with nanoparticles are problematic in turbo machinery because of: dispersion, two-phase flow, and fouling of air foils. Fluids with nanoparticles are problematic in enhanced geothermal systems (EGS) because of cost and losses.

Reviewer 34:
A goal of this program was to test the concept in a power flow loop. Another goal was to develop cost data for power systems using this concept. These goals were not completed and will require additional funding. However, the work did develop a number of nanoparticles that may be useful in power applications. They did demonstrate the ability to use the fluids in a flow boiling loop without plating of the nanoparticles onto the heating surface. It is important that the project at least estimate the additional costs of this concept and the benefits. Costs were not presented, and the benefits were not quantified. The presentation stated that efficiency improvements were possible, but this was not quantified. (The presentation stated that the particles would "increase heat extraction rate by 30%", but this claim is not put on a basis that allows evaluation of a decreased levelized cost of electricity (LCOE) or increased efficiency. The reviewer assumed that the statement essentially meant that the effective heat capacitance was 30% higher.)

Reviewer 7:

Researcher has some initial results that are encouraging. Some extension of turbine output and uptake of particles is reasonable. Some issues such as a dependence on movement will need to be addressed for real applications.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
It is difficult to determine if such a unique investigation of a previously untried concept should be coordinated. When the funds are reduced, should the new fluid development efforts be slowed and the demonstration aspects started early? It is clear that not all of the goals of the project were completed.

Reviewer 7:
Research seems on track.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
This is problematic for turbomachinery and EGS; it may have may have an application as a heat transfer fluid.

Reviewer 34:
Quantitative measures of cost and benefit should have been estimated.

Reviewer 7:
This research could lead to some discoveries that might help in ways not currently envisioned. For example the absorbing quality of the nanoparticles could lead to their use not only in working fluids but maybe well testing, drilling or other applications. This research is important because it brings into the geothermal arena more tools. How they will be used is not certain and that is why the research is needed.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
The basic research aspects of this project were strong.

Reviewer 7:
Offshoots into other areas could provide a very high return. Nanoparticles have been shown to have very different properties than traditional particles. One application might be to use the particles to penetrate a well bore, as an example, and create a weaker rock and improve the drilling rate (the particles might be applied through mud). They might also be used to create fractures. Who knows where this research could lead? It deserves funding.

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
It was proposed that the application of this concept to geothermal energy would be investigated via cost estimates and a physical demonstration. However, this was not completed due to funding redirections.

Reviewer 7:

Suggestions for Improvement

Reviewer 21:

Reviewer 34:

The program should have presented rough estimates on the costs and benefits of this project. In this way it would be obvious what aspects of the project needs further work (e.g., the cost of the production of the particles, the performance of the particles in improvement of the cycle, the agglomeration of the particles, etc.). It is possible that this concept may be better suited to a CO2 cycle where the fluid inventory is significantly reduced. Maybe this should be investigated.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0204
Presentation Title: Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy
Investigator: Jody, Bassam (Argonne National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project tries to examine a novel concept of extraction of energy from a geothermal reservoir via chemical energy instead of just thermal energy. This opens up a number of avenues for improvement of energy extraction: 1. The energy density of the fluids may be significantly increased, thus reducing the amount of fluid that has to be transported from deep underground. 2. Transport of chemical energy may result in less losses during the vertical transit in the wellbore. 3. The energy conversion efficiency may be greater than a typical thermal system. This is an important area of research, but one of high risk.

Reviewer 7:
The use of an alternate carrier to bring up geothermal energy could revolutionize the geothermal industry. It is hard to know where this research might lead. Even if unsuccessful it could inspire a notion or concept that will succeed.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
The investigation has taken a very broad look at various chemical reactions that may be incorporated into a geothermal system. This is appropriate for this early stage of the research.

Reviewer 7:
The first issue to determine is if there is a carrier that might have a chance of success, which is where the research is focused. Depending on that carrier and its mechanism, there may be a host of other issues, which will need to be addressed to determine if this could work.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:

Reviewer 34:
The investigation has determined a number of potential candidates for transport of chemical energy. However, at this point the project should try to establish a better screening process that will evaluate the feasibility of the various prospects. Available energy should not be the only thing used in evaluating the prospects; the project should examine such things as costs, toxicity, corrosion, chemical stability, etc. Injection of chemicals underground will not be a concept that the public will embrace.

Reviewer 7:
Some potential carriers have been identified.

Comments Regarding Project Management/Coordination

Reviewer 21:

Reviewer 34:
This project is well coordinated and seems to be obtaining interesting results.

Reviewer 7:
Satisfactory progress is being made.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
Although in a very early stage, this research presents a basic advantage of transferring heat at constant temperature with a reduced flow, therefore less pumping losses with further development; it may be very important for enhanced geothermal systems (EGS) where this is critical for EGS.

Reviewer 34:
This project investigates new ways to extract energy from a geothermal source. The concept may result in a better levelized cost of electricity (LCOE). However, the applicant did not address costs at this early point of development.

Reviewer 7:
This research could lead to radical changes in how a lot of things are done. For example, a chemical carrier of energy might lead to a different strategy for distributing heat (as compared to steam or hot water for example). The reviewer would recommend that the current research continue to identify and test potential carriers. No doubt that the carriers will bring issues of their own that will require solutions.

Comments Regarding Strengths

Reviewer 21:

Reviewer 34:
This study essentially introduces another free parameter available to the system designer. If energy can be extracted via thermal and chemical means, the design space becomes larger and the optimal point is likely outside the space with no chemical extraction. The reviewer liked the presentation very much where they identified that the optimal solution is dependent upon the actual site. For example, deeper wells will drive the design to different optimal points.

Reviewer 7:
This is a new way of developing a resource.

Comments Regarding Weaknesses

Reviewer 21:

Reviewer 34:
The concept is in its initial phase, however, some discussion still should have been provided to address the potential drawbacks to this program: 1. cost of loss of working fluids, 2. contamination of working fluids, 3. corrosion problems, 4. pollution, etc.

Reviewer 7:

A success in the carrier will likely come with issues that must be resolved. The research underway will likely not identify all the issues.

Suggestions for Improvement

Reviewer 21:

Reviewer 34:
The presentation could have been more balanced if potential problems were identified that make this concept less attractive.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0205
Presentation Title: Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources
Investigator: Hays, Lance (Energent Corporation)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project is to demonstrate a unique thermal power cycle for low-temperature applications. The goal of this project is to lower the levelized cost of electricity (LCOE) by demonstrating a low-cost, low-efficiency cycle.

Reviewer 7:
This is good basic research that can improve the output of existing systems by a significant margin.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
The design tries to maximize the power extracted from the geothermal brine. This typically results in a low-efficiency cycle but may result in a better LCOE. The applicant has adapted a low-quality turbine that is used in cooling systems to the trilateral cycle.

Reviewer 7:
There is nothing as powerful as building a working example, which is what is being done.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:

Reviewer 34:
This project is on schedule. As might be anticipated for a new cycle, it is over budget (however, this is being covered by the applicant and not DOE). Unfortunately the chosen site has high-concentration brine which prevents one from taking full advantage of the main feature of the trilateral cycle (low brine return temperatures). The brine also has resulted in a larger evaporator and a larger inventory of working fluid. Both of these have further increased costs.

Reviewer 7:
The nozzle and turbine efficiencies combined with the increase in output are very encouraging.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
The project has overcome the extra costs encountered due to the brine concentrations. They have adapted the design to enable a successful demonstration.

Reviewer 7:

The project is on track. It has a small team, limited focus, and is result-oriented.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
This project has very impressive results with practical applications for low-temperature heat sources. This is the first really practical application of a trilateral cycle.

Reviewer 34:
The reviewer was impressed by the knowledge demonstrated by the presenter and his ability to present the project without exaggerating its capabilities.

Reviewer 7:
This research takes an idea that has been around a long time, resolves the limitations and demonstrates the solution. The results to date suggest a significant improvement in turbine output.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
This project (as should any demonstration project) is concentrating on demonstrating a low LCOE, and not fixated on the thermal efficiency. Thermal efficiency is of no real importance to a power cycle where the input energy is free. The isentropic efficiency of their turbine is very impressive given the low quality (vapor content) of the working fluid flow.

Reviewer 7:

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
It is unfortunate that this demonstration is set at a site with high brine concentrations. The advantages of the trilateral cycle cannot be fully demonstrated with high brine concentrations. There are some other geothermal applications where the brine concentration is significantly less. Unfortunately these are not the norm. However, this cycle can be applied to waste heat applications where brine concentration is not an issue.

Reviewer 7:

Suggestions for Improvement
Reviewer 21:

Reviewer 34:
The reviewer does not see any significant improvement that could be made in the project. However, the presentation could be improved by providing more details about the turbine. The performance of the turbine is what makes this cycle optimal. The isentropic efficiency of the turbine is much larger than the reviewer anticipated. Also, the reviewer was impressed that this turbine has been in operation in cooling systems. Stressing these two features would have been of more interest to the audience. The presentation could also have stressed that the goal of the cycle is to generate more

power from a resource, and this results in a lower efficiency due to the fact that much of the energy is extracted at low temperatures. However, this was not fully demonstrated in this application due to the high brine concentrations.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0206
Presentation Title: Optimization of hybrid-water/air-cooled condenser in an enhanced turbine geothermal ORC system
Investigator: Wu, Hailing (United Technologies Research Center)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project seems to be centered on the increase in geothermal cycle efficiencies. This is only an indirect measure of geothermal performance. Since geothermal energy is essentially free, the efficiency is not a parameter to optimize. Levelized cost of electricity (LCOE) is the most important parameter in determination of the success of a geothermal project.

Reviewer 7:
The research proposed in this study has been done in the past. It basically proposes to select the optimum water/dry air heat rejection strategy and then look at varying other components of the ORC. This work has been done. The researcher appears dedicated and sincere; it‘s just that the mission here has already been achieved.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
The major focus of this project was to incorporate water into the condenser design at times of peak ambient temperature. This would decrease the condensing temperature and improve the power output of the cycle during the time periods when the power output is the lowest. The project also is developing a water purification concept which would enable the use of water in the condenser. Finally, the project is examining a new turbine design for variable cycle conditions. The project will test much of their designs, and this will help in determination of the feasibility of the concepts.

Reviewer 7:
The reviewer sees no work proposed that has not already been achieved and could be referenced in existing research.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
When starting from a specific low-efficiency turbine it is easy to improve the efficiency. Use of variable nozzles does improve the efficiency at high ambient temperatures but because it is done by reducing the throat cross section it reduces flow so that there is no power output gain.

Reviewer 34:
The presentation provided little details about the project accomplishments. Much was declared proprietary, and thus not presented. It is unclear how the new turbine design is of any use to the community. The design seems to try to increase the isentropic efficiency of the turbine at the expense of a reduced mass flow. This will likely result in reduced turbine power output.

Reviewer 7:
The researcher is making progress towards goals set within the program.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
The project seems to be well coordinated with demonstrations planned for the major design goals.

Reviewer 7:
The researcher is using existing facilities for testing, which conserves cost.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:

Reviewer 34:
This project is difficult to evaluate due to the limited details provided by the presenter.

Reviewer 7:
It's not that this project is not being executed with good intent and dedicated researchers. The issue with the project is that nothing new is being brought to the industry.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
The investigation of a water purification system into the on-demand water cooling condenser is important. Many water cooling systems will fail (clogging, scaling, reduced heat transfer, etc.) with poor quality water. The testing of the new designs will help demonstrate their ease of use and operational difficulties (if any). However, the costs of the water purification system were not presented.

Reviewer 7:
This project should be redirected towards new research.

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
It was not clear how the proposed new turbine design resulted in any gain in a geothermal application. The presenter stated that the new turbine design would dampen power fluctuations, but the reviewer was still unsure of how this was accomplished. The reviewer was under the impression that the turbine incorporated variable nozzles that could be adjusted to maximize the turbine isentropic efficiency, and this would potentially lower the cycle output power under certain conditions. Since the heat is free from a geothermal resource, the cycle efficiency (or isentropic efficiency) has no direct impact on the LCOE. Thus, the design should be trying to optimize the output power, and not the cycle efficiency. It seemed that the primary goal of the project from the presenter's perspective was efficiency. Use of spray water in a condenser often results in scaling problems. The applicant realizes this potential problem and is

investigating water purification to avoid this problem. However, there was no discussion about the cost impact of the water purification.

Reviewer 7:

Suggestions for Improvement

Reviewer 21:

Reviewer 34:

The project should present the impact of all design changes on the LCOE. The reviewer realizes that this is very cumbersome, but LCOE is the major metric for geothermal power where the input heat is essentially free.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0207
Presentation Title: Hybrid and Advanced Air Cooling
Investigator: Bharathan, Desikan (National Renewable Energy Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
This project examines the addition of water to an air-cooled condenser during time periods when a significant performance improvement can be made. This is measured as an increase in thermal efficiency. It is important to lower the levelized cost of electricity (LCOE) of geothermal energy. Increasing the efficiency of a cycle (without increasing costs) is one way to lower LCOE. Adding water to an air-cooled condenser would increase the efficiency. However, water availability and quality is often poor making this concept difficult to universally apply.

Reviewer 7:
The researcher is investigating areas that have had numerous investigations in the past. The optimization of the ORC using wet/dry heat rejection strategies has been thoroughly investigated, even the use of nozzles. The reviewer sees nothing the research purports to discover that would be new to the industry.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
The modeling of water cooling equipment is well within the capabilities of the industry, and it is unclear how this project adds to the knowledge base. Designing unique, cost-effective modifications to air-cooled equipment would be of use, but it is not clear that this has been accomplished. The strength of this project will be the demonstration of a system that can be utilized only when needed, is cost effective, and low maintenance. Achieving all of that will be difficult, and will likely require novel design features.

Reviewer 7:
This research is looking at solutions to wet/dry cooling that have been thoroughly investigated in the past. The approach being implemented is very likely to arrive at previously published results.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
This project developed a methodology which will be a good base for planning and analyzing hybrid, advanced and conventional air cooling.

Reviewer 34:
At this stage the project has only presented modeling results. The project has not presented what novel features will be incorporated into the design to make it economically feasible.

Reviewer 7:
Research is proceeding along time and budget lines.

Comments Regarding Project Management/Coordination

Reviewer 21:

Reviewer 34:
The project seems to be on budget only if one considers the fraction of the time spent. It is unclear how the remaining budget will not only support the personnel for the remaining time but also acquire, install and test equipment at a demonstration site. It is unclear if late summer and early fall provide a suitable time frame for testing the equipment since inevitable time delays may result in the project not being tested in the hottest time of the year.

Reviewer 7:
The research uses existing facilities to maximum advantage.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
This project is important for future planning and analyzing hybrid, advanced and conventional air cooling.

Reviewer 34:
This project should be centered on the development of a novel design that allows incorporation of water cooling on an on-demand basis. The project does not seem to offer something unique to the community.

Reviewer 7:
This research is unlikely to identify any new breakthroughs. From what the reviewer can see they are pursing problems that have been looked at in the past with the same type of investigations. The reviewer has little doubt they will arrive at very similar solutions as the ones published in the literature.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
The testing of a design will provide operational experience of an on-demand water-cooled condenser. It is important that the designs chosen be carefully considered, for there is not much funding left for a wide-ranging test program.

Reviewer 7:

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
This project correctly identifies a barrier to the use of water cooling as the lack of water at the geothermal site. This project does not provide any insight on how to overcome that barrier. The use of poor quality water is also a barrier, and this project does not seem to include this in the project design. Many cooling concepts will not work reliably with poor quality water. The project seems to only include capital costs for the added water-cooling equipment. Operation and maintenance costs might also be considerable.

Reviewer 7:

Suggestions for Improvement

Reviewer 21:

Reviewer 34:
The project presentation clearly acknowledges that the addition of water cooling to a geothermal power site is site dependent. Each site may require a unique solution depending upon the cost of water, the quality of the water, and the local climate. However, the project did not supply any guidance as to how this might be solved. It would have been interesting if the presenter gave specific examples on what would be optimal at a few distinct sites. This would provide guidance to the industry on what factors would drive the design in particular directions.

Reviewer 7:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0208
Presentation Title: Air-Cooled Condensers in Next-Generation Conversion Systems
Investigator: Mines, Greg (Idaho National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 21:

Reviewer 34:
It is important to lower the levelized cost of electricity (LCOE) of geothermal power. One way to accomplish this is to increase the thermal conversion efficiency without significantly increasing the cost of the equipment. This project attempts to accomplish this by examining relatively standard improvements to relatively standard thermal cycles.

Reviewer 7:
This research has already been done. It adds little, if any, new information that helps resolve geothermal issues. It is already known that power output increases with lower rejection temperatures.

Comments Regarding Scientific/Technical Approach
Reviewer 21:

Reviewer 34:
The reviewer is concerned that the approach is destined to fail since these standard thermal cycles have been investigated, and thus all of the standard modifications to standard cycles have already been investigated. However, the reviewer is pleased that this program has concentrated on reducing the cost of the electricity instead of increasing the thermal efficiency. One can always increase the efficiency of a cycle (use larger heat exchangers), but this often requires significant excess costs. Geothermal cycles are best rated by the LCOE, and the thermal efficiency does not enter this calculation. The reviewer feels that the route to major improvements is the development of radically different cycles. One might consider a cycle with very low efficiency and very low costs that would deliver a low LCOE. This is being attempted by Energent with their trilateral cycle. The alternative is to develop a high-cost, high-efficiency cycle like the Kalina cycle, and this has met limited success. Of course the ultimate goal is a low-cost, high-efficiency cycle.

Reviewer 7:
The presenter was very good, honest, and to the point. He understood that the research he was presenting had already been done. So while the approach appeared to be reasonable and on track, the reviewer‘s issue with it is that the endstate is already known.

Comments Regarding Accomplishments, Results and Progress
Reviewer 21:
There is nothing new in recuperation which is widely used in ORC. Mixed working fluids require more analysis and tests to evaluate the impact on flow and sensitivity to selective leaks of fluids. The method presented will be useful for future work on mixtures.

Reviewer 34:
The presentation concludes that "it is unlikely that large improvements can be made..." Thus, it is difficult to rate this program well in terms of accomplishments. The project was well performed, and the results were accurate and fairly presented. However, the negative result had no impact on lowering geothermal LCOE and should have been anticipated.

Reviewer 7:
The reviewer has no doubt that the research is being conducted as proposed and finds no issue with the researchers. They are on target to do what they set out to do.

Comments Regarding Project Management/Coordination
Reviewer 21:

Reviewer 34:
The project investigated a large variety of potential areas of improvement to geothermal cycles, and compared them in terms of the effect on LCOE. Each modification was examined in a fair manner.

Reviewer 7:
The project appears on schedule and within budget.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‗s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 21:
Although the project doesn't look too promising, the method presented may be useful for future work on mixtures.

Reviewer 34:
It is difficult to evaluate a project with a goal of finding innovations to lower the LCOE of a geothermal power system. Power systems have been perfected over a number of years and innovations are difficult to obtain on demand. It would be better to fund programs that have a novel idea that needs funding to develop.

Reviewer 7:
The reviewer‗s issue with this project is that it does not bring any new aspects to solve a heat rejection problem. Even if successful it is unlikely to discover any new knowledge or solutions. It‗s more of the same that has been done over the past 30 years.

Comments Regarding Strengths
Reviewer 21:

Reviewer 34:
The reviewer was very impressed by the honesty of the presenter. After listening to others promise large improvements in geothermal cycle efficiency, this presentation stated the obvious. The large improvements presented by others were all based on comparing to a very poor design that was designated a "baseline."

Reviewer 7:
The researchers are honest and forthright about their efforts.

Comments Regarding Weaknesses
Reviewer 21:

Reviewer 34:
The reviewer thinks additional work on trying to incorporate an air-cooled condenser into a mixed fluid thermal cycle is destined to fail. Optimal air-cooled condenser designs have a low-pressure drop on the air side and run with low-temperature increases on the air side. Reworking them to have multiple air passes (or air passing over multiple condenser

tubes) will defeat this feature. Also, these condensers work best with cross flow of the air to the working fluid path, and thus the fins that are typically used will make countercurrent flow arrangements difficult to obtain.

Reviewer 7:

Suggestions for Improvement

Reviewer 21:

Reviewer 34:

Reviewer 7:
The focus of the research needs to be on innovations, and not more of what's been done over the last 30 years.

Reservoir Exploration, Characterization and Modeling

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0900
Presentation Title: Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling
Investigator: Newman, Gregory (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
Improved imaging of reservoirs and their development through time is clearly congruent with the program's goals.

Reviewer 19:
The impact of the project is good be quite important and could change the emphasis we have on geophysical exploration methods.

Reviewer 40:
It would be useful if the model worked but currently has not been tested or validated. There are difficulties in finding a suitable area to test, which suggests that the technique may be limited.

Reviewer 25:
If successful, this project will provide a very valuable tool for monitoring EGS reservoir creation and development (i.e, fluid location), and assist with operations management (including injection and production well location)- so make important contributions to the Geothermal Program mission. The ability to accurately "image" the reservoir will help more successfully site wells and define drill depths. Consequently, the industry can expect to reduce costs- a very important consideration and necessary contribution to making EGS cost competitive and therefore a viable technology. If proven, this technique could provide important fundamental information about how to create reservoirs in different settings/environments. Also, being able to determine pre-stimulation and post-stimulation conditions in the created reservoir could provide valuable information on the success of various stimulation methods and a method for monitoring reservoir evolution during long-term production. All of this information is needed for determining sustainable operation.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
The teamis experienced in the type of work necessary and have made significant progress in developing the necessary joint inversion codes.

Reviewer 19:
The scientific approach is solid.

Reviewer 40:
Resolution is a major problem. The lack of observed earthquakes will be a problem with programs such as TomoDD. Proven time-lapse signals from CSEM and MT are useful, if they can be accurately defined spatially. Resolution is an issue, especially if there are not enough earthquakes. It would be good to provide bounds on what can be imaged - what is the expect spatial resolution? The technique is limited to areas with low noise.

Reviewer 25:

Though the individual survey techniques used are innovative, the use of proven geophysical methods, MEQ and resistivity surveying, in a combined/synergistic manner is also innovative and would increases the probability of success in fluid location (i.e., reservoir location). Design using the same equipment and techniques to obtain background (i.e., pre-stimulation) conditions (rather than using information from previous survey data), change and post-stimulation data/information will give more confidence in making the comparisons.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Progress in joint inversion is satisfactory and the necessary baseline data has been acquired.

Reviewer 19:
Due to low natural micro-seismic activity in the area, little information has been gathered. However, during stimulation this will change.

Reviewer 40:
Results and progress seem to be somewhat on schedule although not all datasets have been analyzed (e.g. CSEM). PI seemed to have great difficulty in identifying a site.

Reviewer 25:
Project is on track both with time schedule and expenditure.

Comments Regarding Project Management/Coordination

Reviewer 3:
No issues noted.

Reviewer 19:
The site decision making poor. This site is not very well suited for this study. This could have been known beforehand.

Reviewer 40:
Fair flexibility given problems with site selection.

Reviewer 25:
There is a problem with the geothermal field selected to develop andtest this technique. The selected test field was not first choice. The final chosen area, Raft River, has a reservoir depth 600 meters deeper than first choice. This could make it very difficult to detect and measure the resistivity changes desired (5% change is expected minimum change detectable). Baseline (pre-simulation) data has now been collected, but the low seismicity of the site could be an issue for defining initial reservoir volume; but expected the increase in seismicity when injection begins should help. The combination of collaborators, including the developer (US Geothermal) provides a good range of expertise and support. Appropriate decision points have been set.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
The change in demonstration's site, driven by circumstances beyond the team's control, is unfortunate as the depth, fluid character and volume characteristics of the Raft River site are marginal for the technique's expected resolution. However,

parallel projects on other sites in the US and Iceland mean that the techniques, which are generic, will be evaluated elsewhere in addition to Raft River.

Reviewer 19:
Sound methodology and scientific merit. Lack of micro-seismic activity causes problems.

Reviewer 40:
Innovative project but may have difficulties with resolution.

Reviewer 25:

Comments Regarding Strengths
Reviewer 3:
The project team knows what they are doing and they are making satisfactory progress.

Reviewer 19:
The project‘s strength is its scientific approach.

Reviewer 40:
The use of advanced algorithms applied to several data sets is the project‘s strength.

Reviewer 25:

Comments Regarding Weaknesses
Reviewer 3:
Raft River is not an ideal test site, but other sitesthat are being worked on will allow additional testing for the techniques under development.

Reviewer 19:
I question whether it is necessary to continue funding this project since this methodology is being applied in other fields with a similar scientific team. One could rather increase the budget for the other projects.

Reviewer 40:
It is not clear how the model will be validated and no clear plan for validation is presented. There is little comparison available with known geology. The lack of earthquakes means that use of algorithms such as TomoDD are likely to perform poorly.

Reviewer 25:

Suggestions for Improvement
Reviewer 3:

Reviewer 19:
The PI should focus on other sites rather than this one.

Reviewer 40:

Reviewer 25:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0901
Presentation Title: Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-Dimensional Electrical Resistivity Structure
Investigator: Wannamaker, Phillip (University of Utah)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Improved resolution in 3-D electromagnetic (EM) inversions is of great significance to geothermal projects.

Reviewer 19:
The project's aim is to improve interpretation simulator for resistivity data. If successful, this could influence the industry's choice of program and could enhance the information we can get from the field data gathered. With improved computer technology, this is a logical step forward. However, it is no leap in technology.

Reviewer 40:
An improved algorithm to model resistivity would be useful if it is a substantial improvement over previous methods.

Reviewer 25:
This project addresses the need for obtaining more accurate information (location of fluid in fractures associated with EGS) from magnetotellurics (MT) survey resistivity data through development of an algorithm which incorporates topography and can be run on mainstream multi-core workstations. This may prove to be a valuable tool for resource assessment, and reducing exploration and drilling risks; hence, will benefit the Geothermal Technologies Program. Successful porting of simulation to mainstream workstations could speed-up and help reduce analysis cost.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
Utilization of existing, major research efforts as the basis for his work is a sound and cost-effective approach to which the magnetics functionality is being added.

Reviewer 19:
The information given is really not enough to comment on the scientific merit of the approach. However, from a broader perspective, if the interpretation of the authors is to be used, I would recommend looking atother data that exists for this field, i.e. alteration of minerals in the wells drilled and see how well this correlates with the model that the simulator suggests. This feature could be added to the simulator as observations for example to correlate the parameters to some extend.

Reviewer 40:
The PI appears to have a solid understanding of the topic and is taking a reasonable approach to constructing the algorithm. The development is still underway so it is difficult to assess the approach completely.

Reviewer 25:
The overall project planning seems OK and could provide useful input to the Geothermal Technologies Program, if successful. However, it is not clear to me how the final results of the "best" algorithm will be assessed, i.e., will they be compared to a known field well and other data and information?

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
Progress is good on both the code evaluation and development and on the parallelization tracks.
Reviewer 19:
Hard to really comment on the results yet.

Reviewer 40:
It appears that they have made a start on the code development. Not quite as much progress (~ 12 %) as would be hoped for at this stage and it will require focused work to complete on time.

Reviewer 25:
The project is only about 12% complete, though progress seems to be good. However, it is not clear if the results are satisfactory relative to attaining the project's final objectives within the allotted time frame. Accomplishments could have been more clearly presented; confused by too much technical detail.

Comments Regarding Project Management/Coordination
Reviewer 3:
Good to date. I retain some concerns about prioritization of work for the team in the future given the number of commitments they have.

Reviewer 19:
The management seems to be in order although only a small portion of the funds have been spent.

Reviewer 40:
Budget is at 12% but 50% of the project period is complete. It appears that this project is not a priority for the PI.

Reviewer 25:
The project is only 12% complete and the spending is in accord with this. I did not understand the explanation about times being "pushed-back" to accommodate other (related?) projects. There may be difficulty in completing this project in the remaining time, considering the total effort indicated for PI (1.5 years) and student (2.25 years) (it was not clear how much time was to be contributed by the post-doc). The presenter also indicated that a time extension might be requested-without request for extra funding.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 3:
PI is clearly on top of the problem and has forged a highly effective team.

Reviewer 19:
The simulator could possibly use observed data from other field measurements beside resistivity measurements as to correlate the model better or for model validation. That is how the simulator would be used in practice by the industry, so

having a built-in feature for that would be an improvement.

Reviewer 40:
The project =strength is technical sophistication.

Reviewer 25:
The information presented was too technical at the expense of providing a clear explanation of the practical aspects of the project. There is no official "outside" collaboration with other organizations, though this is probably not a serious problem.

Comments Regarding Strengths
Reviewer 3:
Existing code base and progress-to-date on testing and modification.

Reviewer 19:
The project is relatively controllable and will likely to get results.

Reviewer 40:
Innovative and useful algorithm.

Reviewer 25:

Comments Regarding Weaknesses
Reviewer 3:
Risk of over commitment.

Reviewer 19:
Lack of a more comprehensive approach towards consideringother types of field data besides resistivity measurements for model validation purposes.

Reviewer 40:
Not clear if the work will be completed given the apparent lack of progress so far and list of other projects being worked on by the PI.

Reviewer 25:

Suggestions for Improvement
Reviewer 3:
Guidance on prioritization from the Geothermal Technologies Program.

Reviewer 19:
Look at whether other field data could be incorporated into the model.

Reviewer 40:
Prioritize this project. It seems to be a low priority among the PI's projects. Ensure that the code is open-source for maximum impact.

Reviewer 25:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0902
Presentation Title: Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes
Investigator: Faulds, James (Board of Regents NSHE on behalf of the University of Nevada Reno)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Project aims to improve site selection. This isrelevant to both EGS and other geothermal systems.

Reviewer 19:
The objective is to come up with a catalogue of physical characteristics deemed important for fluid extraction. This is an important and practical aspect of geothermal development.

Reviewer 40:
Better conceptual models for geothermal system are urgently needed and this fills a gap.

Reviewer 25:
This well-focused project directly addresses important barriers identified by the Geothermal Technologies Program and is directly relevant to reducing drilling and development risk for both EGS and hydrothermal, especially "hidden resources". If successful, the methods and results will be very valuable for directing expensive drilling to high priority sites, so this should help reduce costs and improve development success. Geothermal education is extremely important for the future success of geothermal RD&D in the US (and globally). An important part of this project is its recognition of this education issue and its apparent successful development and conduct of a course on geothermal exploration.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
The approach utilized is based on current structural geology concepts including fault zone categorization, structural (kinematic) analysis and slip/dilation 'tendency' analysis. It is good to see workers in the geothermal community starting to embrace such a suite of modern geological concepts. I am a little puzzled by some of the structural settings described. Several of them seem to be rather similar, but this is a minor criticism. Much of the value of this work will accrue from the initial analysis of Great Basin geothermal systems, but there will be additional utility in the more detailed site-specific work, including in particular, the slip/dilation tendency analysis.

Reviewer 19:
The scientific merit is sound in regards to the level of information given to the reviewers.

Reviewer 40:
Approach seems reasonably straightforward and takes a big picture view that moves geothermal exploration into a more mature approach, similar to that taken by oil and gas exploration. One comment: the structural settings for geothermal fields along normal faults was expressed as a percentage but was not compared (or normalized) to the percentage of the fault that occurs in that settings. For example, 32% of the geothermal areas were in step-overs or relay ramps. What percentage of the fault length is typically occupied by step-overs or relay ramps? If, for example, 32% of the fault length typically occurs in relays or step-overs then this would suggest geothermal areas are simply randomly distributed. Can GPS/strain data be used?

Reviewer 25:

A combination of proven (conventional) and innovative (slip tendency analysis) techniques is well thought out and the project well designed, and should produce the desired outcomes. The analysis methodology, data and information collected should make a valuable contribution to future EGS and hydrothermal exploration.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Progress to date has been reasonable, although spending is not in-line with time. The initial analysis is clearly of utility to explorers already.

Reviewer 19:
Very good results.

Reviewer 40:
Good progress despite some personnel issues.

Reviewer 25:
The project has made good progress with all but one of the planned milestones achieved.It seems the necessary tasks have been completed to allow the project to finish in the scheduled time.

Comments Regarding Project Management/Coordination

Reviewer 3:
Progress has been adequate to date, with most milestones met, although co-PI participation could have been better managed.

Reviewer 19:
Good management.

Reviewer 40:
Appears to be handled well.

Reviewer 25:
The project is a little behind schedule, and spending is correspondingly at about 20%. Problems due to loss of two PIs are apparently being addressed with inclusion of new researchers and several graduate students and spending is expected to accelerate because more expensive analyses are beginning. The manager seems to be dealing with these issues appropriately with good set of achievements to date and the way forward clearly specified. Good range of collaboration with industry and integration with other Geothermal Technologies Program-funded projects gives this project strength and access to geothermal areas and the data/information required. No decision points were specified in the schedule and it could be useful to prepare some for the remainder of this project. However, the key activities for the remainder of the project are very well specified, and if the schedule is followed there should be no problem in its completion.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project utilizes standard, current structural geology methodologies in a new application domain (i.e. geothermal exploration) and has already yielded useful and useable results. It has the potential not only to develop and embed new and significant concepts into geothermal exploration (for EGS and other types of systems, in the Great Basin and more

broadly) but also to produce a cohort of new ―explorationists" educated in recent structural geology concepts likely to benefit the industry in the long term.

Reviewer 19:
The project deals with a practical problem the industry always faces with developers deciding which area to investigate further. It is important to look at this closer and determine if this is possible.

Reviewer 40:
A good project that is likely to have significant long-term impact in discovering and evaluating geothermal prospects. On track.

Reviewer 25:
This is a valuable project for developing a methodology for initial exploration for EGS and hydrothermal systems where little surface expression is present. It is also valuable for its educational aspects, since the desired U.S. goal of significant geothermal development by 2050 will require a significant increase in the number of exploration experts.

Comments Regarding Strengths
Reviewer 3:

Reviewer 19:
The strength of the project lies in its simplicity.

Reviewer 40:
Well-focused effort to improve exploration strategy and may pay off in future by enhancing drilling success.

Reviewer 25:

Comments Regarding Weaknesses
Reviewer 3:

Reviewer 19:
There is only a limited number of fields being investigated in the same area. This of course results in the catalogue not being complete. However, it is a good first step.

Reviewer 40:
Not clear to me why teaching a class is part of the funded grant. While future geothermal expertise is needed, the total cost per student is likely very high. As the students are paying tuition it seems that the University ought to be covering the time. If Federal funds are covering time, class notes, etc. The materials should be made available to a wide audience.

Reviewer 25:

Suggestions for Improvement
Reviewer 3:
Ensure that understandings from the extensive work on structural settings undertaken by/with/for the oil and gas industry is fully utilized.

Reviewer 19:
It could be useful to look at a developed field as a green field using the catalogue and see if suggestions according to the catalogue turn out to be correct.

Reviewer 40:
Calculate the expected percentage of geothermal settings along faults, if the geothermal areas were randomly distributed. This would help in assessing significance. Possibly include GPS data.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0903
Presentation Title: Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation.
Investigator: Iovenitti, Joe (AltaRock Energy, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
This project has the potential to be a significant contribution to EGS exploration strategies in the Basin and Range and beyond.

Reviewer 19:
In general, it is important to look at geostatistics as this project is doing.. This results in the possibility of creating a favorability map, which will be based on the parameters stress, temperature and lithology. However, such an approach might though never succeed the capacity of an experienced geologist in the relative area. So a favorability map should be looked at as supplementary advice for decision makers.

Reviewer 25:
This project is directly relevant to the Geothermal Technologies Program goals since, if successful, it will provide a useful method for combining exploration geoscientific data/information in a cost-effective synergistic way to produce a (favorability) map to guide more successful well siting, hence reduce exploration costs and assist with project (both EGS and Hydrothermal) development.

Reviewer 5:
Synthesizing interdisciplinary methods seems to be the best way to get the most out of disparate data types and glean the best information regarding the configuration of a potential reservoir and likelihood as a prospect for EGS. Although use of seismic noise is not new for velocity determination, using it for attenuation is not nearly as well developed a method and any innovations on this front will benefit the wider community.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
While the concept of a regional favorability analysis is sound, there a several features of concern in the approach being undertaken: 1. A number of the parameters under consideration are both modeled and intrinsically correlated. Modeled data is always based on assumptions. Further, seismic velocities and density, for example, will inevitably show a correlation due to the underlying physics. Other parameters will correlate with depth and at least crudely, with temperature. A rational selection of parameters to input into the favorability analysis would seem essential rather than merely relying on statistical analysis to identify potentially misleading correlations. 2. Some data sets, such as soil gas, would appear out of place in a regional analysis as they are point data and not being collected systematically across the area. Other data,such asseismic, MT, are being gathered only along traverses. This information will not be available across the entire area and therefore is not useful in developing a uniformly informed favorability distribution.

Reviewer 19:
The parameters based on the results of the feasibility map will be stress, temperature and lithology.

Reviewer 25:
There appears to be an excellent group of collaborators including well-qualified experts from universities, a national lab

and industry. Though the integration of geoscience data sets has been used for decades in siting wells, and the generation of 3-D sub-surface models for resource visualization has also been used for the past several years, the suggested methodology for deriving a "favorability" map by combining such data-of varying resolutions-in a cost-effective and quantitative manner is new. However, I am concerned that the 5 km x 5 km area resolution is not fine enough for targeting wells and consequently rated this aspect "Fair" rather than "Good". Also, if demonstrated, the application of "ambient noise" seismic technique would be a valuable addition to exploration. How the "favorability" map is to be generated was not explained. The chosen geothermal field (Dixie Valley) for the study appears a good one since there seems to be a large amount of required data available, especially sub-surface information from over 30 wells.

Reviewer 5:
Looks like an innovative approach to data synthesis. Not joint modeling but statistical evaluation of the significance and consistency of the independent data and their meaning. I like the combination with the thermal anomalies and using the lithology in the mix.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
No analysis of the statistical correlations has been made yet, and there appears little rationale behind the choice of data types. There seems to be a move towards a traditional exploration mindset in data gathering rather than remaining focused on the development of a favorability map at a scale of 5km x 5 km.

Reviewer 19:
Few results were shown in the presentation, so it is hard to comment.

Reviewer 25:
The project appears to be behind schedule (35% complete) but it is not clear what the spending status is (<10%?). I am not convinced that the entire planned project will be completed by the specified deadline. It would have been a good idea to include more "decision points (go/no-go?)" in the schedule. A go/no go decision after Task 3, which involves generation of the first (baseline) favorability map, might have been especially appropriate, since this is the first attempt at producing a favorability map. It would have been very useful for the "supporting" figures, tables and plates to be included in the project summary, especially since the goal of this project is to produce a "favorability" map and 3-D sub-surface model. Information about how the "ambient seismic noise survey" method works would have been helpful.

Reviewer 5:
Seems on target and on schedule with the proposed tasks. Too early to really evaluate the magnitude of the significance, as a decision point is not yet reached and data gathering appears to still be underway.

Comments Regarding Project Management/Coordination

Reviewer 3:
The project is marred by a lack of clarity on the scientific approach to be taken in order to achieve its stated objectives.

Reviewer 19:
No real issues with the management that could be seen. The exploration portion of the project hasn't started which will take up most of the funds.

Reviewer 25:
The project has made reasonable progress, however, it is behind work schedule due to a 7-months delayed start and significantly behind in expenditure--though the surveys planned for 2011 may bring spending into line. Comments regarding problems with keeping university participants on schedule raises concern. Based on the information provided, I am not convinced the entire project will be completed within the planned schedule.

Reviewer 5:

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
The is project came across as utilizing a random grab bag of techniques typically used in exploration in the area, with little evaluation of what new information each data set will bring to the analysis. It aims to trial some new techniques such as passive seismic, which is encouraging, but there does not appear to be any clear reason why these techniques are being investigated, and whether they will yield information of relevance or appropriate spatial resolution.

Reviewer 19:
The fundamental idea of the project is sound and it is important to guide the geothermal industry into this direction. Geostatistics has not been used that extensively by developers.

Reviewer 25:
Overall, this appears to be a good project.It could provide a valuable methodology for identifying EGS sites and has a strong team, but progress has been slow. It is questionable if a "resolution" of 5 km x 5 km is high enough for providing a meaningful target for well siting. Perhaps the available data is too "coarse" for application here? The project is behind schedule and requires more "strict" management for completion.

Reviewer 5:
Good proposal, interesting approach and has promise of providing a statistical approach to evaluating a prospect bringing in not only geophysical data types but also lithology and mapping.

Comments Regarding Strengths
Reviewer 3:

Reviewer 19:
The objective of the projects are its strengths.

Reviewer 25:

Reviewer 5:

Comments Regarding Weaknesses
Reviewer 3:

Reviewer 19:
The weakness of the project lies in its complexity from a statistics point of view--to be able to reach to a favorability map that shows us something we don't already know.

Reviewer 25:

Reviewer 5:

Suggestions for Improvement

Reviewer 3:
Develop a clearly stated logic for each data set that is being integrated into the overall analysis.

Reviewer 19:
Look at whether there is a compelling basis for conducting the soil gas study and whether or not it serves the objective of the project to do so.

Reviewer 25:

Reviewer 5:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0904
Presentation Title: Integrated Chemical Geothermometry System for Geothermal Exploration
Investigator: Spycher, Nicolas (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Useable and robust chemical geothermometry is a useful aspiration for geothermal exploration.

Reviewer 19:
It is a simple program that the PI's are developing and can be quite useful for those interpreting the raw data.

Reviewer 25:
This project is well planned and focused. If successful, it could prove useful in providing reservoir temperatures from analyses of surface feature waters, hence assist with the prioritization of, or decision to proceed with, exploration drilling. Consequently, this project could contribute to more cost-effective exploration and directly benefit the Geothermal Technologies Program.

Reviewer 5:
If it works, it should be a very useful, non-invasive and inexpensive means of initial evaluation for possible EGS prospects.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
The optimization stage of the work represents an effective technique used in other geothermometry/geobarometry applications such as those for metamorphic rocks. I am, however, less convinced of the merits for the inversion work to be undertaken. I strongly suspect that any solutions obtained, even those meeting some best fit criterion, will be non-unique. While it may well be possible to identify a best-fit solution to multiple unknowns using multiple fluids, assumptions concerning equilibration and number of fluids will remain. I am not convinced that it will be possible to reliably or usefully identify both proportions and compositions of multiple undefined component fluids.

Reviewer 19:
The scientific approach sounds solid, although not a lot of information could be given out.

Reviewer 25:
The approach to using comprehensive chemistry of fluids from springs and wells for estimating reservoir temperatures is interesting and is potentially very useful. Though this method is supposed to provide a more reliable assessment of target reservoir temperatures than the "classical" geothermometers, I have not yet been convinced this is true and there appear to be no plans in this study to compare the two.

Reviewer 5:
I do not feel qualified to evaluate this proposal. I'm no chemist.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
Progress to date has been sound and the results appear sensible.

Reviewer 19:
The PI's are likely to succeed in developing the program and achieve the project's objectives.
Reviewer 25:
The project is 20% complete in agreement with about 23% of budget spent, and it appears the project can be completed on time. The results provided in the presentation and summary to date are not completely convincing. The estimated temperature results illustrated, using well fluids, show large differences from measured temperatures in some cases. Also, possible difficulties could arise from "multiple" solutions. Applications using surface spring water analyses, perhaps the most important application for pre-drilling exploration, have not yet been performed, and these fluids can be much more complex due to mixing with shallow acid sulphate and carbonate waters.

Reviewer 5:
Accomplishments have been met despite slippage of project due to difficulty finding a post-doctoral fellow.

Comments Regarding Project Management/Coordination
Reviewer 3:
Progress and spending are in step. Recruitment delays will potentially impact on the rate of progress and perhaps total spending too.

Reviewer 19:
No special comments on the management.

Reviewer 25:
It seems that the project is now proceeding according to plan even though slippage of the second and third quarters occurred initially due to lack of staff caused by difficulty obtaining a post-doctoral fellow. This position is still not filled. Plans for the remainder of project are clearly laid out and completion of the project is likely.

Reviewer 5:
Project is staying on track. Although I wonder what they're going to do with the post-doctoral fellow, if they find one.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
Improved chemical thermometry in geothermal systems is a worthy goal. However, as noted above, I have reservations about the appropriateness of the inversion work to be undertaken and the utility, reliability and relevance of results from such inversions. A lack of clarity on the complexity of chemical analyses required to yield useful results from the optimization stage is also of (relatively minor) concern.

Reviewer 19:
This is a simple and well-structured project that is likely to reach solid results.

Reviewer 25:
It is possible this project will develop a useful tool for estimating reservoir temperatures. However, results presented are not completely convincing. I am not sure that the technique will be applicable to some types of surface spring waters due to mixing with complex near-surface fluids.

Reviewer 5:

I looks like the project is on track and meeting the proposed (and funded) goals despite lack of the requested post-doctoral fellow. Thus, although, I cannot evaluate the technical side per se, not being a chemist, it looks like they are doing a good battery of tests and comparisons, and the plans for test datasets and real datasets to evaluate the method are well thought out and should provide important feedback on the method. The project is certainly meeting delivery schedule and milestones.

Comments Regarding Strengths

Reviewer 3:
The optimization work looks to be successfully implemented.

Reviewer 19:
The goals can be reached and the code could turn out to be quite useful for the industry and scientists alike.

Reviewer 25:

Reviewer 5:

Comments Regarding Weaknesses

Reviewer 3:
Please see my previous comments

Reviewer 19:
It might be hard to find the global minimum with iTOUGH2 and PEST due to the nature of the objective function and its many local minima. It might be necessary to look at the optimization algorithm used and whether or not the one being used is the right one for this type of problem.

Reviewer 25:
Significant effort should be directed toward developing and testing this methodology on surface water features, since this application will be most important in the pre-drilling exploration phase.

Reviewer 5:

Suggestions for Improvement

Reviewer 3:
Effort could be usefully expended in clarifying (1) the effect of water analyses of varying numbers of elements on the optimized temperature calculations and (2) the uniqueness or otherwise of the results of 'inversions'.

Reviewer 19:
None.

Reviewer 25:

Reviewer 5:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0905
Presentation Title: Coupled Thermal-Hydrological-Mechanical-Chemical Model and Experiments for Optimization of Enhanced Geothermal System Development and Production
Investigator: Sonnenthal, Eric (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Coupled thermal-hydrological-mechanical-chemical simulations (TMHC) are important in both exploration and reservoir simulation.

Reviewer 35:
The impact of this work will be realized when the tool being developed is successfully applied to geothermal reservoir problems in a fully tractable manner. This work when successfully completed will provide a tool to assess some aspects of thermal-hydrological-mechanical-chemical (TMHC) response of geothermal systems. One of the benefits of this work is the coupling of laboratory experiments and modeling. No analyses of experiments using the software developed were presented as yet, but it is supposed that this will be part of the planned work, so that a small-scale evaluation of the software may be obtained. The scaling of experimental work or results from experimental-scale work to field-scale work was not fully explained.

Reviewer 19:
If successful the thermal-hydrological-mechanical-chemical (THMC) could really enhance the capabilities of modelers being able to model nature in all its complexity.

Reviewer 25:
This work is highly relevant to the Geothermal Technologies Program, especially EGS development, as it develops a new coupled thermal-hydrological-mechanical-chemical (THMC) simulation code which is valuable for investigating fracture generation and reservoir sustainability and includes the design of laboratory experimental methods for validation and field testing applications in other industry-led Geothermal Technologies Program-funded projects.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
The code coupling approach--using an iterative sequential technique in this project--is a sensible route to reduce development time and cost. This approach may mean that code parallelization may not yield the performance gains available with fully integrated, simultaneous approaches being utilized elsewhere. The implementation of deformation beyond poroelastic effects is yet to be progressed and validated.

Reviewer 35:
Not enough information was provided on experimental methods to determine rigor of experimental methods.This is not necessarily a fault of the presenter, there was a lot of wasted time in the presentation due to imposed content by the Geothermal Technologies Program. There was no mention was made of code documentation--this will be both important and necessary.

Reviewer 19:
The methodology described is sound to the extent that it could be presented.

Reviewer 25:

The technical approach is very well planned with clear milestones.The inclusion of laboratory experimental validation and use in two field EGS projects makes this an excellent, well-rounded project.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Good progress to date.

Reviewer 35:
The researchers appear on task in achieving stated goals.

Reviewer 19:
Model validation looked good.

Reviewer 25:
There have been major accomplishments to date and the project appears to be well on track, with appropriate milestones achieved.

Comments Regarding Project Management/Coordination

Reviewer 3:
No issues with progress. I would like to see greater communication with other Geothermal Technologies Program-funded projects also developing coupled thermal-hydrological-mechanical-chemical (THMC) simulators, and for these to include comparisons between results from different codes on the same problems as the validations against analytical solutions are not available for THMC problems.

Reviewer 35:
Tough to judge- on budget, work progressing

Reviewer 19:

Reviewer 25:
The project is 60% complete, and appears to be well on planned schedule for completion. Though, only about 30% of budget is spent at this time, the PI indicated a planned increase in the number of participants will result in accelerated expenditure.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
A good development, well managed and yielding useful results already in field site trials. Given the diversity in codes being developed by different groups, clarifying the application areas that this code is best suited for would be useful.

Reviewer 35:
Are there data sources that, for example, show the relationship between temperature and permeability at a constant stress, etc. for the other coupled parameters? Does this method use a 2-D or 3-D implementation?

Reviewer 19:
The idea of creating a fully coupled thermal-hydrological-mechanical-chemical (THMC) model is a very ambitious endeavor and the path is filled with obstacles which will have to be overcome. This team will deal with certain aspects of

this goal and will probably contribute greatly to it.

Reviewer 25:
Overall, this project aims at advancing geothermal simulation methods and, if successful, will provide a valuable tool for studying shear fracture and chemical changes in EGS reservoirs. It has made significant progress and appears to be a very good investment.

Comments Regarding Strengths

Reviewer 3:
Building on an strong existing code base.

Reviewer 35:

Reviewer 19:

Reviewer 25:

Comments Regarding Weaknesses

Reviewer 3:

Reviewer 35:

Reviewer 19:
The number of parameters added to the model with a fully coupled thermal-hydrological-mechanical-chemical (THMC) model requires a lot of observations to correlate the model to prevent over parameterization. This was really not dealt with in the presentation. So the question remains whether the industry will ever be able use the model to its full capacity without over parameterizing it leading to a non-unique solution..

Reviewer 25:

Suggestions for Improvement

Reviewer 3:

Reviewer 35:

Reviewer 19:

Reviewer 25:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0906
Presentation Title: Development of Advanced Thermal-Hydrological-Mechanical-Chemical (THMC) Modeling Capabilities for Enhanced Geothermal Systems
Investigator: Wu, Yu-Shu (Colorado School of Mines)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
Good progress with code development means that simulation of an EGS trial has commenced.

Reviewer 35:
Tools such as the one being developed will become important in assessing geothermal reservoir characteristics and performance and its impact will be fully felt at a later date. At this time, the impact is that of development of a tool.

Reviewer 19:
If successful, this could really enhance the capabilities of modelers being able to model the nature in all its complexity.

Reviewer 25:
This project addresses a very important issue - the development of a comprehensive numerical modeling tool which incorporates rock deformation and chemical reaction processes, and can be applied to aid in the development and management of EGS reservoirs. It also aims to design the simulator for implementation using parallel computing methods to enhance the computational efficiency.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
The combination of a true fully coupled thermal-hydrological-mechanical-chemical (THMC) simulator and an architecture intended for parallelization and already demonstrably scaleable is excellent. I would have like more information on the deformation processes being simulated - do they go beyond poroelastic and fractures?

Reviewer 35:
It was stated that laboratory and field applications were being sought for comparison purposes. I am a bit puzzled that laboratory and field examples for model comparisons are just now being sought. It would make sense to me to have in hand and have studied such cases in advance of developing models and couple models. Data sources for material parameters utilized were not stated.

Reviewer 19:
The methodology described is sound to the extent it could be presented.

Reviewer 25:
This project is well planned and the technical approach is sound. The participants seem well qualified and include a broad range of experience from the university, national laboratory and industry sectors.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
The project is making very good progress, developing a new code base already capable of thermal-hydrological-mechanical-chemical (THMC) simulation. With the time and resources utilized, this is an excellent outcome.

Reviewer 35:
The stated accomplishments to date are consistent with the resources expended.
Reviewer 19:
Model validation looked good.

Reviewer 25:
The achievements to date seem appropriate and progress is on track to complete the project on time. If successful, this project will make a very good contribution to the Geothermal Technologies Program.

Comments Regarding Project Management/Coordination
Reviewer 3:
Project management is clearly sound given the on time completion of milestones and with appropriate budget spent.

Reviewer 35:
The work was stated to be on task and on budget.

Reviewer 19:

Reviewer 25:
The project seems on schedule with no major variances from the original plan- 50% completion and 50% of budget spent. Though there are no stated decision points, the milestones seem appropriate and no "no-go" points/decisions are expected. There appears to be good management and coordination, with participant communication and technical exchange on a regular basis.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project shows great promise and progress. I would like to see greater communication with other Geothermal Technologies Program-funded projects also developing coupled thermal-hydrological-mechanical-chemical (THMC) simulators, and for these to include comparisons between results from different codes on the same problems, as the validations against analytical solutions are not available for THMC problems.

Reviewer 35:
There was no discussion of software documentation. This should be included as part of this work. Are there data sources that, for example show the relationship between temperature and permeability at a constant stress, etc. for the other coupled parameters? Does this method use a 2-D or 3-D implementation?

Reviewer 19:
The idea of creating a fully coupled thermal-hydrological-mechanical-chemical (THMC) model is a very ambitious endeavor and the path is filled with obstacles which will need to be overcome. This team will deal with certain aspects of this goal and will probably contribute greatly to it.

Reviewer 25:
Overall, this project could make an important contribution to the Geothermal Technologies Program since it addresses the important issue of simulating EGS reservoir development and operation.

Comments Regarding Strengths

Reviewer 3:

Fully coupled thermal-hydrological-mechanical-chemical (THMC) code with simultaneous solution and designed to be parallelized and scalable from the outset.

Reviewer 35:

Reviewer 19:

Reviewer 25:

Comments Regarding Weaknesses

Reviewer 3:

Reviewer 35:

Reviewer 19:

The number of parameters added to the model with a fully coupled thermal-hydrological-mechanical-chemical (THMC) model requires a lot of observations to correlate the model to prevent over parameterization. This was really not dealt with in the presentation. So the question remains whether the industry can really ever use the model to its full capacity without over parameterizing it, leading to a non-unique solution.

Reviewer 25:

Suggestions for Improvement

Reviewer 3:

Given the diversity in codes being developed by different groups, clarifying the application areas that this code is best suited for would be useful.

Reviewer 35:

Reviewer 19:

Reviewer 25:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0907
Presentation Title: THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity
Investigator: Elsworth, Derek (Pennsylvania State University)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Using coupled thermal-hydrological-mechanical-chemical (THMC) code to investigate induced seismicity and identify mitigation and management strategies through the understanding of competing and/or coupled processes is a significant step forward for the Geothermal Technologies Program.

Reviewer 35:
The project's impact on geothermal will not be realized until the modeling tools being developed are successfully applied to geothermal problems of interest --field examples. Using the continuum and discontinuum approaches will facilitate a broad range of applications of the methods.

Reviewer 19:
If successful the thermal-hydrological-mechanical-chemical (THMC)could really enhance the capabilities of modelers being able to model nature in all its complexity.

Reviewer 25:
This project addresses the very important topic of coupling thermal-hydrological-mechanical-chemical (THMC) to simulate reservoir stimulation, development and evolution, and investigate the extremely important problem of induced seismicity arising from fracture development. It contributes directly to the Geothermal Technologies Program efforts in EGS development, and if successful, could help manage induced seismicity. Also, the issue of expanding geothermal expertise and experience through education of the next generation of geothermal scientists and engineers is incorporated.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
The approach is good, and appears sound although no validation against analytical or accepted solutions was shown. I am also less than clear about the linkages/couplings between the particle and continuum code work, how dynamic such linkages/couplings are and what combinations of modules were used for the illustrated examples.

Reviewer 35:
The approach of using both discontinuum and continuum methods is good in that it covers both ends of the spectrum to better understand the processes. Data sources for material parameters not referenced the data set, upon which the code bases its development, was not presented i.e. relationships between material parameters and how they vary and interrelate. Scaling from laboratory data to field data applications were not fully explained.

Reviewer 19:
The methodology described is sound to the extent it could be presented. In this approach, the team decided on using existing models to call upon for subroutines. That is working out for them and they are able to focus on other issues that are more related to their main objective which is good.

Reviewer 25:
The technical approach taken in this project seems appropriate and very well focused. The importance of using a coupled

thermal-hydrological-mechanical-chemical (THMC) model is recognized and incorporated in a model developed for use in the project investigations into the effects of stress and chemistry on fracturing. The research team appears well qualified and includes industry. Inclusion of a combined graduate/undergraduate geothermal course (including site visits) as part of this project is an excellent additional activity.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Progress to date has been very good, with the demonstration of the importance of thermal-hydrological-mechanical-chemical (THMC) simulation as opposed to thermal-hydrological-mechanical (THM) or thermal-hydrological-chemical (THC) solutions. The clarification of the time/length scales different processes dominate over is welcome and will play a significant role in informing the industry about key processes whileallowing intelligent management strategies of fracture stimulation to be adapted. This work should also contribute to informing the messages given in public outreach about microearthquakes.

Reviewer 35:
The author presents a lengthy list of presentations and papers of this work demonstrating a desire to communicate and vet their results to the technical community.

Reviewer 19:
Model validation looked good.

Reviewer 25:
Although the accomplishments to date are identified, and seem significant, it is not clear to this reviewer exactly how they relate to the identified tasks.

Comments Regarding Project Management/Coordination

Reviewer 3:
No issues revealed - progress is good and the budget is on track.

Reviewer 35:
The work appears to be on budget and on task.

Reviewer 19:
No specific issue with the management structure of the program.

Reviewer 25:
The project is only 30% complete and underspent at the time of this review. Though a project schedule with defined tasks was presented and two decision points were identified, milestones were not presented. There appeared to be good coordination among the participants. It was not clear if this project is on schedule or what the "spend plan is". It is also not clear if this project is on track to be completed on time.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project has yielded some impressive results/understandings even though it is still in its early stages. I would have liked to see evidence of validation of the coupling and to have received more information on the induced seismicity simulations, including the role, if any, of the particle code. I would like to see greater communication with other

Geothermal Technologies Program-funded projects also developing coupled thermal-hydrological-mechanical-chemical (THMC) simulators, and for these to include comparisons between results from different codes on the same problems, as validations against analytical solutions are not available for THMC problems.

Reviewer 35:
Software method documentation should be spelled out. Validation against real data has not yet been demonstrated or presented. What is the plan for source data for the models? Are there data sources that, for example, show the relationship between temperature and permeability at a constant stress, etc. for the other coupled parameters? As for the calculated induced seismicity-- has the result, a time dependent halo of induced seismicity, been compared to field observations? Is this real? Does this method use a 2-D or 3-D implementation?

Reviewer 19:
The idea of creating a fully coupled thermal-hydrological-mechanical-chemical (THMC) model is a very ambitious endeavor and the path is filled with obstacles which will have to be overcome. This team will deal with certain aspects of this goal and will probably contribute greatly to it. By using existing simulators, the team is more able to focus on specific issues related to creating a fully coupled THMC model.

Reviewer 25:
This is potentially an excellent project but the presentation and summary are confusing andvague when addressing how accomplishments to date relate to scheduled tasks. The lack of clearly defined milestones and corresponding expenditure makes it difficult to comment on its current status.

Comments Regarding Strengths

Reviewer 3:
The use of off-the-shelf mechanical code has allowed rapid progress, and the tackling of induced seismicity is yielding some interesting and potentially significant results. I suspect that the code (given the limitations noted below) will be best suited to gaining understanding of meso-scale processes rather than the simulation of whole reservoirs, but I am prepared to be pleasantly surprised!

Reviewer 35:

Reviewer 19:

Reviewer 25:

Comments Regarding Weaknesses

Reviewer 3:
The reliance on commercial mechanical code available only in compiled form renders the broader applicability and utility of the code coupling developed here limited. This is due in part to the inability of the developed package to run on parallel architectures, which will limit the potential of running large and complex models. Clearer explanation of the relationship between continuum and discontinuum, modeling is desirable.

Reviewer 35:

Reviewer 19:
As for other programs related to creating a thermal-hydrological-mechanical-chemical (THMC) model the number of parameters added to the model with a fully coupled THMC model requires a lot of observations to correlate the model to

prevent over parameterization. This was really not dealt with in the presentation. So the question remains whether the industry can really ever use the model to its full capacity without over parameterizing it, leading to a non-unique solution.

Reviewer 25:

Suggestions for Improvement

Reviewer 3:

Reviewer 35:

Reviewer 19:

Reviewer 25:

Develop a detailed schedule of milestones and associated budget expenditure.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0908
Presentation Title: Modeling and Simulation of EGS Reservoir Thermal Performance
Investigator: Desilets, Darin (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research
Reviewer 3:
Thermal drawdown in EGS reservoirs is a critical issue for the Geothermal Technologies Program.

Reviewer 19:
The overall objective is good, although a bit unclear as to what will be done.

Reviewer 25:
See Overall comments.

Reviewer 66:
The concept is a good one and its success could have considerable positive impact, but the actual accomplishments are disappointing, at least so far. See below.

Comments Regarding Scientific/Technical Approach
Reviewer 3:
The general approach adapted in this project appear sensible, but currently no clearly appropriate strategy to include and model complex fracture networks has been identified and adapted. The use of a fully coupled model appears to have some significant limitations that have not yet been evaluated. These limitations result from the necessity to resolve a stochastic fracture network onto a square lattice, coupled with apparently gross simplifications regarding heat flow. This project should have a go/no-go point around this issue because without a sound physical basis to drawdown modeling, and conclusions will be worthless

Reviewer 19:
The scientific merit is poor as presented.

Reviewer 25:
See Overall comments.

Reviewer 66:
The concept is excellent. The realization is another story. See below.

Comments Regarding Accomplishments, Results and Progress
Reviewer 3:
The retirement of the initial PI has led to a significant slowdown in the work and a lack of clear evidence that milestones have been or will soon be met.

Reviewer 19:
Very little has been done to reach objectives.

Reviewer 25:
See Overall comments.

Reviewer 66:
See below.

Comments Regarding Project Management/Coordination
Reviewer 3:
Delays in replacing the PI have adversely impacted progress, including fundamental issues around appropriate modeling technique.

Reviewer 19:
Due to the change in the PI the project stopped.

Reviewer 25:
See Overall comments.

Reviewer 66:
See below.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
This project is disorganized, unclear and presentlyat significant risk, owing largely to the retirement of the original PI and a hiatus prior to commencement of the new PI. I remain concerned that no suitable modeling strategy has been identified to mitigate the limitations already identified. At least one of the other modeling projects have developed code that is better suited than the options discussed in this project to tackle the thermal drawdown problem. Ceasing this project and perhaps focusing additional resources on others that are demonstrably better able to tackle this problem may be appropriate.

Reviewer 19:
The value of continuing this project should be checked since the driving force of the project, the original PI, is no longer on the team.

Reviewer 25:
Due to a misunderstanding, I missed the presentation for this project. Therefore, I think it inappropriate for me to review it, so I have not done so.

Reviewer 66:

Comments Regarding Strengths
Reviewer 3:

Reviewer 19:

Reviewer 25:

Reviewer 66:
Conceptually, this is a good project. The basic idea is to use a variety of techniques to try to answer the question: "If an EGS project is to perform well enough to meet the Geothermal Technologies Program's goals, what are the minimum specifications required of the subsurface resource?" These specifications might include depth, stress state, volume, fluid content, temperature, uniformity/heterogeneity, fracture density, fluid chemistry, geology, etc. Note that the project does not assume ahead of time that any such system really exists or is likely to be found. This kind of "reality check" could certainly have value for the Program's future planning of other EGS research, exploration and demonstration projects.

Comments Regarding Weaknesses
Reviewer 3:
See above. I would like to see communication with other Geothermal Technologies Program--funded projects developing coupled thermal-hydrological-mechanical-chemical (THMC) simulators as other groups look to have more sound software strategies.

Reviewer 19:
The management.

Reviewer 25:

Reviewer 66:
The project hasn't gotten as far as it should at this stage, in terms of both time elapsed and funds spent. This appears to be caused by: (1) the loss of the original project PI to retirement shortly after the project began, combined with a Sandia rule prohibiting his re-employment as a consultant for a considerable period of time afterwards, and (2) the diversion, by parties unknown, of a portion of the project resources for an unrelated purpose involving evaluation of single-well downhole heat exchangers. While the latter effort may be worthwhile, it should be independently justified and provided with its own source of funds.

Suggestions for Improvement
Reviewer 3:

Reviewer 19:
The vision needs to be clear and what the group actually plans to do with the rest of the funds needs to be specified before deciding if funding this project should continue.

Reviewer 25:

Reviewer 66:
The Geothermal Technologies Program and/or Sandia should seriously consider putting this project on "hold" with a no-cost time extension until the original PI is again available to lead the project. No criticism is meant of the present interim PI, who is evidently trying his best, but he appears to lack much of the experience and background that is really needed for such a comprehensive in-depth evaluation.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0909
Presentation Title: A New Analytic-Adaptive Model for EGS Assessment, Development and Management Support
Investigator: Danko, George (Board of Regents NSHE on behalf of the University of Nevada Reno)

Comments Regarding Relevance/Impact of Research

Reviewer 3:
Fully coupled thermal-hydrological-mechanical-chemical (THMC) simulators are of potentially great value to the Geothermal Technologies Program.

Reviewer 35:
The value of this work will be fully realized when the modeling technique being developed is successfully applied to real problems. Some initial comparisons have been made to Fenton Hill data, with varying degrees of success. It is difficult for me to see which is a good comparison and which is not so good.They all look OK to me, even though the discriminators used by the PI were not well communicated. The heat exchange/life cycle/total system model will become of significant value to asses a geothermal field's life potential

Reviewer 19:

Reviewer 25:
The thermal-hydrological-mechanical-chemical (THMC) model for EGS will be valuable for guiding power extraction from EGS and, if successful, will address several barriers to EGS development and benefit the Geothermal Technologies Program.

Comments Regarding Scientific/Technical Approach

Reviewer 3:
I have difficulty in identifying exactly what is being done in the project from the supplied materials. At least some of the work looks to have been undertaken prior to the initiation of this funded project. Significant portions of the code appear to be proprietary, and it is not at all clear what had been achieved to date in terms of code coupling - or exactly what is intended. IN addition, a rather cumbersome workflow appears to be potentially likely. The work on Fenton Hill fracture geometry and evolution seems to be sound and the conclusions are certainly interesting, but progress in other coupling domains was not discussed.

Reviewer 35:
The technical approach of comparing model results with the Fenton Hill data is good, and the judgment presented better fits to the field data using this method. However, the criteria for claiming a better fit, is not well described.

Reviewer 19:
The project will probably be able to reach the objectives for some example problems that were presented. There is a lack of error- and sensitivity analysis.

Reviewer 25:
The approach seems sound. There is a good range of collaboration, which includes industry.

Comments Regarding Accomplishments, Results and Progress

Reviewer 3:
Good in the thermal-hydrological-mechanical (THM) domain with the Fenton Hill fracture simulations, but is unclear in other areas.

Reviewer 35:
The technical accomplishments listed are consistent within the statement of work. There are no publications listed.

Reviewer 19:
The examples given show that the simulator is able to model the data quite well. However, a sensitivity and error analysis was not given.

Reviewer 25:
The objectives and milestones are clearly identified and the achievements to date agree with the scheduled work phases. The PI received a significant award (D.Sc.) in recognition of the high quality of his work.

Comments Regarding Project Management/Coordination

Reviewer 3:
No issues.

Reviewer 35:
The work appears to be on schedule and consistent with planning.

Reviewer 19:
No issues could be seen with the management of the program.

Reviewer 25:
Project is about 30% complete with about 35% of budget spent, hence in reasonable agreement. The schedule for remaining work is clearly planned, although there are no "decision points".

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 3:
How couplings are being simulated was not discussed in this project, much of which seems to be tied up in proprietary code. As a result, it is not clear what has been achieved to date. It is also not clear how rigorous the process to date was of fitting the model Fenton Hill fracture scenario. The approach taken is very distinct to that in other thermal-hydrological-mechanical-chemical (THMC) project, which is both an advantage and a disadvantage. I would like to see greater communication with other Geothermal Technologies Program-funded projects also developing couple THMC simulators, and for these to include comparisons between results from different codes on the same problems as validation against analytical solutions are not available for THMC problems.

Reviewer 35:
Are there data sources that, for example show the relationship between temperature and permeability at a constant stress, etc. for the other coupled parameters? Are there plans for code model documentation? Does this method use a 2-D or 3-D

implementation?

Reviewer 19:
As the other thermal-hydrological-mechanical-chemical (THMC) model programs, the overall goal of creating a fully coupled THMC is quite ambitious and could result in a leap in modeling geothermal systems.

Reviewer 25:
I was a bit confused by parts of this presentation, especially the single discrete fracture model results and comparison. It is not clear to me if and how this model relates to the real fracture characteristics of an EGS reservoir.

Comments Regarding Strengths

Reviewer 3:

Reviewer 35:

Reviewer 19:

Reviewer 25:

Comments Regarding Weaknesses

Reviewer 3:

Reviewer 35:

Reviewer 19:

Reviewer 25:

Suggestions for Improvement

Reviewer 3:

Reviewer 35:

Reviewer 19:
Look at adding error and sensitivity analysis for model validation. The only model validation looked seemed to be a maximum residual of observed and calculated data, which is not quite adequate from a statistics point of view.

Reviewer 25:

Seismicity and Reservoir Fracture Characterization

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0500
Presentation Title: Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems
Investigator: Toksoz, Nafi (Massachusetts Institute of Technology)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
The approach outlined in this project has the potential to provide methodologies that can significantly improve the ability to detail and characterize geothermal reservoirs. The joint solution for multiple geophysical data sets is the wave of the future, and addressing the tradeoffs between the different parameters is an important part of making the method work. By coupling the thermal and gravity modeling to the seismic, along with iterative relocation of seismic sources, it should be possible not only to more accurately map the fractures but also to assess the potential of the field.

Reviewer 37:
The goals of this work certainly seem relevant to the Geothermal Technologies Program. However, I'm a bit concerned about the overall impact. In particular, although one of the main goals of the work is to combine geophysical methods for fracture characterization, this does not appear to have been done. On the other hand, the regional tomographic work identified a potential future geothermal development site located to the northeast of the Cove Fort (CF) geothermal field that could have a large impact, if followed up on. Additionally, the project has developed and published geothermal field monitoring techniques that will be used by other researchers.

Reviewer 38:
The combination of lab data and geophysical methods with field work is appropriate and suitable for meeting the objectives of the project and is the preferred approach. If successful, the research has a high potential for positively impacting the industry. The uncertainty of the approach was not quantified in the presentation, particularly with respect to the integration of lab data.

Reviewer 18:
The detection and characterization of induced fractures in the subsurface due to EGS activity is very relevant and directly addresses known and significant technical knowledge gaps. If this research achieves its objectives, EGS mission and goals will advance. This work is attacking one of the most difficult EGS technical issues, namely subsurface fracture detection and characterization and the most difficult part, connecting fracture mechanics to induced seismicity was glossed over.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
Because this is an implementation of new methodologies, it is not certain how successful the effort will be. Preliminary results are promising. However, this is really exploratory research and it may be that the complete joint inversion does not succeed beyond what can be done with seismic and gravity alone. This remains to be seen. I think the addressing of anisotropy and attenuation could be very important factors in characterizing a field in 3-D, but this will require very high quality data.

Reviewer 37:
In many ways the scientific/technical approach was excellent. In particular, the regional modeling and tomography in the

large region around Cove Fort geothermal field was cutting-edge research. However, given the short time remaining in the project, it seems that it will be difficult for the PIs to obtain similar results on a reservoir scale. It appears that a great dataset has been obtained by the installation of the 10-station network at Cove Fort. However,five of the nine technical slides were devoted to the regional-scale modeling using USArray and University of Utah broadband stations. An example is shown of location and focal mechanisms from —a oil field” and it is unclear why results were not shown for Cove Fort. On Slide 15 (Future Plans), it appears that there will be some challenges in obtaining the project goals in the next four months. Perhaps too much time was spent on the regional studies, leaving too little time to really characterize Cove Fort on a local scale. The lab experiments are showing very good results as a function of temperature and pressure and tie in well with measured in-situ seismic velocities. I would think the fracture imaging and characterization would be a major goal of the project, but to date has not happened. On the other hand, the publication record is great and the PIs have developed numerous seismic techniques which others will follow in future geothermal field characterization studies. The moment-tensor results appear promising and it would be interesting to examine the tie between isotropic component (e.g. crack opening) and geothermal well activities. First, questions would have to be answered regarding the veracity of the isotropic components.

Reviewer 38:
The integration of the several datasets is a preferred approach for characterization. This project covers a broad range of aspects requiring good communication and integration, all of which the project seems to have accomplished.

Reviewer 18:
While the technical approach involves a series of data gathering and inversions both individually and jointly, to be combined with laboratory measurements, the overall approach seems scattered. The details of the joint inversion were not presented in a manner that could be scientifically evaluated. The devil is in the details and the most important part of detection and characterization of fractures was not presented clearly. Given the technical plan presented, I am not sure how project goals will be achieved. Finally, in order to detect, characterize and induce fractures in the subsurface, spatial resolution is of prime importance. Inherent limitations for useful spatial resolution will hamper this project and need to be addressed. For example, electrical conductivity inversions will not be able to constrain important fault parameters, even in pristine conditions.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
So far there has been good work done. As someone who is actually familiar with the code that the PI is developing, I will say that more work needs to be done to explore the trade-offs in data weighting and the empirical relationships between delta-T and delta-V among others. So far it looks like good work has been done in getting any reasonable results and a lot of credit has to be given just for this. The proof of the pudding, however, will be robust fault/fracture mapping and this is still in the wings.

Reviewer 37:
Although much has been accomplished in this project, it seems that it comes up a bit short in the really important objectives of characterizing and mapping fractures in a geothermal field. Also, I notice that there was a task to perform attenuation studies (actually attenuation anisotropy, but I'm not sure what that means). Attenuation studies were lacking in all of the projects reviewed which seems to be a shame. Of course, attenuation measurements are very difficult to make and are subject to uncertainty, but from the waveforms shown, it appears that these would be possible. In theory, attenuation can be more sensitive to material properties such as small-scale fluid flow from bulk attenuation and temperature effects from shear attenuation than to velocity perturbations.

Reviewer 38:
It is not clear where the data came from for the joint inversion of gravity and phase velocity. I am unsure of the uncertainty regarding the inversion of temperature from the velocity data. Not sure how all summary points were

addressed based on the presentation. Good publication record.

Reviewer 18:
Progress is only fair because data collection has been hampered by network implementation and operational issues. Looks like local natural seismicity is very low in amplitude and requires careful gathering and analysis not originally in the project plan. The spend plan lags, as to be expected from a project is behind schedule. It seems like more work should have been accomplished. The PI has a very good reputation and track record and the project will, most likely, achieve useful results. However, what was presented was not up to the PI's previous work products.

Comments Regarding Project Management/Coordination
Reviewer 5:
This project seems on track as proposed.

Reviewer 37:
There appeared to be good coordination between the three partners on this project. There could be better coordination between the two MIT projects (i.e. Toksoz and Fehler) because they are both using many different yet complementary techniques for characterizing geothermal field operations.

Reviewer 38:
This project is being managed appropriately. The project schedule, scope, milestones and deliverables are appropriate and probably above average for similar projects of similar scope and budget.

Reviewer 18:
First impressions are that the project management has been weak and the Geothermal Technologies Program should contact the PI and request a more detailed review with corrective action recommendations as follow up.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 5:
I think the work is proceeding as promised and there is good likelihood that the deliverables will be met as proposed. I would like to see more on the attenuation and anisotropy, both of which should be highly sensitive to fractures.

Reviewer 37:
An excellent project that developed and published innovative geothermal field monitoring techniques.

Reviewer 38:
This appears to be a well thought out and well run project that has above average performance.

Reviewer 18:
The stated project goals are very important to the success of EGS and many important datasets have been or are being collected. However, the promised joint inversion seems to be missing and the details of how it will be done were also missing. This is not the normal work of this PI and points to the possibility that he has not been as engaged as he could be. It is recommended that a more detailed review be made including the development of a corrective action plan.

Comments Regarding Strengths
Reviewer 5:
The team to accomplish the goals is a good team with the technical capabilities required.

Reviewer 37:
Use of full waveforms is a good extension to tomographic techniques to better characterize subsurface properties. Excellent regional geothermal exploration techniques have been developed.

Reviewer 38:

Reviewer 18:
Project objective is extremely important for the success of the EGS subprogram. The PI is a world-class researcher with years of pertinent experience. Many different datasets are brought to bear to solving the problem. Laboratory measurements are being made.

Comments Regarding Weaknesses

Reviewer 5:
Haven't yet seen the high-resolution images, but perhaps these will be accomplished by the end of the project. In any of these projects when the first parts are given over to method development, it's not unusual to not see the results on real data until the end of the project.

Reviewer 37:
Has not yet reached goal of characterizing and mapping fractures in a geothermal field.

Reviewer 38:

Reviewer 18:
Project seems to be off-track both in technical focus and progress. In addition, details of the joint inversion were not presented and are at the crux of whether or not this project will succeed. If individual datasets are inverted and just plotted on top of each other, then EGS technology will not be informed. Finally, the spatial resolution of the datasets is way too coarse to provide any fracture imaging as was promised.

Suggestions for Improvement

Reviewer 5:
Please address the issues of variable resolution in the disparate datasets and how sensitive the results are to relative weighting. What ground truth can you bring to the problem to determine the validity of the results other than pretty pictures of pretty colors in your model? Find a fracture that was independently known? Predict temperatures that can be sampled and proven some other way?

Reviewer 37:
Probably a greater focus on the smaller-scale study of the geothermal field itself and on actually mapping and characterizing fractures.

Reviewer 38:

Reviewer 18:
It is recommended that a more detailed review be made including a corrective action plan to get the project back on track and focused on the original objectives. Also, a detailed technical review of the joint inversion scheme is suggested.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0501
Presentation Title: Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir
Investigator: Fehler, Michael (Massachusetts Institute of Technology)

Comments Regarding Relevance/Impact of Research

Reviewer 37:
This project appears to be highly relevant to the Geothermal Technologies Program and is going a step further than traditional velocity tomography used for characterizing a geothermal field by using cutting-edge technologies for relocating reservoir seismicity and determining mechanical mechanisms of deformation. I think this project is highly relevant not only because of the good research, but the apparently good collaboration between the geothermal field operator, the seismologists and the reservoir simulations.

Reviewer 38:
There is a good basis to meet project objectives. However, it is not clear how the results will be constrained by real data. It would benefit with a laboratory leg to reduce uncertainty.

Reviewer 18:
This research addresses the core issues with regard to EGS monitoring and a successful project outcome would make a significant impact to the program. Monitoring and modeling fluid flow in the subsurface in an active EGS reservoir is key to successful application. Induced seismic events hold the key to understanding, tracking and controlling fracture creation; however, spatial coverage remains an inherent limitation.

Comments Regarding Scientific/Technical Approach

Reviewer 37:
This is a tightly focused project in that is not overly ambitious in its scope and appears to have great synergy between the geothermal field operator and the seismological and modeling aspects. The project is at its midpoint and a lot of data has been collected and processed. A number of techniques have been identified -waveform correlation, collapsing and interferometry-and should provide accurate maps of seismicity changes during well injection. As acknowledged by the PIs, geomechanical effects from seismicity patterns and focal mechanisms are only one aspect in modeling reservoir dynamics, but their proposed approach should contribute significantly to the understanding of these effects. The PI has extensive experience in understanding the physical effects that movement of fluids in the subsurface have on seismicity and seismogram characteristics and I would hope that waveform studies are extended to include these. It might be good to coordinate with the other MIT project (PI: Toksoz) in the waveform modeling and moment-tensor inversion. The modeling appears to focus on shear displacements, but it seems that volumetric components (e.g. from tensile cracks) would be important to identify as well and tie into field operations. I hope that the PIs do not get overly absorbed on the location and focal mechanism aspects and turn to waveform analysis to better identify faulting dynamics thereby improving the understanding of geomechanical effects, which is one of the major goals of the project.

Reviewer 38:
A good base dataset for analysis would aid review if this project was further along. If appropriate, the decision point not clear. Borehole, fracture mapping and other real data might aid interpretation. How will you add structures to the deterministic model to constrain model? It seems like project is just getting started. Collapsing appears to be a valid approach. The injection history may be important for understanding microearthquakes (MEQs).

Reviewer 18:

The seismic techniques and the PI' s prowess are world class. Not sure the number and location of the seismic stations is adequate to provide useful constrains on the reservoir modeling. Location data presented, even after collapsing, showed trends but was not adequately spatial resolved. The velocity model, key to the tomographic inversions, was not discussed. Source mechanism studies could be more useful compared to the limitations inherent in the location techniques and station number and distribution. It is not clear how results from this work will meet the intended goals.

Comments Regarding Accomplishments, Results and Progress
Reviewer 37:
The project appears to be on track and many of the mundane aspects suchdata collection and some processing have been achieved. There were some delays on data delivery and funding, but things seem to be going well. On a parallel front, the FEHM modeling appears to be progressing. I have a bit of a concern regarding the scale of the FEHM (i.e. micro scale versus macro scale) but from the short presentation it was difficult to get a feel for this. As I said above, I hope that the PIs do not devote so much effort to earthquake relocation, that they lose track of other waveform studies that could provide additional important information regarding geomechanical changes that occur during geothermal field operations. I am aware that the PI has extensive experience in the field of source mechanisms for volcanic systems and it would be interesting to apply this knowledge to waveform and time function analysis of microearthquakes (MEQ)s in geothermal field operations.

Reviewer 38:
It is difficult to evaluate the improvements to FEHM code on basis of this presentation. It may be related to Los Alamos National Laboratory not getting funds. It is difficult to assess because the project is still underway. A larger study area may benefit progress to include larger pool of events for analysis.

Reviewer 18:
The project's progress is lagging behind the spending which is always worrisome. The key feature of this research, linking and constraining reservoir modeling with seismic tomography, does not seem to be progressing.

Comments Regarding Project Management/Coordination
Reviewer 37:
There appears to be great synergy between groups in this project. However, how about improved synergy between the two similar MIT projects? They both bring excellent analysis techniques to the table.

Reviewer 38:
There is difficulty associated with Los Alamos National Laboratory not getting funds for FY11. This is not the project‘s fault. The project management is acceptable. There is good leveraging of funds with other projects, i.e. Iceland geosurvey, LABL, MIT Eeykkjavik University. However, the late start due to lawyers is problematic.

Reviewer 18:
The project management and coordination seems to be failing. This project brings the Chevron datasets and reservoir modeling results to the fore in a timely manner yet remains as an uncompleted task and is critical to the success of this project. The PI needs to address these issues and a corrective action plan should be developed and implemented soon before the project becomes hopelessly behind schedule and out of resources.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 37:
Excellent, well thought out and coordinated project and closely tied to geothermal operations.

Reviewer 38:
It was a bit difficult to evaluate the progress of this project as it is only in the early stages. Some start-up difficulties have contributed to the relative lack of progress to date. However, that being said, the project seems to be well thought out and it is this reviewer's opinion that when all component pieces are on line the project will make significant contributions to EGS.

Reviewer 18:
Good idea, the right thing to do. The PI is world class researcher and the dataset and location are perfect. Seismic data analysis is proceeding but could have inherent limitations which will not allow the stated goals to be reached. Reservoir modeling and the stated goal of seismic constraints on this modeling, a key part of this work, were not clearly presented and represent a significant concern. Project management and coordination seem to be inadequate to bring the necessary tasks and datasets to the project.

Comments Regarding Strengths
Reviewer 37:
The tie to geothermal field operations is excellent. Modeling and seismic efforts are well coordinated.

Reviewer 38:

Reviewer 18:
Excellent PI. The stated goals are very important to the program. Location is perfect for EGS and the dataset is rich. Seismic techniques are state-of-the-art and results are promising so far.

Comments Regarding Weaknesses
Reviewer 37:
I'd like to see more waveform analysis.

Reviewer 38:

Reviewer 18:
The project is behind schedule and has overspent. Key datasets are not yet part of the project and remain a real problem. Seismic data has inherent limitations which need to be addressed because it will constrain overall location resolution of events and defeat the overall project goals. The Geothermal Technologies Program should request an analysis of this problem. The stated goals of providing seismic constraints on reservoir modeling have not been done and the technical details of how it will be done were not presented. This should be looked into by the Program.

Suggestions for Improvement
Reviewer 37:
The PI has extensive experience in source mechanisms in volcanic regions and it would be good to apply this knowledge to waveform analysis of the geothermal field data.

Reviewer 38:

Reviewer 18:
The Geothermal Technologies Program should request an analysis of the adequacy of the seismic array to meet stated

project goals. Stated goals of providing seismic constraints on reservoir modeling have not been done and the technical details of how it will be done were not presented. This should be looked into by the Geothermal Technologies Program.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0502
Presentation Title: Joint Inversion of Electrical and Seismic Data for Fracture Characterization and Imaging of Fluid Flow in Geothermal Systems
Investigator: Batzle, Michael (Colorado School of Mines)

Comments Regarding Relevance/Impact of Research
Reviewer 5:
The presenter does not show convincing evidence that the joint inversion methodology of seismic and Magnetotellurics (MT) will facilitate groundwater flow imaging. Self-potential (SP) efforts look promising. If the efforts do pan out, then the flow mapping could be quite valuable for field modeling and decisions regarding extraction in terms of drilling location to maximize return on the investment. However, what was presented so far was not really convincing.

Reviewer 37:
This project appears to be highly relevant to the Geothermal Technologies Program and I think it has high impact on the geothermal community, not only in the actual work done in characterizing specific geothermal fields, but in terms of the student programs and community outreach. The development of young researchers in geothermal field monitoring is important.

Reviewer 38:
This is a good approach that should have a significant impact on the industry, especially toward education. Joint inversion of geophysical (i.e. self-potential) data for groundwater flow imaging is a needed method for further advancements of EGS. The approach seems to have broad applicability to other sites.

Reviewer 18:
For potential hydrothermal systems, the critical factors that can decide if a project should continue or not, is the subsurface permeability distribution or as they call it the ―plumbing system". Practically speaking, flow rate, temperature and pressure will determine the viability and economics of any geothermal system. The project's stated objectives of applying joint inversion of geophysical data to image the ―plumbing system" is critical to any hydrothermal system and a successful outcome would make a significant impact to the program.

Comments Regarding Scientific/Technical Approach
Reviewer 5:
In particular, I have issues with the Magnetotellurics (MT) imaging, which by its very nature is broad and long-period (low spatial resolution). The 'joint' inversion is not joint inversion at all, but is a comparison of spatial features derived from individual parameter inversions, separately. One of the points of using joint inversion of disparate data types for geophysical modeling allows the different sensitivities of the datasets to trade-off and constrains model ambiguity for one data type or the other, based on the different sensitivities of the different datasets. If each is modeled separately then the resulting image may fit the inverted data but is not necessarily unique, and could be inconsistent with that of another inverted dataset which may be only one of several that could fit the dataset but not be correct. By not inverting jointly, you lose the ability for the two datasets to impose consistency in the inversion.

Reviewer 37:
The scientific/technical approach is sound and maintains excellent synergy between electro-magnetic (EM) and seismic techniques for geothermal field characterization. I think the utility of students in the field camp setting is an excellent idea and benefits the work itself and trains young investigators to become potential geothermal scientists. There appears to be the possibility of obtaining origin time of seismic events from the EM time series. If it actually works, this is an extremely

important avenue to pursue because it would really help obtain accurate earthquake depth.

Reviewer 38:
The integrated approach with multiple datasets is particularly appealing as is stakeholder involvement. The overall package is very nice.

Reviewer 18:
The use of self-potential (SP) measurements to map subsurface water flows, fault locations and other critical aspects of an active hydrothermal system is not new and is normally fraught with data gathering, poor signal to noise (SN) ratio and non-uniqueness problems. Combining SP with temperature measurements, of uncertain origins, does not jump out as a solution to SP's problems. In fact, because it is not clear where temperature measurements came from or how they were measured, “joint” inversion of SP and temperature is suspect. Also, they mentioned at the end that the joint inversion included temperature, SP and resistivity, but the resistivity results were not presented. Finally, the 3-D active seismic work was at too premature to be included in the “joint inversion”, so the jury is still out on that one. All in all, the stated goals “look” like they have been accomplished but the important technical details were not presented as to “how” these data sets were jointly inverted. This is not a minor omission because these details are the totality of the R&D component of this project and without knowledge of these techniques the project becomes a data gathering exercise.

Comments Regarding Accomplishments, Results and Progress

Reviewer 5:
Things seem more or less on schedule with the proposed activities and resources used to date. After the presentation, I remain skeptical that a significant step forward in the science and robust capabilities will come out of this. On the other hand, the format dictated for the presentations forced them to be woefully lacking in technical content, so I feel it's really hard to give a fair review based on what the PI was told to present. Particularly for a project that raises a lot of questions, there was no way to really get them answered.

Reviewer 37:
I was very impressed with the quality and quantity of the work. The PIs seem to be right on track and are ready to tie in their observations with groundwater flow models. They also have a great publication record.

Reviewer 38:
Good process in accordance with schedule, project objectives, scope and milestones. Good publication record. Joint inversion - what is the physical tie between electrical methods and other methods?

Reviewer 18:
From what they presented adequate progress has been made in stated deliverables. A considerable effort was made to involve students in the fieldwork and this is both an important thing to do and a stated goal of the project. However, this type of approach can pose significant data quality issues and consistent interpretation issues. The presentation concentrated on the student involvement and reviewers would have benefited from greater emphasis on R&D rather than the education component. It gave the impression that this was summer field camp, not serious R&D.

Comments Regarding Project Management/Coordination

Reviewer 5:

Reviewer 37:
This is a well-run program and there appears to be excellent coordination between the groups.

Reviewer 38:

The project has good integration of multiple institutions to meet the project objectives. There is good outreach to government agencies and stakeholders and a nice story for geothermal development and exploration.

Reviewer 18:
Project management issues seem to be in hand and coordination of the numerous partners looks to be adequate.

Overall

In addition to the above fourcriterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
Not sure what Magnetotellurics (MT) is going to bring to the problem, as it does not intrinsically allow for high spatial resolution. Does it tell you anything that you didn't already get from the self-potential (SP) and seismic? Particularly given the non-uniqueness of the results and possible ambiguities in interpretation, by inverting separately you may simply be comparing two poorly resolved results. I think the SP has potential for groundwater flow modeling and this may be the best aspect of the project as I see it.

Reviewer 37:
I was impressed by this project. It is broad in scope and is obtaining interesting results.

Reviewer 38:
This project is overall a nice showcase for the Geothermal Technologies Program. The stakeholder involvement and education pieces are very important in this day and age.

Reviewer 18:
The project's stated objectives of applying joint inversion of geophysical data to image the ―plumbing system" is critical to any hydrothermal system and a successful outcome would make a significant impact to the Geothermal Technologies Program. Many of the stated goals look like they have been accomplished but the important technical details were not presented as to how these datasets were jointly inverted. This is not a minor omission because these details are the totality of the R&D component of this project and without knowledge of these techniques the project becomes a data gathering exercise. The presentation concentrated on the student involvement and reviewers would have benefited from greater emphasis on R&D rather than the education component. It gave the impression that this was summer field camp, not serious R&D.

Comments Regarding Strengths

Reviewer 5:
If the flow modeling proves successful, this will reduce costs in developing EGS sites pending the technology is able to be transferred and implemented robustly at other sites.

Reviewer 37:
The use of students in the field experiments is important in that it trains potential young geothermal researchers. This is a well thought out and coordinated project.

Reviewer 38:

Reviewer 18:

Datasets have been collected by masses of students and ―jointly inverted” to seemingly make an impact on the development of an active potential geothermal prospect. PI and partners demonstrated an understanding of self-potential (SP), subsurface water flow and 3-D seismic data gathering, processing and inverting.

Comments Regarding Weaknesses

Reviewer 5:

Reviewer 37:

No major weaknesses.

Reviewer 38:

Reviewer 18:

The use of self-potential (SP) measurements to map subsurface water flows, fault locations and other critical aspects of an active hydrothermal system is not new and is normally fraught with data gathering, poor signal to noise (SN) ratio and non-uniqueness problems. The case for combining SP with temperature measurements to improve the result was not made. Nor were the inclusion of resistivity data and 3-D seismic. The technical details were not adequately demonstrated. Finally, the omission of these details is a fatal flaw and will need to be addressed.

Suggestions for Improvement

Reviewer 5:

I would recommend trying a truly joint, simultaneous inversion of the datasets for a prospect where they are available. Discovering the trade-offs, sensitivities, relative weighting, how the models are driven and whether they converge will provide a better picture than the comparing of separate models.

Reviewer 37:

None

Reviewer 38:

Reviewer 18:

The Geothermal Technologies Program should request a more detailed technical evaluation form this group to determine the adequacy of the joint inversion techniques before continuing on with the project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0503
Presentation Title: Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks
Investigator: Hardage, Bob (The Univesity of Texas at Austin)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
Some of the innovations in this project have the potential to greatly improve monitoring for geothermal prospects. To wit: the cable-free acquisition, allowing optimization and quick reconfiguration of sensors even on difficult terrain. Incorporation of analysis of SH energy could be key to improved reservoir characterization.

Reviewer 37:
A strong case was not made regarding the relevance of the problem of developing geothermal systems beneath exposed high-velocity rocks to the overall Geothermal Technologies Program. I guess it could an issue and the problems encountered would be more different than those in most geothermal settings. I'm more concerned about the impact in terms of the work accomplished to date, but it is still early in the project. I would think that the impact of the project could be increased with a greater emphasis on the use of SH waves for geothermal field characterization.

Reviewer 38:
The high velocity layer is a classic problem in seismology, especially for geothermal projects, which are commonly in igneous regimes. Also quantifying fracture properties is classic problem. Good innovation of the SH wave to exploration. Cable free, multicomponent seismic and back scatter noise are all important areas for research.

Reviewer 18:
A field demonstration that multicomponent seismic data are more valuable for imaging key subsurface components of geothermal prospects, like fracture attributes, as compared to using single-component P- wave data only might have an impact on the Geothermal Technologies Program. However, it is not clear that the proposed plan will achieve that goal.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
Use of SH energy in evaluating prospects with difficult velocity profiles, such as a high-velocity cap over lower-velocity producing levels, could provide a real breakthrough. So far the data analysis has not been done and results are not available but at this stage in the project, the data have only just been acquired. It will be interesting to see progress by this time next year.

Reviewer 37:
The scientific/technical approach appeared fair in that the work described to date was not overly impressive. For example, quite a bit of time was spent discussing surface wave backscatter in seismic profiling and the effects on primary reflections. I was under the impression that this is a problem commonly encountered in reflection profiling and that methods are available to address this problem, especially with three-component seismograms where polarization can be used to separate phases or even frequency-wavenumber filtering. The utility of using SH sources for geothermal field characterization is a unique and important aspect of this work. There was some interesting discussion of the theory of SH propagation or lack thereof in a high velocity over a low velocity layer. But quite often, waves are observed when they are not expected to be such as sinfrasonic arrivals in the ―zone of silence". During the other presentations in the meeting, there was much discussion regarding anisotropy and the information it can potentially provide regarding rock physics and flow paths in a geothermal field. Analysis of waves from SH sources would certainly help characterize anisotropic effects.

Reviewer 38:
The =approach seems a bit tangential for meeting the project objectives. Cable-free seismic data acquisition will be important for geothermal exploration.However, it seems like the technology should either work or not. The benefit to the EGS community after a reservoir is established is not clear. An answer to the question "Will the SH shear wave mode image geothermal systems?" is critical. Application to fracture imaging could be very important. However, at this juncture it was difficult to determine how far along the project is with its technical approach. I was bit disappointed in the discussion of SH wave results.

Reviewer 18:
Certainly it seems very plausible that utilizing multicomponent seismic signals would be a benefit in subsurface imaging but there are several major flaws with this project. First, it is not clear what is ―geothermal" about the University Test Site and the Big Bend site. Of course, Soda Lake is a geothermal site but was not discussed with enough detail to gain confidence that the seismic data collection was suitably and appropriately fielded. ―Document value of 3-C 3-D seismic data for quantifying fracture systems across Soda Lake Field, Nevada" does not look like a particularly significant milestone. What is planned for the only geothermal site? Second, much is said about sediments overlain by high velocity granitic bodies as a major seismic interpretation problem but these types of data analysis problems have been managed before in oil and gas (O&G) exploration. The PI did not mention previous studies and results to set a context for this innovation. Furthermore, what kind of geothermal system are we talking about? I am not aware of this type of geology. Their model doesn't apply. The scientific and technological approach here is flawed in concept and should not continue as is.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
Accomplishments to date seem to be in line with proposal and schedule.

Reviewer 37:
It appears that the project is moving rather slowly relative to other projects reviewed. The overall results appeared disorganized at this point. As stated above, I think that increased emphasis on SH waves and how they can complement more traditional exploration techniques would be of interest.

Reviewer 38:
Good progress of project in accordance with plans. Accomplishments are limited at this point in time, but seem to be OK relative to stage of project. There are no publications at this time, this may be a problem and the investigator should focus on this.

Reviewer 18:
From what they presented some progress has been made in stated deliverables. Sites were selected in the first year and data collection has been accomplished and continues in the second year. This seems like very slow progress.

Comments Regarding Project Management/Coordination
Reviewer 5:
Juggling several distinct companies seems to be working, for acquisition and analysis. This project appears to be on-task and on-budget.

Reviewer 37:
There appears to be good coordination between research groups.

Reviewer 38:
The project management seems to be acceptable and appropriate for this project. The schedule and milestones are on track. There was a good use of subcontracts to stay on schedule and good collaboration with other companies, i.e. two data processing and two seismic contractors, one geothermal company.
Reviewer 18:
The project management issues seem to be in hand and coordination of the numerous partners looks to be adequate.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 5:
I think the project has promise to enhance the methods available for exploiting SH data in evaluating a prospect, where the lithologies are difficult and the imaging is therefore problematic. A cable-free acquisition system is a really good advance.

Reviewer 37:
The project appears to be moving slowly and lacks coherence. However, the innovation of using SH waves is good.

Reviewer 38:
The project needs to focus more on results and less on doing a bunch of cool stuff (at least that is what it seemed like to this reviewer). Publications will help focus the effort and take the project to the next level of transmitting the results to the industry as a whole.

Reviewer 18:
The stated purpose of this project is a worthwhile endeavor. However, the concept and plan to reach the stated objectives are flawed and when completed will not contribute much to geothermal subsurface imaging technology. The seismic acquisition techniques and instrumentation are state-of-the-art and data acquisition is industry standard. It is critical that the Geothermal Technologies Program re-directs this project to study a geothermal site that has application to other relevant sites. Otherwise the project should not continue as planned.

Comments Regarding Strengths
Reviewer 5:
SH utilization could be a real breakthrough.

Reviewer 37:
SH waves for geothermal field characterization.

Reviewer 38:

Reviewer 18:
Datasets have been collected with state-of-the-art seismic acquisition techniques and instrumentation are and industry standard data acquisition.

Comments Regarding Weaknesses
Reviewer 5:

<u>Reviewer 37:</u>
The project moving slowly and lacks coherence.

<u>Reviewer 38:</u>

<u>Reviewer 18:</u>
It is not clear what is –geothermal” about the University Test Site and the Big Bend site. Need more details of what is planned for Soda to gain confidence that the seismic data will be suitably and appropriately collected such that this study will have benefit to other sites. The sediments overlain by high-velocity granitic bodies as a major seismic interpretation problem for geothermal is a flawed concept and has little value to other geothermal systems. The PI did not mention previous studies and results to set a context for this innovation.

Suggestions for Improvement
<u>Reviewer 5:</u>
I would like to see some attention given to anisotropy and attenuation. Having the multicomponent sensors and collection of 3-D waveforms would allow for this in a 3-D modeling effort.

<u>Reviewer 37:</u>
I'd suggest really focusing on the innovative SH aspect of the project. SH waves can be used to map anisotropic effects in a geothermal field which would be very sensitive to possible changes in fracture patterns during operations.

<u>Reviewer 38:</u>

<u>Reviewer 18:</u>
The Geothermal Technologies Program should re-direct this project to study a geothermal site that has application to other relevant sites. Otherwise the project should not continue as currently planned.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0504
Presentation Title: Characterizing Fractures in Geysers Geothermal Field from Microseismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy
Investigator: Aminzadeh, Fred (University of Southern California)

Comments Regarding Relevance/Impact of Research

Reviewer 5:

One way in which the industry has been woefully lacking to my knowledge is the data analysis tools for seismicity (microseismicity). One critical aspect is an improved auto picker, and the method being developed in this project is one of several approaches that could truly revolutionize the speedy analysis of incoming data, with the potential to map in real time the fracture development during stimulation. Precision in microearthquake picking is the only way to obtain precision in event locations, which iteratively feed into the developing velocity field during fracture. Shear wave splitting and addressing of anisotropy are important for fracture mapping. Incorporating anisotropy into the tomoDD code is something we have always felt would be helpful, as anisotropy is being incorporated into many other tomographic approaches. Its time has come.

Reviewer 37:

The overall relevance to the Geothermal Technologies Program seems good on the surface, but I‘m not sure if the impact will be great. The reason for this is that the overall project seems to be fragmented and not well defined.

Reviewer 38:

This project seems to have potential for good industry impact, if successful. Poor time management during presentation makes it difficult to evaluate the project‘s impact and relevance.

Reviewer 18:

Utilizing microearthquake (MEQ) data from the Geysers to better understand the mechanisms during fracture stimulation addresses a very critical need for the Geothermal Technologies Program. If this work is successful a significant impact will be realized for EGS. Substantial progress has been made with the development and testing of a very sensitive autopicker and a MEQs fractal analysis that determined for the Geysers, that most of the events were induced.

Comments Regarding Scientific/Technical Approach

Reviewer 5:

I'd have to say the autopick portion is outstanding, whereas the fractal/b-value notion puzzles me a little bit. In my understanding, the b-values essentially map out the spatially varying characteristics of fracturing, heat or other characteristics that would imply inability to withstand significant strain before failure. Moreover, it has been my understanding that fractal dimension is nearly a proxy for b-value. Thus the two measures are essentially the same feature. It was not clear how induced vs. triggered seismicity can be deduced from the b-value in any given area. However, given the limits on allowed technical content of these presentations, there are a lot of unanswered technical questions in many of them. I think this is a fault of the format and not necessarily a shortcoming of the projects per se.

Reviewer 37:

Although the concept of combining different measurements for obtaining good arrival time estimates is good; I‘m nervous that throwing things in to an artificial neural network (ANN) with fuzzy logic is a good approach. Neural networks can be too much of a black box if the parameters such as the architecture and thresholding functions are not carefully considered. In my experience, they can get the right answer for the wrong reason if the underlying physics and processing is not fully understood. Additionally, if the picks are to be used in tomographic inversions, it seems that the pick uncertainties must be statistically valid, which is not possible to do with the complex architecture of an ANN. In the examples shown, I was concerned about windowing effects for the different measures,as evidenced by precursors to the actual picked arrival time, as well as the units of the inputs to the ANN. For example, the higher-order moments of skewness and kurtosis are unitless, but energy and instantaneous amplitude have units that can be strongly affected by propagation as well as changes in instrument calibration. There was mention that S-wave measurements are difficult to make in a complex area such as the Geysers. How does the ANN perform on picking S-waves? I‘m not sure how the analysis of fractal dimension was an improvement over traditional b-value measurements. What is the physical tie of rock porosity to P-and S-wave velocities?

Reviewer 38:
The approach is fragmented into several pieces to achieve four general objectives. It is not clear how the pieces inter-relate or support each other.

Reviewer 18:
Their scientific and technical approach is top-notch and will achieve the project‘s objectives. In fact, significant progress has been made. The project is focused on overcoming our current knowledge gaps regarding the meaning and value of microearthquakes (MEQ) in the process of reservoir creation. The development and testing of the artificial neural network (ANN) autopicker was significant and will enable other analyses of the MEQ data as well as provide improvement in location statistics. However, the most important goal is to be able to estimate fracture direction and type form the MEQ data itself.Further work should focus on this task, not further refinement of ANN.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
This project looks good and is on track. I would suggest that for the artificial neural network (ANN) autopicker, once a pick has been identified and automatic location obtained, it would be worthwhile to correlate the trace with previous nearby events -as cross-coherency can significantly improve the consistency of even machine picks in the presence of any noise. Another parameter that might be included in the ANN input is time-varying signal polarization since the data are 3-C.

Reviewer 37:
There seemed to be many worrisome problems with delays. The overall results using overly complex approaches do not appear to be convincing on a statistical level-all we saw were a couple of simple examples.

Reviewer 38:
Accomplishments were not documented by publications or supported in the presentation. This may be related to delayed funding and difficulty hiring a post-doctoral fellow It is difficult for this reviewer to understand the accomplishments and progress of the project to date.

Reviewer 18:
From what they presented some progress has been made in stated deliverables: 1) they developed and validated an artificial neural network ANN, 2) confirmed the induced nature of microearthquakes (MEQs) at the Geyser, 3) developed a smooth, Kriged, 4-D velocity field analysis to monitor the changes in velocities with time to infer fluid/steam movements. However, they are still six months behind schedule and need to catch-up.

Comments Regarding Project Management/Coordination
Reviewer 5:
This project seems fine. The six month delay looks well supported given the circumstances.

Reviewer 37:

There is good coordination with Lawrence Berkeley National Laboratory partners.

Reviewer 38:
Project management seems less than what is needed for the project such as there was difficulty ramping up by hiring post-doctoral fellow. However, this may have been a result of institutional problems and not a result of project management.

Reviewer 18:
Project management issues seem to be in hand now after a delayed start, in part due to funding delivery schedule slippage of four months and university-produced delays of two months. In coordination with the partner, different measures were taken to bring the project back on schedule including the hiring additional graduate students, part -time faculty and getting additional help from Lawrence Berkeley National Laboratory (LBNL). A plan is in place to try to reduce the schedule variance.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 5:
Please see my above comments, I've said it all up there. The artificial neural network (ANN) picker is good although additional parameters might be considered. Anisotropy is good and if you can work it into tomoDD, we will all be happy (if you give us the code).

Reviewer 37:
I'm not overly impressed with this project. It is focusing on black box catch word approaches involving neural networks, fuzzy logic and fractals. The idea of using multivariate waveform measurements to improve picking is innovative.

Reviewer 38:
The project is somewhat behind relative to other projects in the same funding cycle. Publications need to become a focus and this will aid in moving the project forward.

Reviewer 18:
Utilizing microearthquake (MEQ) data from the Geysers to better understand the mechanisms during fracture stimulation addresses a very critical need for the Geothermal Technologies Program. Their scientific and technical approach is top-notch and will achieve the project's objectives. From what they presented, some progress has been made in the stated deliverables; however, they are still six months behind schedule and need to catch-up. Project management issues seem to be in hand now after a delayed start and a plan is in place to try to reduce the schedule variance. All in all, this is a very good project that should continue to be supported.

Comments Regarding Strengths
Reviewer 5:
See above.

Reviewer 37:
Improving methods for phase picking using multivariate waveform measurements.

Reviewer 38:

Reviewer 18:

Scientific and technical approach is solid and has already made progress in developing and validating artificial neural network (ANN), confirming the induced nature of microearthquakes (MEQs) at the Geysers from fractal analysis, and estimating a smooth, Kriged, 4-D velocity field to observe changes in velocities with time to infer fluid/steam movements

Comments Regarding Weaknesses

Reviewer 5:

How about a 3-D attenuation structure. You may have enough data to pull it off.

Reviewer 37:

The projectis focusing on black box catch word approaches involving neural networks, fuzzy logic and fractals. I think that the use of multivariate measurements for arrival time picking could be put on a more statistical framework to improve uncertainty estimates.

Reviewer 38:

Reviewer 18:

Only weaknesses are to get back on schedule and to direct their focus away from further refining artificial neural network (ANN) to developing techniques to estimate fracture direction and type form the microearthquake (MEQ) data itself.

Suggestions for Improvement

Reviewer 5:

Reviewer 37:

I think that the use of multivariate measurements for arrival time picking could be put on a more statistical framework to improve uncertainty estimates that are important for mapping out location errors.

Reviewer 38:

Reviewer 18:

The Geothermal Technologies Program should re-focus this project away from further refining artificial neural network (ANN) to developing techniques to estimate fracture direction and type form the microearthquake (MEQ) data itself.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0505
Presentation Title: Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments (GEYSERS)
Investigator: Ghassemi, Ahmad (Texas Engineering Experiment Station)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
In theory if such an establishment between stress field, fracturing, resulting microseismicity and final porosity and permeability could be established, it would be a significant advance and would allow for significantly enhanced recovery after stimulation.

Reviewer 37:
This project seems very relevant to the Geothermal Technologies Program and its impact should be good, if the results are tied into to ongoing seismic research in the field. It seems that an understanding of the location of microearthquakes (MEQs) and fluid flow is very important.

Reviewer 38:
This project addresses a primary technique employed by EGS and the resulting microearthquake (MEQ). It addresses the fundamental causes, pore pressure and rock mechanics, etc. and has wide applicability, if successful.

Reviewer 18:
Probably the most important factor in understanding and eventually controlling subsurface fracturing and is of extreme relevance to EGS technology success is the relationship between state variables such as pressure, temperature, in situ stress field, porosity, permeability, mineralogy, fluid flow, chemistry and surface observables, such as microearthquakes (MEQs). To do this we need laboratory experiments under field in situ conditions that can also monitor MEQs in a small core sample. Further, we need to locate these MEQs and correlate their occurrence in time and space with fracture creation and sustainment. This project attempts to do just that and has already made an impact on current EGS projects, as well as made significant progress on their project tasks.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
The measurements and conclusions on the laboratory scale cores look like they are being done rigorously and data are being recorded well. Interpretations seem a bit lackingat present, and there is no indication that this laboratory-scale work will successfully expand to field conditions.

Reviewer 37:
Excellent scientific results have already been obtained regarding rock physics in geothermal fields and by examining the tie between location of microearthquakes (MEQs) and rock properties that control physical flow.- I would like to see a better tie between the geomechanical properties of small lab samples and in situ rock in the field. I notice that the PI is subcontracting to a structural geologist (Dr. Davatzes of Temple University) which should help elucidate this tie. Many of the seismic studies in this session were attempting to improve earthquake location capabilities in a geothermal field. Additionally, they are now examining the fracture kinematics (and perhaps someday dynamics) through moment tensor analysis and waveform modeling. The study of acoustic emissions from the lab experiments is an excellent start. Would it be possible to obtain seismic signatures from the experiments? I imagine that this would be very difficult, but the payoff could be great for the interpretation of results that seismologists obtain in the field. Seismic waveform analysis from MEQs in the rock samples would perhaps guide the seismic work in the field in terms of defining what signatures are

important to look for regarding the development of fluid pathways.

Reviewer 38:
A good approach for collecting fundamental data for processes to be modeled. Important basis for performing numerical analysis of seismisity and relating to reservoir creation/stimulation. A combined geological-geomechanical approach to understand fracturing is a good start in meeting overall Geothermal Technologies Program objectives.

Reviewer 18:
The scientific and technical approach is logical, very solid in design, sufficiently detailed and extremely thorough. An approach like this instills confidence that the research team will be able to achieve their objectives. The technical team is very strong and is representative of some of the very best scientific leaders in this field. The only weakness is a lack of explanation on how they were going to analyze the acoustic emissions of microearthquakes (MEQs) from the stressed samples in the laboratory.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
On budget, on time, and on target for what was proposed.

Reviewer 37:
The project is just starting and excellent progress has already been made.

Reviewer 38:
The project is just getting started such as the core collection with core characterization. Mechanical tests require machine calibration and perform elastic failure tests, supported by high resolution scanning of samples before and after. The experimental work is ongoing, equipment calibration, and adapting testing procedures to difficult lithologies and limited samples.

Reviewer 18:
Significant progress has been made in some of the planned initial laboratory tasks such as: 1) core collection, preparation rock mechanical testing, 2) petrophysical characterization, 3) calibration of testing apparatus, 4) development of a protocol for multi-stage compression test, 5) tests on aluminum, steel, and Berea SS samples, 6) development of elastic and failure properties for core plugs, 7) high-resolution scanning of some samples to explore pore volume structure before and after failure, and 8) measured permeability before and after triaxial testing low matrix permeability. Some Mohr-Coulomb envelopes have been calculated and a permeability comparison has been made between before and after triaxial stress tests.

Comments Regarding Project Management/Coordination
Reviewer 5:
No comment.

Reviewer 37:
The coordination is good. It would be great to improve the tie between laboratory and field observations and I'm sure this will happen.

Reviewer 38:
The project is only 20 to 25% along with 28% of funds spent. There are a good span of collaborators and good leveraging with other projects to enhance and support the project scope. Data sharing is typical for a project of this type.

Reviewer 18:

The project management and coordination does not seem to have any unresolved critical issues. Funds are 28% depleted and work is about 25% completed with the calendar at about 30%; so project looks on schedule and on budget.

Overall
In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
I'm skeptical about the field-scale expansion of the controlled laboratory results. If it can be shown to work, that's great. The PIs will have to demonstrate convincingly that after stimulation, fracture and seismicity, the porosity and permeability can somehow be related back to the microearthquakes. What guarantee is there that the fractures did not seal themselves again? What about mineral species under pressure/temperature conditions and deposition/blockage?

Reviewer 37:
Excellent scientific results have already been obtained regarding rock physics in geothermal fields and examining the tie between location of microearthquakes (MEQ)s and rock properties that control physical flow is very important.

Reviewer 38:
Responded well to questions. Looks like a good start.

Reviewer 18:
Probably the most important factor in understanding and eventually controlling subsurface fracturing and is of extreme relevance to EGS technology success is the relationship between state variables and microearthquakes (MEQs). The scientific and technical approach is logical, very solid in design, sufficiently detailed and extremely thorough. An approach like this instills confidence that the research team will be able to achieve their objectives. The technical team is very strong and is representative of some of the very best scientific leaders in this field. Significant progress has been made in some of the planned initial laboratory tasks, some Mohr-Coulomb envelopes have been calculated, and a permeability comparison has been made between before and after triaxial stress tests. Project management and coordination does not seem to have any unresolved critical issues and project looks to be on schedule and on budget.

Comments Regarding Strengths
Reviewer 5:

Reviewer 37:
The tie between lab experiments and field studies.

Reviewer 38:
Needed results for verifying numerical simulation. Sound approach.

Reviewer 18:
The scientific and technical approach is logical, very solid in design, sufficiently detailed and extremely thorough. An approach like this instills confidence that the research team will be able to achieve their objectives. The technical team is very strong and is representative of some of the very best scientific leaders in this field.

Comments Regarding Weaknesses
Reviewer 5:

Reviewer 37:
Nothing major.

Reviewer 38:
It would be useful to have step to upscale to field scale.

Reviewer 18:
Only weakness was a lack of explanation on how they were going to analyze the acoustic emissions of microearthquakes (MEQs) from the stressed samples in the laboratory. They showed a figure that looks like the locations of these MEQs were determined in a core sample as a function of time. Are they going to do that or something less ambitious? We need to know because this is a very important deliverable from this project.

Suggestions for Improvement

Reviewer 5:
Would love to see this expanded to room-size from bench-size before drawing too many conclusions about field-scale behaviors. Heterogeneity is a very different thing from a core to a reservoir.

Reviewer 37:
Good coordination between laboratory experiments and field studies of fractures is important to the success of this project. Many of the seismic studies in this session were attempting to improve earthquake location capabilities in a geothermal field. Additionally, they are now examining the fracture kinematics (and perhaps someday dynamics) through moment tensor analysis and waveform modeling. The study of acoustic emissions from the lab experiments is an excellent start. Would it be possible to obtain seismic signatures from the experiments? I imagine that this would be very difficult, but the payoff could be great for interpretation of results that seismologists obtain in the field. Seismic waveform analysis from microearthquakes (MEQs) in the rock samples would perhaps guide the seismic work in the field in terms of defining what signatures are important to look for in regards to the development of fluid pathways.

Reviewer 38:

Reviewer 18:
It is suggested that a more detailed explanation on how they were going to analyze the acoustic emissions of microearthquakes (MEQs) from the stressed samples in the laboratory under fracturing conditions would be beneficial. This should be done before the project reaches that part of the work planned so as not to run out of funds.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0506
Presentation Title: Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions With Microearthquake Data for 3D Velocity Structure, Earthquake Locations, and Moment Tensors in Geothermal Reservoirs
Investigator: O'Connell, Daniel (Fugro Consultants, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
Noise correlation is a huge opportunity to supplement the available seismic data for evaluation of geophysical parameters everywhere, including geothermal sites. The waveform coda is an underutilized feature of seismic data and is ordinarily disregarded in favor of derived parameters such as phase onset, this has meant that a critical part of the collected microseismic archives has been completely neglected. It is high time someone started looking at these features to exploit them to the greatest extent possible - or, in fact, to any extent.

Reviewer 37:
The project seems relevant to the Geothermal Technologies Program. It is probably too early in the project to assess impact, but things are going in the right direction.

Reviewer 38:
Reducing the absolute uncertainty in structure locations and reducing the uncertainty in generating large magnitude earthquakes are important objectives. If successful the project could have high impact.

Reviewer 18:
Application of state-of-the-art seismological algorithms and techniques for the purpose of extracting more, meaningful information from the natural and induced microearthquake (MEQ) waveforms observed at operating and potential EGS geothermal sites is extremely important R&D for the Geothermal Technologies Program. For years these advanced techniques have not been applied to geothermal data because of the low signal to noise and paucity of 3-C broad bandwidth instruments as well other factors. In this project, it is refreshing to see these advanced techniques applied to real data sets at two well-known geothermal sites and some significant findings have already come out of this effort. The impact of this research cannot be underestimated and will have a major influence on the future of EGS as well as hydrothermal projects worldwide.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
Coda-wave interferometry has been around awhile.Poupinet and Ito employed it some 20 years ago for detecting velocity changes in tectonic settings. Thus, although this is an advance for geothermal, the idea is hardly new. Nevertheless if it can be used to improve event location in a time-varying sense, this will be an innovation. Misidentification of S-waves is a problem in any complex geology due to conversions. If 3-C stations are recording, this becomes a bit easier. Not sure why use of L1 is considered pivotal to this other than its general insensitivity to outliers. Exploiting GPU systems is certainly the way to go for finite difference full waveform inversion, which is an intractable problem on standard processor setups.

Reviewer 37:
The project is a nice mix of different advanced seismological techniques (e.g deterministic 3D visco-elastic waveform modeling, ambient noise analysis and coda interferometry) supported by 3-D fluid flow calculations. I looks like there is good coordination between the seismic results and geothermal field operations, which is lacking in a number of the other

projects reviewed. The PI has a good understanding of the limitations of some of the traditional seismic approaches such as the effects of anisotropy on resolution of isotropic moment tensor and focal mechanism effects on correlation functions). Detailed analysis of seismograms in order to identify secondary phases is also an important technical approach not always performed by other projects.

Reviewer 38:
De-fuzzing earthquake locations using two approaches is innovative and appropriate for achieving project objectives. The use of passive body and surface wave interferometry to image at depth is appropriate. Good use of leveraging to enhance project scope.

Reviewer 18:
The scientific and technical approach is logical, very solid in design, sufficiently detailed and exceptionally thorough. An approach like this instills confidence that the research team will be able to achieve their objectives. Technical team is very strong and is representative of some of the very best scientific leaders in this field. The only weakness is a lack of geothermal expertise in this group to better interpret their findings, in terms of geothermal concepts and issues, so as to maximize the impact.

Comments Regarding Accomplishments, Results and Progress

Reviewer 5:
Seems on track as per what was proposed, with typical contract delays considered.

Reviewer 37:
Considering some of the delays that the project has encountered, the progress has been very good.

Reviewer 38:
This project is just getting started. The results seem appropriate for the funding profile. It was difficult to access accomplishments because speaker ran out of time.

Reviewer 18:
Significant progress has been made in executing the project plan and with very interesting, unanticipated but useful results such as: Paradox injection seismicity focal mechanism analyses showed a 15° stress rotation within 2 km of the well in response to continued injection; Paradox coda-wave interferometric analyses show only small average relative velocity change of less than 0.5% in a region subject to two acid hydrofracturing activities near the well; Coso nonlinear L1 velocity-hypocenter inversion found nearly half the Coso borehole stations have multi-modal S-wave arrival time residuals suggesting that a significant portion of the S-wave arrival time picks represent S-to-P conversions in shallow large velocity gradient regions; and finally, interferometric coda-wave analysis at Coso shows that 90% of the multiplets consist of earthquakes with heterogeneous focal mechanisms that undermine body-wave cross-correlation relative relocation resolution and suggest that actual location scatter in the multiplets is three to five times smaller than suggest by the body-wave based locations. This is great stuff and exactly what I foresee as the tip of the iceberg in terms of what will be discovered in the future. Other significant accomplishments were made with regard to speed-up; an important component of this work because these techniques would not be transferable to the general geothermal community otherwise.

Comments Regarding Project Management/Coordination

Reviewer 5:

Reviewer 37:
There appears to be good coordination between the different research groups.

Reviewer 38:
Seems OK but difficult to tell given presentation and running out of time.

Reviewer 18:
Given the information presented, the project management and coordination does not seem to have any unresolved critical issues at this time. Establishing the university subcontracts delayed work for about six months; not very good planning. They say that work will accelerate starting this summer with the full-time availability of Profs. Snieder, Wu, and Chen. The current costing data was missing and work is about 26% complete with the calendar at about 33%; so project looks on schedule and uncertain regarding spending.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
There is some good work here and the developed tools could prove very useful to EGS.

Reviewer 37:
The project is a nice mix of different advanced seismological techniques (e.g deterministic 3-D visco-elastic waveform modeling, ambient noise analysis and coda interferometry) supported by 3-D fluid flow calculations. There looks to be good coordination between the seismic results and the geothermal field operations which is lacking in a number of the other projects that were reviewed. The PI has a good understanding of the limitations of some of the traditional seismic approaches (e.g. effects of anisotropy on resolution of isotropic moment tensor and focal mechanism effects on correlation functions). The detailed analysis of seismograms in order to identify secondary phases is also an important technical approach not always performed by other projects.

Reviewer 38:
This project was difficult to review due to complex and incomplete presentation. The presenter only got through about half of the slides. The other problem is that the project is not very far along given the time delay in getting funding to the contributors. The presenter is obviously quite capable and is using a viable approach for meeting project objectives.

Reviewer 18:
Extracting more, meaningful information from the natural and induced microearthquake (MEQ) waveforms observed at operating and potential EGS geothermal sites as presented in this project will significantly impact the Geothermal Technologies Program and will alter the course of EGS as well as hydrothermal projects worldwide. The scientific and technical approach is logical, very solid in design, sufficiently detailed and exceptionally thorough. The technical team is very strong and is representative of some of the very best scientific leaders in this field. Significant progress has been made in executing the project plan and with very interesting, unanticipated but useful results. Given the information presented the project management and coordination does not seem to have any unresolved critical issues at this time and although thecurrent costing data was missing, the work is about 26% complete with the calendar at about 33%; so project looks on schedule and uncertain regarding spending.

Comments Regarding Strengths
Reviewer 5:
Good project expertise in participants, good innovations.

Reviewer 37:
Leading edge seismological techniques are being brought to the geothermal field monitoring problem.

Reviewer 38:

Reviewer 18:
The scientific and technical approach is logical, very solid in design, sufficiently detailed and extremely thorough. An approach like this instills confidence that the research team will be able to achieve their objectives. The technical team is very strong and is representative of some of the very best scientific leaders in this field.

Comments Regarding Weaknesses
Reviewer 5:

Reviewer 37:
Nothing major.

Reviewer 38:

Reviewer 18:
Only weakness was a lack of geothermal expertise. The seismological, numerical analytics and modeling expertise are impressive but at this stage and from what was presented it is evident that a geothermal- based expertise is missing.

Suggestions for Improvement
Reviewer 5:
Coda interferometry- please think about doing this in a multi-dimensional fashion (i.e. coda anisotropy sensitivity). Velocity changes, if there is an appreciably asymetrical stress field, will be asymmetric and anisotropic due to preferential fracture orientation. This is important to fracture/reservoir development and these tools might give an insight into this kind of new way of looking at it.

Reviewer 37:

Reviewer 38:

Reviewer 18:
It is suggested that someone from the two geothermal projects analyzed for this project should be involved in the interpretation of the findings. This will add significant value to the results and plow the way to ask further questions that more advanced techniques might be able to answer. This should be done sooner than later.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0507
Presentation Title: Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems
Investigator: Gritto, Roland (Array Information Technology)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
This project addresses a key problem for EGS which is the understanding of induced and triggered seismicity as a result of injection and stimulation. Without a robust means of assessing and communicating the risks and hazards of a prospect, the technology will go nowhere, politically guaranteed.

Reviewer 37:
This project is relevant to the Geothermal Technologies Program. It is early in the project and there were some delays, so the impact remains to be seen.

Reviewer 38:
The connections between seismicity and reservoir development and large-scale seismicity are major concerns for EGS. If successful, the project could have good impact to industry.

Reviewer 18:
It is very exciting to see these researchers from the Ground-Based Nuclear Explosion Monitoring (GNEM) Program at NNSA engaged in analyses of Geysers seismic data using state-of-the-art tools and techniques to provide a better understanding of the relationship between reservoir injection and production activities and observed seismicity. This project has already made substantial progress and fresh, new and significant findings have emerged. Clearly, this project has already had an impact on the Geothermal Technologies Program mission and goals. The Program needs more of this kind of outstanding work.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
Technical approach uses the best tools available to date, with a comprehensive synthesis of methods for high-quality hazard assessment and site characterization.

Reviewer 37:
The scientific/technical approach is good. Standard techniques are being used to develop velocity models and locate earthquakes. The extension to 4-D to monitor changes during geothermal operations is important. Most of the work from UCB that I have seen regarding moment tensor inversion involves more seismicity than will be observed in the Geysers and uses low frequency waveforms and assumes step function time dependence. These assumptions reduce the effect of path velocity and attenuation structure. How will the procedures be modified for smaller magnitude events (e.g. source time function and attenuation effects for P and S waves)? The use of empirical Green‘s functions for hazard analysis is good and I think this was the only presentation looking at these issues for a single geothermal field.

Reviewer 38:
Uses of proposed techniques to address the objective of this project seem appropriate. Using the existing large dataset at the Geyers is appropriate.. The analysis of seismicity has resulted in a large database.

Reviewer 18:
The scientific and technical approach is logical, very solid in design, sufficiently detailed and extremely thorough. An

approach like this instills confidence that the research team will be able to achieve their objectives. Technical team is very strong and is representative of some of the very best scientific leaders in seismology. The techniques being applied are state-of-the-art and have been developed and tested for years at GNEM NNSA Program.

Comments Regarding Accomplishments, Results and Progress

Reviewer 5:
The project is not complete, so although I fully expect the final results to move to "outstanding", I must reserve judgment on this kind of stellar rating. The investigators are bringing the right combination of methods and expertise and I have no doubt they will do an excellent job.

Reviewer 37:
It is early in the project and there were delays, so there has not been too much progress to date.

Reviewer 38:
The testing of inversion codes with synthetic data sets seems fairly basic, but is probably just the first step in process. 3-D model is similar. The seismic moment tensor analysis is interesting and shows some progress for projects. The results suggest that the framework of processing source mechanisms is established.

Reviewer 18:
Significant and impactful progress has been made in many of the planned tasks such as: 1) The framework for processing source mechanisms has been established; 2) A suite of source models were employed; and 3) Statistical analyses to assess uncertainties was completed. Results so far are very interesting and will illuminate the induced seismicity mechanisms.

Comments Regarding Project Management/Coordination

Reviewer 5:
This project seems to be on target on budget and on schedule, as funding availability has permitted.

Reviewer 37:

Reviewer 38:
This project is only 20% along. Project signed in June 30, 2010. The project management seems appropriate for level of effort. There is a good span of collaborators.

Reviewer 18:
Given the information presented the project management and coordination does not seem to have any unresolved critical issues at this time except that they are behind schedule and need to pick-up the pace. Current costing is about 18% spent and work is about 20% complete with the calendar at about 33%; so project looks behind schedule and has under spent compared to schedule and to the amount work performed.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
I think this is an excellent example of high quality research and development for EGS with respect to seismic monitoring, modeling and hazard assessment. The tools that are being combined and the methodological advancements will be crucial for evaluating other sites with respect to permitting and public acceptance of the activities, based on sound science and

meaningful estimates of the risk of triggered earthquakes.

Reviewer 37:
The project is in the early stages but a good overall effort is planned.
Reviewer 38:

Reviewer 18:
Application of advanced seismic source modeling techniques developed at the Ground-Based Nuclear Explosion Monitoring (GNEM) Program at NNSA, engaged in analyses of the Geysers will undoubtedly provide a better understanding of the relationship between reservoir injection and production activities and observed seismicity. Clearly, this project has already had an impact on the Geothermal Technologies Program mission and goals. The technical team is very strong and is representative of some of the very best scientific leaders in seismology. Significant and impactful progress has been made in many of the planned tasks and results so far are very interesting and will illuminate the induced seismicity source mechanisms. Current costing is about 18% spent and work is about 20% complete with the calendar at about 33%; so project looks behind schedule and under spent compared to schedule and to work performed.

Comments Regarding Strengths
Reviewer 5:
See all of the above. Good researchers, good tools, good synergy and insightful evaluation process.

Reviewer 37:
This is one of the only projects looking at the seismic hazard analysis of a geothermal field.

Reviewer 38:

Reviewer 18:
Outstanding science and technology applied to the Geothermal Technologies Program's critical needs has made significant progress and already generated new and impactful results. The technical team is very strong and is representative of some of the very best scientific leaders in seismology. The techniques being applied are state-of-the-art and have been developed and tested for years at GNEM NNSA Program.

Comments Regarding Weaknesses
Reviewer 5:

Reviewer 37:

Reviewer 38:

Reviewer 18:
Only weakness is that they are behind schedule.

Suggestions for Improvement
Reviewer 5:
There's a lot of data here. I would like to see waveform correlation methods used to refine phase picks and allow detailed fracture mapping as well as 3-D attenuation structure and an assessment of anisotropy (not just in travel time but also

possibly in attenuation). For the tomographic inversions, the project should explore the use of summary rays (bundling) for productive seismic sources so that paths are evenly weighted in the inversion process.

Reviewer 37:
There will probably be a lot of modifications required to apply the regional moment tensor analysis to geothermal field monitoring.
Reviewer 38:

Reviewer 18:
Pick-up the pace.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0508
Presentation Title: Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing
Investigator: Templeton, Dennise (Lawrence Livermore National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
This method is relevant to the problem of detecting small events in a microseismic catalog, although not enough progress has been shown yet to demonstrate any advancement over existing methods.

Reviewer 37:
The goals of this project are good in that with Matched Field Processing (MFP) it will be possible to detect smaller seismicity during geothermal field operations. I'm a bit concerned about impact at this point because of the work performed so far.

Reviewer 38:
If successful the approach could expand the monitoring capabilities/span of data seismic data sets for GPS. However, the impact will be limited unless the data can be migrated to a more useful domain for analysis.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
The Matched Field Processing (MFP) method is really only a slight modification to the standard subspace approach, by applying narrowband filters to create bandlimited subspaces against which to compare bandlimited incoming signals. The presenter appears not to understand the method or how it is used, although this is not the fault of the method per se. The significant problem is the issue of robust spectral estimation without spectral leakage and although the presenter claims that this has been 'fixed' with an additional subroutine, she does not explain how it was fixed and she does not provide evidence to support the claim. It's a nontrivial problem and needs a better discussion. Also the spectacular improvement in detections w/ the MFP method compared to a Short Term Averaging/Long Term Averaging (STA/LTA) detection is no better than coherency-weighted correlation scanning detectors have demonstrated in the literature. Maybe when the problems are solved the tool will be an advance - it's not possible to tell yet.

Reviewer 37:
The idea of applying Matched Field Processing (MFP) techniques to geothermal field seismicity is good, but I'm not yet convinced it will work. From what I understand, MFP assumes that much of the path is common between different sources and a receiver. That will not be the case for local monitoring. A number of other projects in this review commented on the limitation of using waveform correlation techniques in the geothermal environment because of mechanism variations. I suspect the same limitations will apply to MFP. Detecting smaller events during geothermal operations is good, but is detection enough? I guess with enough templates, it may be possible to locate the small events as well but am not sure. Looking at the plots shown, I'm wondering of a detector based on the spectrogram may work as well. Could the MFP techniques be used for detecting changes in seismicity (i.e. flag events that do not match any templates) during injection? That might be a useful thing to focus on. I also had concerns about the fact that MFP was being applied to signal spectrum and not waveforms and was confused about why this approach was taken. Signal spectrum is more sensitive to tradeoffs between source time function and frequency- dependent attenuation.

Reviewer 38:
The approach seems appropriate and suitable for meeting project objectives. Actually, the project has met several project

objectives. However, migrating to the time domain is essential for advancing process.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:

Reviewer 37:
The results to date are not overly impressive.

Reviewer 38:
Matched Field Processing may have applicability to microearthquake (MEQ) monitoring. As the project develops, this will be determined more completely.

Comments Regarding Project Management/Coordination
Reviewer 5:
OK, I guess. Presentation was unconvincing for the technical value of the project, but the items as stated in the proposal seem on track for delivery nonetheless.

Reviewer 37:

Reviewer 38:
Project management appears to be sufficient for project.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
Reasonable effort.

Reviewer 37:
I have a lot of concerns regarding application of Matched Field Processing (MFP) and how it is being implemented.

Reviewer 38:

Comments Regarding Strengths
Reviewer 5:
Might prove to be an added method for the collection of available ones for detecting weak events. Clearly more work is needed, at least based on what was presented at the review.

Reviewer 37:
The PIs are closely examining data.

Reviewer 38:

Comments Regarding Weaknesses

Reviewer 5:
The project personnel don't seem to fully understand the details of the code.

Reviewer 37:
I also had concerns about the fact that Matched Field Processing (MFP) was being applied to signal spectrum and not waveforms and was confused about why this approach was taken. Signal spectrum is more sensitive to tradeoffs between source time function and frequency-dependent attenuation.

Reviewer 38:

Suggestions for Improvement
Reviewer 5:

Reviewer 37:
The idea of applying Matched Field Processing (MFP) techniques to geothermal field seismicity is good, but I'm not yet convinced it will work. From what I understand, MFP assumes that much of the path is common between different sources and a receiver. That will not be the case for local monitoring. A number of other projects in this review commented on the limitation of using waveform correlation techniques in the geothermal environment because of mechanism variations. I suspect the same limitations will apply to MFP. Detecting smaller events during geothermal operations is good, but is detection enough? I guess with enough templates, it may be possible to locate the small events as well but am not sure. Looking at the plots shown, I'm wondering if a detector based on the spectrogram may work as well. Could the MFP techniques be used for detecting changes in seismicity (i.e. flag events that do not match any templates) during injection? That might be a useful thing to focus on. I also had concerns about the fact that MFP was being applied to signal spectrum and not waveforms and was confused about why this approach was taken. Signal spectrum is more sensitive to tradeoffs between source time function and frequency- dependent attenuation.

Reviewer 38:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0509
Presentation Title: Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in EGS Reservoirs
Investigator: Huang, Lianjie (Los Alamos National Laboratory / National Energy Technology Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 37:
The goal of optimizing geothermal field operations is very relevant to the Geothermal Technologies Program, as well as predicting the placement of new wells.

Reviewer 38:
This work may help optimize drilling and development of EGS reservoirs. Conference papers submitted to date are an indication that this work is important and will be shared with the geothermal community.

Reviewer 18:
Quantitative EGS reservoir monitoring techniques are needed and critical to the Geothermal Technologies Program reach its goals. The objectives of this project, if met, will make significant progress in advancing EGS. The progress to date has been significant but not as impactful as necessary to inform EGS operational decisions as touted.

Comments Regarding Scientific/Technical Approach
Reviewer 37:
By using data from both fracture mapping and core samples, the Discrete Fracture Network (DFN) approach seems like a good and innovative way to approach the geothermal reservoir modeling problem compared to some of the other modeling studies. Of course, the geometry of the fractures projected to the subsurface is critical and in this study they are parameterized as planar, which I guess is all that can be done at this point. It seems that effects of temperature and porosity on P and S velocities are being handled separately. Because P and S waves are sensitive to different rock properties, such as bulk effects on P from fluid flow in cracks and temperature effects on S, it may be better to look at in terms of P/S ratio in order to understand material properties a little better.

Reviewer 38:
Use of core data coupled with modeling is a good approach. It was a bit difficult to see how much new science is being developed as a part of this work. It seems like most of the work was inversion algorithms, which is important, but must be coupled with data. It was difficult to read the core charts with respect to velocity change with temperature. However, the paper and presentations indicate good publishable results and the strength of the scientific approach. Overall the approach is rated as good and the above comments will likely be addressed as the project moves forward.

Reviewer 18:
The scientific and technical approach is logical, very solid in design, but not sufficiently detailed. The technical team is very large, bringing a diverse and solid set of skills to the problem and is made up of some of the very best scientific leaders in their fields. The seismic techniques being applied are modifications to those routinely used in explosion seismology and the reservoir techniques were not adequately described to allow a technical evaluation. Details of the double difference (DD) inversion schemes were not presented and their claimed scientific innovation could not substantiated. Finally, where is the seismic data from Brady Hot Springs coming from? These methods have been developed and tested on synthetic data but real data sources were not mentioned. If seismic data will not be available, then this could significantly reduce the value of this project.

Comments Regarding Accomplishments, Results and Progress

Reviewer 37:

The delay in funding for one of the major players, the National Energy Technology Laboratory, has not slowed the project, which is good. Many other projects seem to use these delays as an excuse for lack of progress. One thing that I did not see was progress towards a comparison of time-lapse models with actual geothermal field operations and would hope to see this in the coming year.

Reviewer 38:

Accomplishments appear to be appropriate for level of funding expended to date. The number of publications is good. It is difficult to see how lab results are tied to modeling but that may be a function of the limited technical slides allowed by the review format.

Reviewer 18:

Progress has been made in some of the planned tasks such as: 1) development of an improved waveform inversion method, 2) three new double-difference waveform inversion algorithms, 3) joint inversion of time-lapse seismic data to estimate reservoir changes, and 4) the waveform inversion algorithms were tested using Brady Hot Springs‘s EGS site synthetic seismic reflection data. In addition, they built a preliminary discrete fracture network model for Brady‘s EGS field and obtained core, production data, and geologic models. Cores were CT scanned to analyze small-scale structures and ultrasonic velocity measurements of two different cores. Results of all of these activities had promise but were not impactful.

Comments Regarding Project Management/Coordination

Reviewer 37:

There are so many partners in this project that management and coordination must be quite a challenge. But, it appears to be successful with most or all players participating.

Reviewer 38:

The project is about half completed and the project management seems to be appropriate for this level of funding. Involvement with industry and NV research institutes is a strong plus.

Reviewer 18:

Given the information presented, the project management and coordination does not seem to have any unresolved critical issues at this time except that they are slightly behind schedule and need to pick-up the pace. The reported project coordination activities seem inadequate given the sheer number of participating agencies and individuals which is a concern regarding inter-task data and idea sharing. Current costing is about 40% spent and work is about 40% complete with the calendar at about 50%; so project looks behind schedule and under spent compared to the schedule and is on track for the amount of work performed.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 37:

By using data from both fracture mapping and core samples, the Discrete Fracture Network (DFN) approach seems like a good and innovative way to approach the geothermal reservoir modeling problem compared to some of the other modeling studies.

Reviewer 38:

This project is well run and progressing nicely towards achieving the Geothermal Technologies Program‘s objectives.

Reviewer 18:
Quantitative EGS reservoir monitoring techniques are needed and critical to the Geothermal Technologies Programreaching its goals. The objectives of this project, if met, will make significant progress in advancing EGS. There has been progress to date but the impact was not significant to inform Brady Hot Springs EGS operational decisions as touted. The scientific and technical approach is logical, very solid in design, but not sufficiently detailed. Finally, the lack of discussion concerning real seismic data could significantly reduce the value of this project. The technical team is very large, bringing a diverse and solid set fo skills to the problem and is made up of some of the very best scientific leaders in their fields. Progress has been made in some of the planned tasks but results were not impactful but do demonstrate promise. Given the information presented, the project management and coordination does not seem to have any unresolved critical issues at this time except that they are slightly behind schedule and need to pick-up the pace. Current costing is about 40% spent and work is about 40% complete with the calendar at about 50%; so project looks behind schedule and under spent compared to the schedule and on track for the amount of work performed.

Comments Regarding Strengths
Reviewer 37:
Excellent modeling component which is closely tied to field observations.

Reviewer 38:

Reviewer 18:
The objectives of this project, if met, will make significant progress in advancing EGS, the scientific and technical approach is logical, very solid in design and the technical team is solid. Progress has been made in some of the planned tasks and project management and coordination. The project does not seem to have any unresolved critical issues at this time and is under spent compared to schedule and on track to work performed.

Comments Regarding Weaknesses
Reviewer 37:
An attempt to characterize fractures at depth could be improved.

Reviewer 38:

Reviewer 18:
Progress to date has not impacted Brady Hot Springs EGS operational decisions as touted. The scientific and technical approach as presented is not sufficiently detailed. The project is slightly behind schedule and and under spent compared to schedule they need to pick-up the pace. Finally, lack of discussion concerning real seismic data could significantly reduce the value of this project.

Suggestions for Improvement
Reviewer 37:
It seems that effects of temperature and porosity on P and S velocities are being handled separately. Because P and S waves are sensitive to different rock properties, such as bulk effects on P from fluid flow in cracks and temperature effects on S, it may be better to look at in terms of P/S ratio in order to understand material properties a little better.

Reviewer 38:

Reviewer 18:
It is suggested that the Geothermal Technologies Program request a review of the scientific and technical details in order to assess the value of the modifications to standard techniques as well as evaluate the value added to Brady Hot Springs. In addition, the lack of discussion concerning real seismic data collection needs to be investigated.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0510
Presentation Title: Joint Seismic-EM Inversion (LBNL)
Investigator: Newman, Gregory (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
Highly relevant if the method can be developed and if implementation produces anticipated results.

Reviewer 37:
The idea of joint inversions of seismic, gravity and electromagnetic (EM) data is relevant to the Geothermal Technologies Program. I‘m not sure about how great the impact will be given some details of the ―joint” inversion method.

Reviewer 38:
Improving geophysical imaging methods using joint inversion is a an excellent objective. Use of real data at multiple sites is also beneficial to enhancing the relevance and impact of the research.

Reviewer 18:
Improved geophysical imaging methods for characterizing subsurface structure, identifying fluid locations, and characterizing fractures are critical to the Geothermal Technologies Program mission. Determining the feasibility of jointly using data from microearthquake (MEQ) and electrical surveys to image the fluid distribution within geothermal systems might be of benefit to the Geothermal Technologies Program. Magnetotelluric (MT) methods have notoriously been unable to resolve detailed features in the subsurface in the past and jointly utilizing thematic mapper (TM) and microearthquake (MEQ) data might improve MT resolving power. Therefore, one needs to ask: What does MT bring to the problem solution? They reached the same conclusion in their analyses of the MT data, which begs the question, why did we use MT in the first place? Some progress has been made but impact to the three sites seems negligible.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
So far although gravity is supposed to drive the model (based on presentation slides) nothing has been done with respect to gravity. The use of double-difference tomography is a good start for the seismic, but the cross-gradient, iterative method is not joint inversion and shouldn't be sold as such. Each independent data set is subject to its own ambiguities and local minima in the inversion process. The point of trying to use them together is to allow them to complement one another, so that a joint inversion is better able to rule out such traps that might fit one dataset but not the other. Thus the final independent models could be very wrong, and comparing in a cross-gradient way does not necessarily provide the robustness that a true joint inversion would. This applies to any disparate datasets. I don't like the approach. It does look like there is good seismic data available.

Reviewer 37:
The scientific and technical approach is good, but the way things were outlined in the talk is more of a ―serial” approach to inversion as opposed to the ―parallel” approach. In the presentation it was stated that gravity inversion serves as input to electromagnetics (EM) which serves as input to seismic inversion. It is not clear how this order was picked and whether it is the best order to use. Each of the datasets is governed by a differential equation having physical constants such as density for gravity, elastic constants for seismic, and conductivity for resistivity. It seems that a tie for each of these datasets could be made through the physical constants perhaps based on laboratory experiments. In this way a true joint inversion could be made rather than separate inversions and subsequent examination of their spatial correlations.

Reviewer 38:
I liked the four step approach for combined analysis that included integrated interpretation, a step wise look at gravity, magnetotellurics (MT) and seismic, a fully coupled acoustic inversion for scaling and finally deep drilling technology (DDT). Simultaneous interpretation of multiple datasets is actually something that geophysicists have been doing mentally for a long time but reducing this to mechanized approach is an excellent touch. The good correlation of MT and seismic data at the Coso field demonstrates the need for coupled interpretations. Good approach to collecting additional data through new/enhanced networks. Not clear how much is from leverage funds and how much is from this project.

Reviewer 18:
Details of the scientific and technical approach were not revealed in the information available to this reviewer hence this assessment is not complete. However, what was presented demonstrated a logical, solid research plan. In fact, the joint inversion scheme was particularly well constructed with a normal integrated approach followed by a novel iterative approach. In the former, individual datasets are inverted independently and then integrated (plotted) on the same map. The proposed iterative joint inversion where the output of one technique feeds into the next was interesting but their choice of order of techniques was not supportable and, more disturbing, the unique parameter to ―pass” to the next technique was not known by the presenter. That being said the research team did integrate double difference (DD) tomography with electromagnetic (EM) inversion using cross gradient constraint—very good approach. The technical team is world-class and scientifically sound with of some of the very best scientific leaders in their fields.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
I don't like the method so am not going to be thrilled with the accomplishments. I do see that the seismic dataset looks good. Think the researchers need to use clustering and ray bundling to increase the homogeneity of ray coverage so they are not getting too much weight from tight event clusters influencing the inversion. The Coso data are highly clustered so this should be a good and easy thing to do. It will also reduce runtime for inversion.

Reviewer 37:
The progress to date appears to be on track, but the results appear to be a bit fragmented between the three different geothermal fields. I think a good direction for this project to follow may be to compare and contrast the geophysical considerations involved with analysis of the three different fields. This may give a good overview of the variability to be expected with geothermal field monitoring.

Reviewer 38:
Excellent accomplishments, results and progress for being so early in the project. Good focus on obtaining baseline data for multiple datasets in first year. Makes good argument for the need for joint, coupled interpretation is presented, hopefully in future presentations actual results joint interpretations will be presented.

Reviewer 18:
Progress has been made in some of the planned tasks such as: 1) new high resolution 3-D resistivity images were made of the Hengill and Krafla fields, 2) the Krafla magma body was imaged, 3) integrated double difference (DD) tomography with electromagnetic (EM) inversion using cross gradient constraint 3) 14 station seismic network were deployed in the Reykjanes-Hengil, 4) obtained data from Krafla borehole seismic network, 5) began DD tomography of data from the Coso Field. At this time results of all of these activities had promise but were not impactful. Finally, results (images) were shown but not described or interpreted. Hopefully, in year two the interpretation of these images will rise in priority and become the main focus, as it should be.

Comments Regarding Project Management/Coordination
Reviewer 5:

Reviewer 37:

Reviewer 38:
There is good international collaboration. This project is about one third along in terms of the funding profile. Good project management and excellent progress on milestones in year one. Good mix of participants and collaborators. Publication/presentations are good.

Reviewer 18:
Project management and coordination does not seem to have any unresolved critical issues at this time, given the information presented, except that it did not seem that much communication had occurred or will occur in the future between researchers. It is suggested that the PI elucidate the details of the project management and coordination plan to the Geothermal Technologies Program. Reported project coordination activities seem inadequate given the sheer number of participating agencies and individuals, which is a concern regarding inter-task data and idea sharing required to accomplish the project‘s goals. Current costing was not given and work completed was estimated at about 33% with the calendar at about 33%; so project looks on schedule and spending was not available to analyze. This needs to be resolved by the Program.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 5:
Please see above. This is not joint inversion. This is iterative inversion and then correlating final models. It isn't the same thing and it won't yield the same results.

Reviewer 37:
The idea of a joint inversion of multiple datasets is a good but I think there could be some better research involved with developing a physical tie between the different measurements rather than just examining their spatial correlation.

Reviewer 38:
This is a showcase project with high international visibility. Scope is broad and the research objectives are aggressive. I look forward to seeing the results.

Reviewer 18:
Improved geophysical imaging methods for characterizing subsurface structure, identifying fluid locations, and characterizing fractures are critical to the Geothermal Technologies Program mission. Determining the feasibility of jointly using data from microearthquake (MEQ) and electrical surveys to image the fluid distribution within geothermal systems might be of benefit to the Program because magnetotellurics (MT) methods have notoriously been unable to resolve detailed features in the subsurface in the past. Some progress has been made but impact to the three sites seems negligible at this time. Details of the scientific and technical approach were not revealed in the information available to this reviewer; hence this assessment is not complete. However, what was presented demonstrated a logical, solid research plan. The technical team is world-class and scientifically sound with of some of the very best scientific leaders in their fields. Progress has been made in some of the planned areas but at this time the results of these activities have promise but have not been impactful. Results were shown but not described or interpreted. Hopefully, in year two, the interpretation of these images will rise in priority and become the main focus, as it should be. Project management and coordination does not seem to have any unresolved critical issues at this time, given the information presented, except that it did not seem

that much communication had occurred or will occur in the future between researchers. Reported project coordination activities seem inadequate, given the sheer number of participating agencies and individuals. This is a concern because inter-task data and idea sharing is required to accomplish the project's goals. Current costing was omitted and work completed was estimated at about 33% with the calendar at about 33%; so project looks on schedule and spending was not available to analyze.

Comments Regarding Strengths

Reviewer 5:
Good data.

Reviewer 37:
The concept of jointly inverting multiple datasets is a good one.

Reviewer 38:

Reviewer 18:
Improved geophysical imaging methods for characterizing subsurface structure, identifying fluid locations, and characterizing fractures are critical to the Geothermal Technologies Program mission. Some progress has been made but impact to the three sites seems negligible at this time. A logical, solid research plan was demonstrated. In fact, the joint inversion scheme was particularly well constructed with a normal integrated approach followed by a novel iterative approach. Also, the research team integrated double difference (DD) tomography with electromagnetic (EM) inversion using cross gradient constraint—a very good approach. The technical team is world-class and scientifically sound with of some of the very best leaders in their fields. Progress has been made in some of the planned tasks and results show promise. Project management and coordination does not seem to have any unresolved critical issues at this time, given the information presented and project looks on schedule.

Comments Regarding Weaknesses

Reviewer 5:
Don't care for the approach. See above.

Reviewer 37:
I'm not sure about how great the impact will be given some details of the ―joint" inversion method.

Reviewer 38:

Reviewer 18:
Determining the feasibility of jointly using data from microearthquake (MEQ) and electrical surveys to image the fluid distribution within geothermal systems might be of benefit to the Geothermal Technologies Program but magnetotellurics (MT) methods have notoriously been unable to resolve detailed features in the subsurface in the past. Therefore one needs to ask, ―What does MT bring to the problem solution? The impact to the three sites seems negligible. Details of the scientific and technical approach were not revealed in the information available to this reviewer and their choice of order of techniques was not supportable and, more disturbing, the unique parameter to ―pass" to the next technique was not known by the presenter. Results were shown but not described or interpreted. Hopefully, in year two the interpretation of these images will rise in priority and become the main focus, as it should be. It seems that not much communication has occurred or will occur in the future between researchers. The reported project coordination activities seem inadequate

given the sheer number of participating agencies and individuals. This is a concern regarding inter- task data and idea sharing that is required to accomplish the project's goals. Current costing was not given.

Suggestions for Improvement

Reviewer 5:
See above. Implement an actual joint inversion and use the gravity. It has far more direct physical tie to seismic velocity than does the electromagnetic (EM) data.

Reviewer 37:
Each of the datasets is governed by a differential equation having physical constants such as density for gravity, elastic constants for seismic, and conductivity for resistivity. It seems that a tie for each of these datasets could be made through the physical constants perhaps based on laboratory experiments. With this, a true joint inversion could be made rather than separate inversions and subsequent examination of their spatial correlations. I think a good direction for this project may be to compare and contrast the geophysical considerations involved with analysis of the three different fields. This may give a good overview of the variability to be expected with geothermal field monitoring.

Reviewer 38:

Reviewer 18:
Several issues need to be resolved by the Geothermal Technologies Program: 1) ―What does magnetotellurics (MT) bring to the problem solution and how will microearthquake (MEQ) data help MT resolution? 2) Impact of this work to the three sites needs to be the focus of year two, 3) More details concerning the scientific and technical approach need to be disclosed and reviewed by appropriate experts, 4) Choice of order of techniques and a scheme to ―pass" the unique parameters to the next technique, need to be explained and supporting arguments made and scientifically defended, 5) Results were shown but were not described nor interpreted—this needs to be remedied, 6) PI should be instructed to elucidate the details of the project management and coordination plan to the Program, and, finally, 7) Current costing numbers should be supplied to the Program

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0511
Presentation Title: Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems
Investigator: Majer, E. L. (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
Collection of microearthquake (MEQ) data is key to characterizing reservoirs and fracture systems. The goal of instrumenting and collecting and archiving data sets for this purpose is crucial to advancing EGS.

Reviewer 37:
The project is very relevant to the Geothermal Technologies Program goals. It will have high impact because the PI makes a great effort to reach out to the public and generously makes data available to all (which must be quite an effort). I am particularly impressed with the PI's efforts for public outreach and defining research directions. In my mind that makes this research project very impactful.

Reviewer 38:
Induced/micro seismicity is a popular new area of research and an area that people rely on for reservoir characterization and monitoring. Improvements in data are needed. This project seeks to enhance the quality of data collected and make it widely available. This should aid industry, the general public and interested stakeholders.

Reviewer 18:
The importance of microearthquake (MEQ) collection and advanced analysis at EGS and hydrothermal sites is increasing as R&D progress demonstrates that other techniques fail to provide the spatial and temporal resolution that MEQs naturally possess. More importantly, MEQs deliver insight and understanding about the location and time history of subsurface volumetric permeability enhancement,fluid movements and preferred pathways. In addition, they provide data to the operators for managing production and injection rates for reservoir model validation and optimization of reservoir performance and expansion planning. Just as important, if not more so, is that MEQs can provide a better understanding of the mechanisms of induced seismicity allowing accurate, performance-based risk assessments and providing science-based information to the public and regulators. This project provides the basis for MEQ monitoring at all Geothermal Technologies Program EGS sites by providing instrument installation, data collection, access and archival services. In addition, this project provides processing services such as: moment magnitude, locations, 3-D display, full waveform display, injection correlations, b-values, and at the Geysers only, double difference (DD) locations (cross- correlation), 3-D tomographic models, and advanced moment tensor inversions.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
The networks were installed as robustly as money allowed. More stations would be better - more is always better. The public access website is an excellent idea and will address the nonscientific but equally important issue of public education so that there is not a backlash out of ignorance. Data availability for other researchers, including waveforms cannot be overstated in its appropriateness and importance.

Reviewer 37:
This is quite an ambitious effort with the installation and fielding of the microearthquake (MEQ) networks at five different geothermal sites with additional sites added during injections. This is more of an operational approach to the problem, so the science may not be cutting edge but gets the job done. The technical approach is outstanding in terms of

installing networks and making data available. It looks like 3C 4.5 Hz geophones are used and it might be interesting to have some broadband data, but of course this would be expensive. It seems that the thought of borehole installations as suggested by the PI should be supported. I was going to try and get some data to test things out, but it takes a couple of days to get registered with NCEDC, so was not able to in time. However, I did check out the website and it is great for public outreach. It might be good to check out the number of hits on the website and number of data requests as a metric of success.

Reviewer 38:
The real time interpretation of MEQ is a worthy goal that may aid industry, if successful. Nice distribution of areas at a variety of sites (five sites, plus it looks like at least one more). I have a =similar comment for temporary monitoring during stimulation. The public outreach with access to real-time data is important and significant. Also, a national database is an important data aspect for this type of research. The project has a very broad and diffuse scope. This project was a bit difficult to review because it actually consisted of 10 smaller projects, nevertheless, the approach appears sound and well suited for achieving project goals and objectives.

Reviewer 18:
Details of the scientific and technical approach were not revealed in the information available to this reviewer but were presented in other projects that coordinate with this project. The research team presented a logical, solid project plan with state-of-the-art algorithms and techniques. The technical team is world-class and scientifically rigorous with the very best scientific leaders in microearthquake (MEQ) seismology at geothermal sites.

Comments Regarding Accomplishments, Results and Progress
Reviewer 5:
If Dixie Valley really has to wait 19,000 years for instruments, I hope they will be more technically advanced than today's equipment. Installations that do not involve typographical errors seem on track. Do processed locations include location uncertainties?

Reviewer 37:
The accomplishments, results and progress are impressive. The overall operations involved with the project probably impact the science a bit, but the participants are using good techniques for locating and studying microearthquakes (MEQs) from geothermal fields. I am also particularly impressed with the PI's efforts for public outreach and defining research directions. In my mind, that makes this research project very important.

Reviewer 38:
Good accomplishments at a wide range of sites. Good involvement of felt motion detectors to aid public and stakeholder perceptions of industry. This is important work for creating a baseline for publicly available data. The progress is good.

Reviewer 18:
Significant progress has been made in all of the planned tasks such as: 1) ~ 80 stations installed and operating microearthquake (MEQ) arrays at existing and potential EGS sites, 2) augment EGS sites with temporary instrumentation (34 stations) during injections, 3) data access and archiving, 4) data processing and analyses, 5) instrumentation upgrade and deployment, and 6) induced seismicity program support and participation. At this time results of all of these activities are or will be extremely impactful to the individual sites and their operators as well as the Geothermal Technologies Program.

Comments Regarding Project Management/Coordination
Reviewer 5:
All seems in process but on schedule.

Reviewer 37:

Reviewer 38:
Great range in collaboration and participants. Progress on milestones is appropriate relative to milestones. Project management must be difficult due to the wide range of sub-projects and different sites.

Reviewer 18:
The project management and coordination is outstanding and does not seem to have any unresolved critical issues at this time. Data archiving at NCEDC is behind schedule due to contractual issues. The reported project coordination activities are exemplary especially given the sheer number of participating companies, agencies and individuals. Current costing was 71% spent and work completed was estimated at about 50% with the calendar at about 50% (based on EGS demos completed); so project looks on schedule for the work performed and overspent with respect to schedule and work performed. Note: spending estimates are based on Geothermal Technologies Program funds only and do not include other funds because that data was not included. This needs to be resolved by the Program.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 5:
Really good project and good work so far. This is important - both the data access, preliminary analysis results, against which researchers in the future can compare their own advances, and data availability. This is crucial.

Reviewer 37:
This is quite an ambitious effort with the installation and fielding of the microearthquake (MEQ) networks at five different geothermal sites with additional sites added during injections. This is more of an operational approach to the problem, so the science may not be cutting edge but gets the job done. The effort of public outreach and setting geothermal research directions is excellent.

Reviewer 38:
The Geothermal Technologies Program needs to find ways to support and fund similar projects targeted at collecting high quality datasets.

Reviewer 18:
This project provides the basis for microearthquake (MEQ) monitoring at all Geothermal Technologies Program-funded EGS sites by providing instrument installation, data collection, access and archival services. In addition, this project provides processing services. The importance of this project, of MEQ collection and advanced analysis at EGS and hydrothermal sites for the Program cannot be overstated—it is essential to the Program‘s success,. Details of the scientific and technical approach were not revealed in the information available to this reviewer but were presented in other projects that coordinate with this project. The research team presented a logical, solid project plan with state-of-the-art algorithms and techniques. The technical team is world-class and scientifically rigorous with the very best scientific leaders in MEQ seismology at geothermal sites. Significant progress has been made in all of the planned tasks and at this time the results of all of these activities are or will be extremely impactful to the individual sites and their operators as well as the Program. Project management and coordination is outstanding and does not seem to have any unresolved critical issues at this time. Reported project coordination activities are exemplary especially given the sheer number of participating companies, agencies and individuals. The project looks on schedule for the work performed and overspent with respect to schedule and work performed.

Comments Regarding Strengths

Reviewer 5:

See above. All good.

Reviewer 37:

I am particularly impressed with the PI's efforts for public outreach and defining research directions. In my mind, that makes this research project very impactful. The PI is an excellent spokesman for the Geothermal Technologies Program.

Reviewer 38:

Reviewer 18:

The importance of this project and of microearthquake (MEQ) collection and advanced analysis at EGS and hydrothermal sites is essential to the success of the Geothermal Technologies Program. Details of the scientific and technical approach were presented in other projects that coordinate with this project and are exemplary. The research team presented a logical, solid project plan with state-of-the-art algorithms and techniques. The technical team is world-class and scientifically rigorous with the very best scientific leaders in MEQ seismology at geothermal sites. Significant progress has been made in all of the planned tasks and at this time results of all of these activities are or will be extremely impactful to the individual sites and their operators as well as GTP. Project management and coordination is outstanding and does not seem to have any unresolved critical issues at this time. Reported project coordination activities are exemplary especially given the sheer number of participating companies, agencies and individuals. Project looks on schedule for the work performed.

Comments Regarding Weaknesses

Reviewer 5:

Reviewer 37:

The overall operations involved with the project probably impact the science a bit, but the participants are using good techniques for locating and studying microearthquakes (MEQs) from geothermal fields.

Reviewer 38:

Reviewer 18:

Not many weaknesses to report upon.

Suggestions for Improvement

Reviewer 5:

Reviewer 37:

It looks like 3C 4.5 Hz geophones are used and it might be interesting to have some broad band data, but of course this would be expensive. It seems that the thought of borehole installations as suggested by the PI should be supported.

Reviewer 38:

Reviewer 18:

None.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0512
Presentation Title: Distributed Thermal Pertubation Sensing
Investigator: Freifeld, Barry (Lawrence Berkeley National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 5:
I have absolutely no expertise in this arena - thermal sensing and hardware - so my opinions probably don't count for much. But the tools as described sound like a significantly advanced and very useful.

Reviewer 37:
This is not my field of research, but the project seems very relevant to the Geothermal Technologies Program monitoring goals.

Reviewer 38:
This technology may add an important new tool to the geothermal tool box. It leverages a great body of research towards addressing an EGS problem.

Reviewer 18:
A fluid imaging technology would certainly advance the Geothermal Technologies Program mission. Thermal profiles can be used to image fluids but an interpretation step (model) is needed. The Distributed Thermal Perturbation Sensor (DTPS) is basically a continuously reading temperature depth profiler with a heating cable nearby. However, DTPS is the basic design of ocean heat flow probes that have been used for decades but now on land and over the entire borehole. The software needed to interpret these profiles is an application/modification of TOUGH2/ITOUGH2, though details of this part of the project were not given. Also, they extended the temperature range of this device to operate at up to 240°C and they plan to extend that further to 350°C for the remainder of the project.

Comments Regarding Scientific/Technical Approach

Reviewer 5:
Looks like the technical (manufacturing/engineering) approach was successful and the tool provides a significant advance over previous methods. Coming from an inexpert reviewer, that is.

Reviewer 37:
The approach is excellent in that it is piggybacking on other projects making an otherwise very expensive project inexpensive.

Reviewer 38:
A rather simple technology that appears to actually work! Distributed Thermal Perturbation Sensor (DTPS) has been used successfully in other places, but need to overcome harsh environment for use in geothermal industry. The research team appears to have selected an appropriate and focused approach.

Reviewer 18:
The scientific and technical approach for extending the cable operating temperature range is straightforward but is not R&D. The development of a model to interpret these temperature v. depth (T-D_ profiles is R&D and was not discussed sufficiently to assess.

Comments Regarding Accomplishments, Results and Progress

Reviewer 5:
Looks like a good and solid/robust tool has been developed that can withstand the hostile conditions and be deployed easily, seems to function well.

Reviewer 37:

Reviewer 38:
Cable development seems to be coming along nicely in accordance to budget and schedule. There is a good combination of research and field testing. Parameter estimation uncertainty analysis looks promising.

Reviewer 18:
Progress has been made in executing the project plan regarding the cable but task #2, development of a numerical method for analysis of the Distributed Thermal Perturbation Sensor (DTPS) data for flow profile imaging and in situ determination of thermal conductivity profiles and heat flux is still not done. They assert that results from a carbon sequestration demonstration will be leveraged to complete this task. Details of the task were missing.

Comments Regarding Project Management/Coordination

Reviewer 5:
On track, on budget (small budget!)

Reviewer 37:

Reviewer 38:
Good project management for level of funding and scope of the project. Nice use of leveraged funds to support field deployment.

Reviewer 18:
Given the information presented project management and coordination does not seem to have any unresolved critical issues at this time. Current costing is 42% spent and work is about 50% complete with the calendar at about 50%; so project looks on schedule and a little under spending.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 5:
This looks like a well-done project. I'm afraid my insights were extremely limited due to this being outside my field of expertise, but I'm convinced, based on the presentation, that the work has been successful.

Reviewer 37:
It was difficult for me to give a useful evaluation of this project, but it appears to be going well.

Reviewer 38:
This project is progressing appropriately.

Reviewer 18:
Thermal profiles could be used to image fluids but an interpretation step (model) is needed. The Distributed Thermal Perturbation Sensor (DTPS) is basically a continuously reading temperature depth profiler with a heating cable nearby, which is an extension of the ocean heat flow probe technique, also the needle probe technique, to land over a much greater depth range. The innovation is in the interpretation technique, which was not discussed in enough detail to evaluate. However, a fluid imaging technology would certainly advance the Geothermal Technologies Program mission, The scientific and technical approach for extending the cable operating temperature range is straightforward but is not R&D. The development of a model to interpret these temperature v. depth (T-D) profiles is R&D and was not discussed sufficiently to assess. Progress has been made in executing the project plan regarding the cable but task #2, development of a numerical method for analysis of DTPS data for flow profile imaging and in situ determination of thermal conductivity profiles and heat flux is still not done. Given the information presented project management and coordination does not seem to have any unresolved critical issues at this time. Current costing is 42% spent and work is about 50% complete with the calendar at about 50%; so project looks on schedule and a little under spending.

Comments Regarding Strengths
Reviewer 5:

Reviewer 37:
Inexpensive for the amount of and type of work being performed.

Reviewer 38:

Reviewer 18:
Progress has been made in executing the project plan regarding the cable operating temperature range extension to 240°C.

Comments Regarding Weaknesses
Reviewer 5:

Reviewer 37:

Reviewer 38:

Reviewer 18:
Only weakness was a lack of progress on the interpretation technique. This is the most innovative part of the project and it needs to be addressed.

Suggestions for Improvement
Reviewer 5:

Reviewer 37:

Reviewer 38:

Reviewer 18:
It is suggested that a more detailed presentation concerning the interpretation technique be requested by the Geothermal Technologies Program for this project.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Specialized Materials and Geopolymer Sealing Materials

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0600
Presentation Title: Geopolymer Sealing Materials
Investigator: Butcher, Thomas (Brookhaven National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 84:

The project is clearly very relevant. The economic impact will be substantial. Understanding and knowledge of the underlying materials science and engineering of sealing, self-degrading cements will be greatly advanced. And the researchers discuss environmental considerations and potential improvements in this area. However, the environmental impact (such as carbon dioxide, CO_2, reductions) of different approaches was not specifically analyzed. If it is going to be listed as an impact, a clearer evaluation of the relative costs and benefits would be appropriate to include.

Reviewer 83:

The topic of developing a geopolymer sealing material is opportune – not just for down-hole drilling, but also in other applications such as in the nuclear industry. This research, if successful, has the potential of drastically reducing the costs associated with the drilling process. Moreover, this research could be the catalyst for developing other self-degradable cementious materials.

Reviewer 11:

This project addresses two critical needs—better cementing and zonal isolation materials. It is also an interesting use of industrial byproduct material. However, it is not clear whether that inherently leads to reduced cost.

Reviewer 61:

The reviewer doesn‘t understand how these materials can be used for well casing cement if they self-degrade when exposed to water. Wouldn't this make any leaks in the well casing considerably worse if not well controlled? Also, the reviewer doubts the economic claims that these materials will be cheaper than existing cement. It seems that the only argument supporting this is the fact that the starting material is a byproduct. Is that the major cost driver for current cement costs? New Comments: It would be preferable to see the cost analysis that they have done. The reviewer suspects that this is just a back of the envelope calculation done at the lab. Since there are industrial partners, the reviewer would prefer to see some more rigorous analysis showing that this process actually reduces the cost of the materials. The reviewer is not convinced right now.

Reviewer 80:

The ability to achieve the goals would be good to support DOE‘s mission.

Reviewer 62:

The progress and impact of this research appears sufficient within the scope of work and project timeline.

Comments Regarding Scientific/Technical Approach

Reviewer 84:

Judging by the success of the project—the technology has already been transferred to industry—the scientific and technical approach was clearly effective.

Reviewer 83:
The technical approach seems sound. There is one aspect of the technical approach that is of concern. The PI has decided to look at specific cement formulations to apply the geopolymer material. Based on experience in other industries, the pedigree (or formulation) of the cement used by different manufacturers may not be the same. Therefore, it is of concern that the cement formulations that the PI has decided to focus on may not encompass the majority of cement systems observed in the field. The PI was not very clear on this question during the peer review. This may have been because of proprietary issues surrounding the geopolymer itself.

Reviewer 11:
The approach is appropriate to the stated goals of the statement of work. All laboratory work is complete or near completion for formulation and analysis of sealing and self-degradation. It is not clear where work stands regarding formulating and analysis for cementing.

Reviewer 61:
New Comments: How much long-term stability is needed? The reviewer is still concerned about preventing water from the environment from changing the long-term stability of this process. Perhaps the reviewer is missing it, but it seems like this needs to be addressed if a major environmental component can catalyze the fracturing.

Reviewer 80:
The technical strategy—the ―why‖ for choosing the system—was not articulated. The technical strategy involved a "make and test" approach but no focused strategy as to why different additives were added and what results were anticipated. This presentation/project would be stronger if an overarching framework for strategy were presented/taken.

Reviewer 62:
More of the scientific reasoning and motivation for choosing the selected additives and percentages prior to optimization to achieve the desired material criteria may have been useful background.

Comments Regarding Accomplishments, Results and Progress

Reviewer 84:
The project has been successful to date. They have also disseminated their work in the form of publications and presentations.

Reviewer 83:
The PI has made good progress in the development of the geopolymer sealer material. The project seems to be on track and the PI has published results of the work conducted.

Reviewer 11:
Much progress has been made in the laboratory, but field trial results would be needed soon to establish the overall value of this work.

Reviewer 61:
What is the rationale behind the proposed mechanism for self-degradation? Is it based off of the DSC? If so, it seems unclear how this level of detail was reached. Normally, that wouldn't be a concern, but there is a lot of acid-base chemistry being thrown around here. The reviewer worries about the in-situ CO2 and NaOH that might be produced as a result of this mechanism. New Comments: The presentation clarified why geopolymer prevents self-degradation. The reviewer is less concerned about byproducts now.

Reviewer 80:
The results presented were sufficient for this stage of the project. The presenter stated that the benefit of the MgO was

expansion of the material. This project would be stronger if expansion of the material had been measured directly.

Reviewer 62:
Further characterization via electron microscopy or other means might be useful to show differences and visualization of self-degradation at a micro level.

Comments Regarding Project Management/Coordination
Reviewer 84:
Judging by the success of the project up to this point, it is highly likely that there is an effective management structure in place.

Reviewer 83:
Project management appears to be on schedule. In addition, the PI appears to have leveraged the BNL cost-share effectively in the completion of other aspects of the project.

Reviewer 11:
Project management is good on this project. There is a stated need to secure a cement researcher. Good industrial connections have been made. The reviewer is pleased to see that this work is being transition to an established industrial partner for field evaluation.

Reviewer 61:
It is good to see industrial partners involved. The reviewer is interested in Halliburton's upcoming work.

Reviewer 80:
The presentation did not identify go/no-go decision points. This is a significant weakness to this reviewer. The requirements were well identified. The DSC was ok but degradation would be better measured by measuring weight versus temperature, particularly since the byproducts were stated as volatile species. DSC will also measure glass transitions and melting temperatures. One needs complementary data to validate the interpretation of the data.

Reviewer 62:
Additional details on the coordination with industry and stakeholders would be useful to evaluate effectiveness.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 84:
The project objectives are to develop and characterize self-degradable temporary cementious sealing materials for fractures in enhanced geothermal system (EGS) wells, and then transfer the technology to drilling companies. The team has successfully achieved the project objectives—the sealing materials met all technical criteria and were formulated, and the technology was transferred for independent evaluation and modification for in-the-field to AltraRock Energy and Halliburton. Further research is under investigation.

Reviewer 83:
Overall, the project is very timely and could have a significant effect on the development of geopolymer sealing materials for cement systems.

Reviewer 11:
This is an interesting project that addresses critical needs in the geothermal industry. Actual validation of costs would be

valuable to communicate to the industry. The reviewer would encourage further work in this area, and is particularly interested in seeing further work on cementing.

Reviewer 61:
From an applied technology perspective, this project seems to be right on track. The reviewer is not an expert in drilling or geothermal technologies, which makes a detailed analysis difficult. Also, the reviewer is unclear about the economic benefits of this material over traditional cement well-casings. That may be due to a lack of information. However, from a chemistry perspective, it is unclear how the investigators reached their conclusions about the degradation mechanisms. The reviewer is a bit concerned about the byproducts contaminating the water sources or being vented.

Reviewer 80:

Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a scientific/technical standpoint.

Comments Regarding Strengths
Reviewer 84:
In addition to strengths listed above, the project team is a collaboration of many industrial partners in addition to SNL.

Reviewer 83:
The development of the polymer appears to be in a mature state and is being applied to particular cement systems.

Reviewer 11:
This project has a good technical team with a well thought-out statement of work and good collaborations with industrial partners.

Reviewer 61:

Reviewer 80:

Reviewer 62:
This project includes an overall realistic timeframe and proposal.

Comments Regarding Weaknesses
Reviewer 84:
Some parts of the presentation itself were difficult to follow.

Reviewer 83:
Due to possible proprietary issues, there is concern that the selected cement systems in which the geopolymer sealer material is to be applied may not encompass the breadth of cement systems in the field.

Reviewer 11:
Currently there is a lack of reported field trial data.

Reviewer 61:

Reviewer 80:

Reviewer 62:
Additional details on the coordination with industry and stakeholders would be useful to evaluate effectiveness.

Suggestions for Improvement
Reviewer 84:
The reviewer has no suggestions for improvement.
Reviewer 83:

Reviewer 11:
Further work on field trial validation is needed as well as further evaluation of cementing capability.

Reviewer 61:

Reviewer 80:

Reviewer 62:
Experiments identifying effectiveness of sealing are needed to fully assess achievement.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0601
Presentation Title: High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells
Investigator: Fabian, Paul (Composite Technology Development, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 84:
The reviewer cannot accurately assess the relevance/impact given how much of the project is proprietary. There was very little technical information conveyed in the presentation because of its proprietary nature. The project seems relevant, and if successful, it will likely have a notable impact.

Reviewer 83:
This project is developing a rather resourceful technology to provide zonal isolation within piping systems. This project will fill the research gap that exists in reliable zonal isolation systems for geothermal applications.

Reviewer 11:
This is an important and innovative approach to zonal isolation. Concept feasibility has been demonstrated, however, much validation work needs to be completed.

Reviewer 61:
This is an interesting technology. It is nice to see an approach that gives more controllable fracking and an increasing ability to test individual fractures. It will be nice to see this applied to other technologies as well. New comments:

Reviewer 80:
The project is relevant to the program goals.

Reviewer 62:

Comments Regarding Scientific/Technical Approach

Reviewer 84:
The reviewer cannot accurately assess the scientific/technical approach given how much of the project is proprietary. There was very little technical information conveyed in the presentation because of its proprietary nature. One comment is that the lab set-up is not realistic of the down-hole conditions, and it was not clear after the question and answer (Q&A) session after the presentation how much of the results/work using the lab set-up would be transferable to the more realistic temperature and pressure ranges.

Reviewer 83:
The scientific/technical approach is fair. There is a bit of concern with only one length of piping that has been used as a proof-of-principle for this technique. Other in-bore materials besides granite should be tested to insure that the expanding material can create a functional seal within the conduit/pipe. Also, since the trigger solution is not environmentally friendly, there is concern about damage that the solution will have on the environment as well as to the effectiveness of the reclamation process for the trigger material. It would be nice if there was a task to develop an eco-friendly trigger solution, if at all possible.

Reviewer 11:
The project is focused and oriented towards achieving well defined laboratory results. It is difficult to understand the probability of success because of the proprietary nature of the materials being evaluated.

Reviewer 61:
This project has a clever approach. What is the size of the capsules? It seems like there will be a mass flow challenge here. The first capsules that interact with the chemical solution are the farthest from the capture screen. Once they react and create a seal, how will the others interact with the chemical solution?

Reviewer 80:
The challenges and requirements are well articulated. A technical strategy for the material development was not presented. The talk did not review what polymers were considered and why. Nor was a strategy presented as to what governs the choice of specific polymer. The HOW was presented adequately; however, the WHAT was not. Perhaps if this project has intellectual property (IP) issues regarding sharing the specific polymer system, this presentation may be premature. The way this is presented is too vague to accurately review the technical merit of the work. This is the justification for low marks, however, the PI/project should not suffer without a thorough review performed in a manner that protects the company's IP.

Reviewer 62:

Comments Regarding Accomplishments, Results and Progress
Reviewer 84:
Given the goal is to "Design, demonstrate, and qualify high-temperature high pressure zonal isolation devices compatible with the high temperature downhole Enhanced Geothermal Systems (EGS) environment," it seems as though the progress of the project is lacking. The demonstrations at this point are still at laboratory temperatures and pressures, not high-temperature or high-pressure conditions. Given that the project is already 45% complete, the reviewer wonders how much further toward the project objective the PIs will be able to get.

Reviewer 83:
The PI has done a good job in showing that the proposed material can expand to seal conduits. It remains to be seen if the material has the appropriate stiffness to resist high temperatures and pressures.

Reviewer 11:
Roughly half of the funds have been spent which is in line with approximately half of the work being completed. Again, because of the proprietary nature of the materials work it is difficult to assess how much difficulty will be encountered in the second phase of work which is targeted at high-pressure and high-temperature evaluation. There is a concern that the set-up for testing is unable to currently achieve realistic temperatures and pressures.

Reviewer 61:
The reviewer has no doubt that they can create materials that will expand as they predict, but the design of the system downhole will be challenging. The reviewer is not terribly impressed with the proof-of-concept for the trigger. Rather than placing it in a beaker, it should be exposing the material to the bottom side of a cylinder. Perhaps this is being shown on Slide 10, but that information is very unclear to the reviewer. New comments: The demonstration on Slide 11 is very helpful. Would like to know the time elapsed, pressure build-up and any temperature increase from the reaction with the chemical trigger.

Reviewer 80:
Detailed data is not sufficiently provided to adequately support the claimed result. If this is proprietary then they should get their IP protected and then present. This limitation in the talk does the project a significant disservice.

Reviewer 62:
It is difficult to fully assess this project without knowledge of the proprietary information.

Comments Regarding Project Management/Coordination

Reviewer 84:
The project seems decently managed and structured, although very significant challenges remain to be addressed in the second year.

Reviewer 83:
Since this project has been front-loaded heavily, e.g. 50% of funds have already been spent, there is a bit of concern if the PI will have enough funding left to cover the field testing as well as the desired material iterations.

Reviewer 11:
Project management and coordination appears to be adequate. There are important national laboratory and commercial participants in the project.

Reviewer 61:

Reviewer 80:
The talk did not specifically cite any go/no-go decisions points. For such high risk in developing materials for these requirements the project would be stronger with specific stage gates.

Reviewer 62:
More details on this would have been useful.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 84:
The project aims to design, demonstrate, and qualify high-temperature, high-pressure zonal isolation devices compatible with the high-temperature downhole EGS environment. They have made progress toward this goal by working toward identifying high-temperature, high-pressure sealing materials to utilize in a wellbore system device. There are many remaining challenges for Year 2, and likely beyond.

Reviewer 83:
Overall, the project is very innovative by taking a relatively simple idea and applying it to such a complex task. It still remains to be seen if the material will be able to withstand the rigorous high temperatures and pressures that will be seen in the field. Furthermore, the trigger solution is not environmentally friendly, which means that the reclamation process for the trigger solution needs to be robust.

Reviewer 11:
This is a potentially strong project. The proprietary nature of the materials being evaluated makes it difficult to assess the overall probability of success.

Reviewer 61:
The reviewer would like to see more information on the system design. The chemistry is straightforward here, but the mass transfer (and likely any heat transfer as well) will be very difficult to get right. It is concerning that they haven't addressed this and have already spent more than half of their funds. New Comments: the reviewer is less concerned about system design after the presentation, but would like to see quantitative data.

Reviewer 80:
The presentation did not provide sufficient detailed technical information and this severely hinders an adequate evaluation of the work. The speaker claims innovation, but there is no data providing evidence of this claim. The way this is presented is too vague to accurately review the technical merit of the work. This is the justification for low marks, however, the PI/project should not suffer without a thorough review performed in a manner that protects the company's IP.
Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a scientific/technical standpoint.

Comments Regarding Strengths
Reviewer 84:
The project has partnered with appropriate companies from industry and the national laboratories.

Reviewer 83:
The use of an expandable foam-like material to effectively seal a section of piping is clever and has the potential to be very effective.

Reviewer 11:
The innovative approach and a strong project team make this a potentially important project.

Reviewer 61:

Reviewer 80:

Reviewer 62:
Interesting design approach

Comments Regarding Weaknesses
Reviewer 84:
Again, it is difficult to comment on weakness given how much was proprietary. One concern mentioned above is that it was not clear how useful the Year1 activities will be for meeting the Year 2 objects, given how different the operating conditions are between the lab demonstration and downhole environment.

Reviewer 83:
The trigger solution is not environmentally friendly which could pose a significant problem if the solution is not handled effectively.

Reviewer 11:
Lack of testing data at elevated temperature and pressure is a concern. Also, there is a concern about when actual field testing will occur.

Reviewer 61:

Reviewer 80:
If the materials are proprietary then the merit review venue does not work for this project. One has to respect the IP issues and protect the company rights, however, perhaps a different venue with non-disclosure agreements (NDAs) signed would be a better way to review this work.

Reviewer 62:
No project summary was included.

Suggestions for Improvement
Reviewer 84:
It is difficult to comment on weakness given how much was proprietary.

Reviewer 83:

Reviewer 11:
Perhaps Sandia National Laboratories should take a more active role in designing a test set-up for elevated temperature and pressure.

Reviewer 61:
More quantitative data are needed for future program reviews. Overall, the presentation helped clarify quite a bit.

Reviewer 80:
See above.

Reviewer 62:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0602
Presentation Title: Temporary Bridging Agents for Use in Drilling and Completion of Engineered Geothermal Systems
Investigator: Watters, Larry (CSI Technologies, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 84:
The project will have a huge impact on the broader geothermal program mission and goals.

Reviewer 83:
The project has the potential of developing innovative materials to temporarily seal fractures during the drilling of enhanced geothermal system (EGS) wells. Due to the proprietary nature of the project, not much specific data was presented during the presentation.

Reviewer 11:
The project is 85% complete although there is a 9-month extension. The team has achieved a number of important milestones already.

Reviewer 61:
The inability to make multiple fractures is certainly a major issue. This could be very high impact. New Comments: What do these materials degrade to? It would be best to see that they limit the materials testing to ones that are environmentally friendly. Otherwise, there is over what is used in a commercial space (think fracking fluid and water contamination).

Reviewer 80:
This work is relevant to DOE's mission and objectives.

Reviewer 62:
This was well presented.

Comments Regarding Scientific/Technical Approach
Reviewer 84:
It was difficult to evaluate the scientific and technical approach given that a significant portion of the project could not be presented because it is proprietary. Generally, the approach seems reasonable.

Reviewer 83:
The scientific/technical approach is fair. One variable that needs to be addressed is the effect of particle size on the efficiency of the sealant. Moreover, the PI did not effectively communicate the methods in which the mechanical properties of the materials will be determined. This latter fact may be due to the proprietary nature of the project.

Reviewer 11:
The team has an excellent understanding of zonal isolation issues and has followed an approach that has yielded a number of candidates. Disclosure of the materials being evaluated is very useful in assessing the probability of success. The completed field testing is a major milestone.

Reviewer 61:

Fair progress so far, but would like to see a bit more since it has been more than a year. New Comments:

Reviewer 80:
Requirements and challenges are articulated well. The technical strategy to identify candidate materials is not presented. Is this work also proprietary? If so, the venue may not be appropriate at this stage.

Reviewer 62:

Comments Regarding Accomplishments, Results and Progress

Reviewer 84:
It was difficult to evaluate the progress given that a significant portion of the project could not be presented because it is proprietary. Given the project is 85% complete, it appears as though a commensurate number of milestones have been achieved.

Reviewer 83:
There has been successful diversion of flows using some of the proposed materials. Although not well explained, the PI is developing some methods to test the mechanical properties of the material. If properly done, this test should help in the down-selection of the appropriate candidate material.

Reviewer 11:
This project has excellent focus on achieving results. Quality data on characterization degradation of the materials was presented.

Reviewer 61:
The results in Figure 1 are confusing. Wouldn't there be more space between larger particles, making diversion effectiveness decrease with increase in PSD? Maybe this is more of a function of the particle shape or the particle packing? Has this analysis been done? New Comments: Wow. The data presented in Figure 1 was somewhat misleading. They didn't show the distribution of particle size or the distribution of particle shape. This would have clarified a lot. It's unfortunate that it wasn't included here.

Reviewer 80:
Detailed data were not presented, possibly due to the proprietary nature of the work. The fact that field tests are complete shows good focus on meeting the project/market/use requirements. Again, the rating would be higher if more detailed information could be provided.

Reviewer 62:
It is difficult to fully assess due to the proprietary nature of the results.

Comments Regarding Project Management/Coordination

Reviewer 84:
The project appears to be effectively managed, given the progress of the project to date. The reviewer is unsure why there was a 9-month extension, but that may not necessarily have been a management issue.

Reviewer 83:
A project completion of 85% would suggest that a suitable candidate would have already been identified and tested. This is not the case. There is a concern that there will not be enough funding remaining to thoroughly test the candidates, identify a suitable candidate, and perform the appropriate iterations to make the candidate material robust enough to handle the task required of the material.

Reviewer 11:

Excellent project management and coordination has been demonstrated. Working with AltaRock to do the field testing is a major milestone. Also, the plan to transition the technology to AltaRock for commercialization is a strong point of this project.

Reviewer 61:

Reviewer 80:
Project management seems effective and matching cost is excellent.

Reviewer 62:

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 84:
The project objective is to develop materials or systems that bridge to seal or divert flow from fractures existing while drilling EGS wells and that eventually decompose. The development of the bridging agents will enable a higher level of production of energy from EGS wells. The project is currently 85% complete, and many milestones have already been achieved.

Reviewer 83:
Overall, the project could have a significant effect on the development of bridging agent sealant materials. However, due to the proprietary nature of this task, it is rather hard to effectively evaluate the materials used in this project.

Reviewer 11:
This is very good project showing focus on quality results and transitioning the technology to commercialization.

Reviewer 61:
It is good to see field tests by Altarock. The data presented here was very confusing and somewhat misleading. The reviewer would strongly encourage people to show data that is clearer during later reviews. Also, the exact tests that are being done for pressure, temperature and mechanical properties are unclear. This makes it difficult for reviewers to assess the effectiveness of the data.

Reviewer 80:
This presentation does not come across well with such vague information. If this is due to the proprietary nature of the materials, perhaps the venue does not work for this type of project.

Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a scientific/technical standpoint.

Comments Regarding Strengths
Reviewer 84:
It was difficult to evaluate the project strengths given that a significant portion of the project could not be presented because it is proprietary. Clearly the reviewers do not have a complete picture.

Reviewer 83:
The material's ability to seal existing fractures and to re-direct the flow of water is impressive.

Reviewer 11:
This project has high quality data generation as well as excellent coordination with AltaRock.
Reviewer 61:

Reviewer 80:

Reviewer 62:
This project has an interesting design approach.

Comments Regarding Weaknesses
Reviewer 84:
The project is 85% complete, but there are no publications or presentations. The reviewer recognizes that much of the information is proprietary, but the project could potentially benefit from greater interactions with the scientific community.

Reviewer 83:
There may not be adequate funding remaining to effectively select, characterize and optimize a material needed to accomplish this task.

Reviewer 11:
No particular weakness was identified.

Reviewer 61:

Reviewer 80:

Reviewer 62:
Further details of material composition and characterization are needed to fully evaluate this project.

Suggestions for Improvement
Reviewer 84:
The reviewer has no suggestions for improvement.

Reviewer 83:

Reviewer 11:
Continue to identify materials that are environmentally sound.

Reviewer 61:

Reviewer 80:
Have a closed review with NDAs to effectively review these types of projects.

Reviewer 62:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0603
Presentation Title: Development of an Improved Cement for Geothermal Wells
Investigator: Trabits, George (Trabits Group, LLC)

Comments Regarding Relevance/Impact of Research
Reviewer 84:
The project will have a positive impact and is relevant to the Geothermal Technologies Program mission and goals. It will also address knowledge gaps and barriers.

Reviewer 83:
This project is highly significant in that it is developing cement mixtures that could greatly reduce production time and increase efficiency in constructing geothermal wells. The project will greatly expand the technical knowledge on zeolite-based cement systems.

Reviewer 11:
This is the only project focused on cementing. Cementing is an extremely important technology area for geothermal. The project is only 30% complete.

Reviewer 61:
In the end, will this cement be cheaper than (or as cheap as) existing cements? If not, the reviewer doesn‘t see this project being implemented at scale. The reviewer is surprised that the project team would use zeolites for a wide range of temperature. They are often not the most stable materials across temperatures because they are likely to undergo physisorption. What is the long-term stability? New comments: The questions post presentation made the role of water in this technology much clearer to the reviewer. It would be very useful for this information to be included in the presentation.

Reviewer 80:
This project is relevant to DOE's mission/goal.

Reviewer 62:

Comments Regarding Scientific/Technical Approach
Reviewer 84:
The scientific and technical approach appear rigorous.

Reviewer 83:
The scientific/technical approach is very well thought out as well as proactive. For instance, storing extra zeolite compounds for future study shows great forethought for future needs. Moreover, the use of XRD, XRF and SEM analysis for characterization of the materials candidates is impressive.

Reviewer 11:
Approach is excellent. Team has a lot of experience in cement issues and is particularly knowledgeable about geothermal issues.

Reviewer 61:

Approach seems reasonable for the goal at hand. From a materials perspective, it is still unclear to the reviewer why zeolites are going to make an improved cement at higher temperatures. New Comments: There were a lot of things that needed to be clarified about the technology for the reviewers. That meant that there was little time for more rigorous questioning.

Reviewer 80:
Excellent articulation of technical and operational requirements. The technical strategy is well articulated too—building on the zeolite body of knowledge. Selection of candidates for testing follows a logical path with go/no-go decisions. Volumes that address commercial scale are identified as key issues too.

Reviewer 62:
More data would be useful to fully evaluate this project.

Comments Regarding Accomplishments, Results and Progress
Reviewer 84:
The project is on track.

Reviewer 83:
The PI has made significant accomplishments by conducting XRD/XRF/SEM analysis as well as preparing cement mixtures of varying particle sizes. This effort has shown high productivity which, if continued, should lead to the successful completion of this project.

Reviewer 11:
Good results have been achieved so far. However, there appears to be a lot of work left to be done.

Reviewer 61:
They have accomplished a lot in the first year. While the reviewer is skeptical about the viability of the project, they are on track to be able to answer his questions in Year 2. New comments: The reviewer appreciates the choice of zeolites that are available at a scale that can be commercialized. How geographically dispersed are the resources? Are the costs associated with solids handling considered in an economic analysis? It would be useful to have that information. The reviewer is surprised that the literature review was one of the major tasks. This should have been done before the research started.

Reviewer 80:
The plan is well thought out and risk mitigation was addressed—for example, the volume of zeolite up front. The literature review ensures understanding the current state of the art. The execution of the project includes appropriate characterization at logical stages of the project—for example SEM, XRD and XRF of starting material zeolite. This careful groundwork ensures that the researchers know what they are working with.

Reviewer 62:
Additional experimental results are needed to fully evaluate the analysis of materials.

Comments Regarding Project Management/Coordination
Reviewer 84:
The project appears well structured and coordinated. Furthermore, up to now, concrete steps (excuse the joke) have been made toward realizing the project goals, supporting that there is effective management in place. They also effectively dealt with the challenge of discovering their Analcime sample wasn't zeolite, and changed direction accordingly. The reviewer wonders if on-site materials characterization or a two-step small-sample then large-sample material collection process would have prevented the acquisition of non-zeolytic material.

Reviewer 83:
The project appears to have a very straightforward and deliberate process. There are various stage-gates within the task that must be accomplished before the next phase can be accomplished. The remaining funding levels seem to be appropriate to accomplish this task.

Reviewer 11:
An excellent team has been assembled by the project leader. One concern is that the loss of one of the important participants early may have delayed progress on the project. The team does appear to be making significant progress since that setback.

Reviewer 61:

Reviewer 80:
The project team has shown excellent planning, go/no-go stages and risk mitigation. A literature review of the state of understanding ensures that prior problems will not be repeated—good risk mitigation. There has been excellent industry and academic involvement. Variability in starting material and its impact on product performance is well identified and an issue that is important to understand well.

Reviewer 62:
Initial subawardee was unable to participant and adjustments were made accordingly.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 84:
The project aim is to develop a novel, zeolite-containing lightweight, high-temperature, high-pressure geothermal cement, which will provide operators with an easy to use, flexible cementing system that saves time and simplifies logistics. Significant steps have been made, commensurate with the duration of the project to date. Challenges remain, but the team is on track to address them.

Reviewer 83:
Overall, the project is very well conceived and will increase the knowledge of zeolite-based cement structures for geothermal applications.

Reviewer 11:
This is a very important project with plenty of industrial support.

Reviewer 61:
It was nice to see the PI of the project present. This was the fourth presentation of the session and the first PI that we saw speak.

Reviewer 80:
This project has demonstrated excellent planning and execution to date.

Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a

scientific/technical standpoint.

Comments Regarding Strengths

Reviewer 84:
The project is on schedule, well managed, and has a clear and concise plan forward.

Reviewer 83:
The systematic evaluation of zeolite-based cement systems may lead to improved processes in the construction of geothermal wells.

Reviewer 11:
The team has a very good understanding of all of the technical issues as well as a very strong industrial support team.

Reviewer 61:

Reviewer 80:
Keep up the great work.

Reviewer 62:
The project has a well laid-out technical approach.

Comments Regarding Weaknesses

Reviewer 84:

Reviewer 83:
One potential weakness is that the candidate materials may not effectively cover the spectrum of zeolite-containing systems that exist in the United States.

Reviewer 11:
There is concern about the level of progress to date toward the overall goals given the amount of time left on the project.

Reviewer 61:

Reviewer 80:
None noted.

Reviewer 62:
While literature review is important, it should occur quickly and concurrent to data collection since end results can affect actual materials obtained.

Suggestions for Improvement

Reviewer 84:
The reviewer does not have suggestions for improvement.

Reviewer 83:

Reviewer 11:
Accelerate the initial screening of the formulations in order to complete the second stage of cement development on time. Perhaps it is time to narrow the field of candidates.

Reviewer 61:

Reviewer 80:

Reviewer 62:
See weaknesses.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0604
Presentation Title: Evaluation of Thermal Spray Coatings as Pressure Seals
Investigator: Henfling, Joe (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research
Reviewer 84:
The project is clearly in line with the overall goals of the Geothermal Technologies Program and will have a significant impact.

Reviewer 83:
This project has the potential to develop innovative thermal metal spray coatings to be used as seals on high-temperature tools. This coating will be a redundant seal to ensure the integrity of the tool. This coating could revolutionize seals not only in geothermal applications, but other applications that require seals in high-temperature, high-pressure environments.

Reviewer 11:
This is a good alternative approach to elastomer seals. This project has made a lot of progress.

Reviewer 61:
Thermal sprays are clearly one of the most necessary developments for any high-temperature or high-pressure technologies. It is good to see flexibility between materials/processes. A lot of consideration of field work was taken here.

Reviewer 80:
This topic is relevant to DOE's goals.

Reviewer 62:
This is a novel route for the end result.

Comments Regarding Scientific/Technical Approach
Reviewer 84:
A significant portion of the project was not presented due to its proprietary nature. Suffice it to say, it is impossible to accurately assess the scientific and technical approach.

Reviewer 83:
The technical approach conducted by the PI is sound and logical. By evaluating the coating techniques, the PI is on the right track of determining the best coating approach for the materials.

Reviewer 11:
The project was impacted by safety issues at the laboratory, but good focus on achieving results was followed through to enlisting Thermal Spray Solutions to complete the work. Excellence progress has been achieved on this project given such a small budget.

Reviewer 61:
The reviewer wonders if the different thermal spray processes have the potential to be economically viable. The reviewer honestly doesn‘t know the answer, but it would be nice to see it addressed. New comments: Glad to hear that the thermal expansion was considered in the allow selection.

Reviewer 80:
The technical strategy for the choice of candidate materials and means of deposition is not articulated. The justification is that Sandia has experience in these processes –a nice fact, but does not articulate a strong technical justification. This appears to be a survey of different means of deposition. Go/no-go decisions were not identified. Requirements were not articulated in great detail.

Reviewer 62:
The presentation of the project was laid out nicely.

Comments Regarding Accomplishments, Results and Progress
Reviewer 84:
The project appears to be progressing, with modest delays.

Reviewer 83:
The PI has done a good job in evaluating different spray coating techniques and evaluating the properties of the various coatings. The PI has also identified a major factor (porosity) which will affect the performance of the thermal spray coatings. Moreover, this factor may be the driver which will identify the best coating for this application.

Reviewer 11:
Mock tools have been tested at elevated temperature.

Reviewer 61:
There has been fairly good progress so far given their delays. New comments: The reviewer is not terribly concerned with the coating failure. It is certainly better to have a robust process. It seems like they are on the right track with the HVOF system. The reviewer would prefer that they rule out negative results early. The reviewer views this as a fairly positive result.

Reviewer 80:
A test is cited at 5,000 pounds per square inch (psi) but the means of deposition is not identified. Mechanism of failure has not been identified in detail. Is this data held back for proprietary reasons? This project would have presented itself better if details of deposition and identified failure mechanism had been presented. Porosity is cited as the problem but deep understanding and how to overcome this issue is not presented as well as it could be. This approach is more of a make and test instead of following a rigorous scientific process.

Reviewer 62:
Additional results are needed to fully evaluate this project.

Comments Regarding Project Management/Coordination
Reviewer 84:
The project appears to be effectively managed. Although there were delays, this may or may not have been avoided through different management strategies.

Reviewer 83:
The PI has done a good job coordinating efforts with industry and lab partners. Due to the delay in funding, there is slight concern that the deliverables will not be completed on time. The PI did not mention the potential cost share from the collaborators.

Reviewer 11:
Good project management has been exhibited. The leader has overcome a major obstacle and enlisted very capable

partners. The project had been delayed, but progress has been made in spite of this.

Reviewer 61:
It is nice to see industrial partners. The reviewer is surprised that project completion has only been delayed by two months. The reviewer suspects that will continue to fall backwards as the project continues.

Reviewer 80:
Project management is adequate but would be stronger with go/no-go decisions. Metrics for milestones are not clearly specific.

Reviewer 62:

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 84:
The project objective is to develop a thermal spray coating for high-temperature applications that can be easily removed and reapplied. Many details of the technical approach are proprietary, so it is difficult to form a complete picture of the project strengths and weaknesses. The project has experienced modest delays, but they are making significant progress toward achieving the project objectives.

Reviewer 83:
Overall, this technique could have cross-cutting applications across a variety of technologies which operate at high temperatures and pressures.

Reviewer 11:
This is an excellent project. This is a good alternative to elastomers. There is a good technology transition plan in place. The technology appears to be broadly applicable to a number of potential coating suppliers.

Reviewer 61:

Reviewer 80:
The approach appears as a make and test instead of expanding the knowledge base in a disciplined scientific manner.

Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a scientific/technical standpoint.

Comments Regarding Strengths

Reviewer 84:

Reviewer 83:
Strengths include the ability to develop a metallic spray coating as a redundant seal on high-temperature tools.

Reviewer 11:
The project delivered significant results at low cost.

Reviewer 61:

Reviewer 80:

Reviewer 62:
This is a novel approach.

Comments Regarding Weaknesses
Reviewer 84:

Reviewer 83:
The PI has not fully investigated the effects of differences in coefficients of thermal expansion (CTE) that may affect the integrity of the seal coating.

Reviewer 11:
The project is behind schedule, but catching up rapidly.

Reviewer 61:

Reviewer 80:

Reviewer 62:

Suggestions for Improvement
Reviewer 84:
The reviewer has no suggestions for improvement without access to proprietary information to form a more informed picture of the project.

Reviewer 83:

Reviewer 11:
Broadly communicate the results of this project.

Reviewer 61:

Reviewer 80:

Reviewer 62:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0605
Presentation Title: Technologies for extracting valuable metals and compounds from geothermal fluids
Investigator: Harrison, Stephen (Simbol Mining Corp.)

Comments Regarding Relevance/Impact of Research

Reviewer 84:
The work is very much in line with the objectives of the broader geothermal program mission and goals. It is a multifaceted project that will provide a great deal of insight. Given the coordination with industry and demonstration level focus, it will have a significant impact on the industry.

Reviewer 83:
This project has developed an innovative way to reclaim lithium, manganese and zinc from high saline content water from geothermal reservoirs. This project could help the United States in attaining appropriate levels of lithium needed for other areas such as lithium battery production. Furthermore, this project will increase knowledge in the development of sorbent materials for particular material species.

Reviewer 11:
This is an interesting project with the potential to improve the financial metrics of a geothermal well significantly.

Reviewer 61:
The reviewer is intrigued by the possibility to do mineral extraction in concert with geothermal power extraction. However, the reviewer wonders about whether this would be possible to do at a wide variety of locations. Will this be high impact for the industry or just certain mines? New comments: Hour-long processing is a huge advantage. It is clear from the presentation that this is a bit of a niche process that is only viable at high saline concentration like the Salton Sea. It is clear that the Salton Sea is a large resource, but it is still only one resource. The reviewer would have liked to see more about how much of the minerals (relative to potential supplies) can be extracted from the Salton Sea.

Reviewer 80:
This project addresses an excellent approach to making geothermal systems more economically attractive!

Reviewer 62:

Comments Regarding Scientific/Technical Approach

Reviewer 84:
The scientific and technical approach is solid.

Reviewer 83:
The PI‘s technical/scientific approach is sound and robust. The PI has already shown through previous work that the extraction process, on a small scale, is viable. The approach of generating data for scaling up this process is appropriate.

Reviewer 11:
The project is focused on results with particular emphasis on lithium which is a very energy material.

Reviewer 61:
There seem like a lot of separation technologies employed here. It seems like in the interest of time there would be value

in limiting the options sooner rather than later. The reviewer appreciates that the cost analysis is done fairly early.

Reviewer 80:
The technical strategy and justification for the approach is sound and well articulated. The talk stated that these types of systems had not been executed previously because the expense in development, the high operations and maintenance costs, and the issue of high-temperature corrosion. They did not specifically articulate HOW they got around these issues—perhaps this solution is proprietary. The project requirements are well articulated. The approach of scale-up and validation at various stages of production is reasonable, and there are excellent go/no-go gates for development. Overall, this is an outstanding project.

Reviewer 62:

Comments Regarding Accomplishments, Results and Progress

Reviewer 84:
The project has progressed to a stage one would expect given the elapsed time.

Reviewer 83:
The PI has presented some impressive accomplishments such as the lithium extraction demonstration plant and the lithium carbonate and lithium hydroxide lab pilot facility. The PI has also shown great progress in developing the sorbent materials used in the extraction process. If the PI continues along the present course, the project goals will be attained.

Reviewer 11:
Good results have been achieved, however, it is not clear how applicable the process is among geothermal sites outside of the particular area where the process is located. The project has made excellent progress on lithium.

Reviewer 61:
The project has made great progress so far. What is the cost of the lithium from this mine compared to other sources of lithium? The improved lithium sorbent will likely be a sizable challenge to do at a necessary scale. It is good to see the project team sticking with the precipitation method.

Reviewer 80:
The validation of lithium extraction at 93% is an excellent accomplishment. The ability to remove the silicon prior to the lithium and manganese and zinc illustrates a successful process. The scale-up at various stages of larger volumes is a good approach showing validation through successful rates of lithium extraction. This reviewer would like a better understanding of metrics for "full scale volume" showing a typical flow volume for a geothermal plant, estimates of how high the various steps in extraction must be and how frequently the ion absorber must be replaced in order to satisfy a "full production" volume.

Reviewer 62:

Comments Regarding Project Management/Coordination

Reviewer 84:
The project is properly managed and coordinated.

Reviewer 83:
The PI and the PI‘s senior team have done an excellent job at coordinating collaborations and using project funds efficiently to produce tangible results. The project has generated several jobs and seems to be progressing at a steady,

definable pace.

Reviewer 11:
Project management and coordination has been demonstrated to be good. Coordination with CalEnergy and eventual technology transfer will be very important.

Reviewer 61:

Reviewer 80:
This project has an excellent plan and stage gates with go/no-go decision milestones in the figure describing the process, if not explicit in the text. The various demonstration projects at different locations and volumes are an excellent way to validate the processes at increasing rates. The large company match shows significant commitment that reinforces that this is a high priority for the company.

Reviewer 62:
Good collaboration is reflected in accomplishments section.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 84:
The project has multiple objectives. To name the first five, the objectives are: 1. to demonstrate lithium extraction and lithium carbonate and lithium hydroxide production from hypersaline geothermal brines at a demonstration plant on-site at a geothermal power plant in Calipatria, CA, 2. to demonstrate first generation technology for managing silica scaling prior to metal extraction at the demonstration plant, 3. to acquire sufficient data for commercial plant design and to justify and invite conventional bank financing of commercial plants, 4. to produce commercial samples of technical- and electrochemical-grade lithium carbonate and lithium hydroxide, and 5. to manufacture cathode materials for lithium-ion batteries from geothermal precursor materials. The results will help create new revenue streams for plant operators. The project is 40% underway and a roughly commensurate level of the project objectives have been achieved.

Reviewer 83:
Overall, this project, if successful, will have a major impact on the development of extraction processes in geothermal reservoirs. This project shows great promise for commercialization within the geothermal industry.

Reviewer 11:
This is the only project of its kind sponsored today by the Department of Energy. It will be an important test bed for mineral extraction in conjunction with geothermal energy harvesting.

Reviewer 61:

Reviewer 80:
Keep up the good work and continue scale-up!

Reviewer 62:
With all of these proposals, it is difficult to make a full assessment given the relatively short presentations and write-ups. Furthermore, the issue of proprietary information makes it difficult to fully quantify the progress made from a scientific/technical standpoint.

Comments Regarding Strengths

Reviewer 84:

Economic considerations are a focal point of the work. The project is multifaceted and a great deal of insight will come out of it.

Reviewer 83:

Strengths include the development of advanced extraction methods for lithium, manganese, zinc, and potassium.

Reviewer 11:

Strengths include good coordination with an industry partner such as CalEnergy.

Reviewer 61:

Reviewer 80:

This is an excellent project overall.

Reviewer 62:

Strengths include cross-cutting relevance and potential impact.

Comments Regarding Weaknesses

Reviewer 84:

No publications or presentations were listed. Surely interaction with the broader scientific, engineering, and industrial community would benefit the project.

Reviewer 83:

One definite weakness of the project is not addressing the ability to extract materials from low-saline content water. It would be nice if this technology could be used in low-saline environments.

Reviewer 11:

There may be too many different mineral extraction activities being attempted.

Reviewer 61:

Reviewer 80:

No weaknesses were found.

Reviewer 62:

Suggestions for Improvement

Reviewer 84:

Reviewer 83:

Reviewer 11:
Focusing on lithium extraction may be the most important goal.

Reviewer 61:

Reviewer 80:
Possibly proprietary are the details of the absorption medium and the solution to reducing corrosion. One would hope that the absorption medium for the lithium chloride formation had a long shelf life even at fast rates. Likewise, one would hope that the durability of the system enables long runs without the need to replace components that could require temporary shutdown of the process or add significant cost to the process.

Reviewer 62:

Stimulation/Fracture Prediction Modeling

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0300
Presentation Title: Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs
Investigator: Carrigan, Charles (Lawrence Livermore National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 35:
When the work is complete and the software is applied and used to assess enhanced geothermal systems (EGS) problems, its relevance/impact/significance will be realized.

Reviewer 10:
Determining the evolution of the transport characteristics of fracture networks is important/crucial in EGS. This work includes the evaluation of permeability and HM deformation processes. It uses a smoothed mechanical algorithm capable of accommodating differential deformation across block-dissecting fractures. The ability to couple both thermal effects in terms of advection and feedback on thermal stresses is key. The use of HE propellants for stimulation could be useful but has not been determined. The hypotheses to be explored in the work are not clear—is this a model development project or is it exploring the unknown physics of geothermal reservoirs?

Reviewer 16:
This project evaluates the potential enhancement of permeability as a response to hydraulic/ explosive fracturing. By varying the formation characteristics, the model allows a more precise decision-making process.

Comments Regarding Scientific/Technical Approach

Reviewer 35:
The approach taken to use the LBT as a starting point was good in that it is a test beyond lab scale; however, the reviewer is not sure that its upscaling is necessarily representative of a real system. It is hoped that this will be demonstrated at some point by a field problem analysis.

Reviewer 10:
The scientific approach is appropriate to the EGS goals to be probed. This approach can address the majority of questions anticipated from the description of the problem. Issues in many modeling related projects relate to the difficult issue of verification of response with real data—that says something about the form of the real coupling. This is not fully addressed in the presentation. For example, if the LBT is to be used as a method to verify/validate the code, what are the known/measured parameters in the experiment and how can these constraints be addressed in the test.

Reviewer 16:
The project provides a computational test bed. The team is able to consider "dynamic" fracturing, including the use of propellants. Efforts were undertaken to validate the model. There are reason(s) for "small explosions" away from the crack tip. The team needs to investigate the influence of pumping rate and fluid viscosity. Incorporating multi-phase flow will be a challenge.

Comments Regarding Accomplishments, Results and Progress

Reviewer 35:
The work appears to be on track and there have been a number of presentations.

Reviewer 10:
The reviewer saw this project reported upon last year (informally) and good progress appeared to have been made. This project will yield useful data on the stimulation of initially fractured reservoirs. It is not the only approach that could be applied but useful insights will result. It is not clear exactly what data sets will be used to examine the veracity of observed behavior, but the physical constraints of the model are realistic.

Reviewer 16:
Data from a large block test is available. The team is using "existing" software. The project effort considers heat transfer before/after stimulation as a function of time. There are no fluid transfer possibilities between fractures and matrix.

Comments Regarding Project Management/Coordination
Reviewer 35:
The project manager and project team appear to be doing a good job of working together to work toward their goals. The communication between the researchers and industry is stated but it is unclear what was reaped from the communication.

Reviewer 10:
Project management/coordination is fine.

Reviewer 16:
The project has included good outreach to industry and academics and has created three new jobs.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 35:

Reviewer 10:
See above.

Reviewer 16:

Comments Regarding Strengths
Reviewer 35:

Reviewer 10:
Strengths include development of a model that is applicable to anticipated conditions within EGS reservoirs.

Reviewer 16:

Comments Regarding Weaknesses
Reviewer 35:

Reviewer 10:
There is no clear plan for verification against real data—an important part of the overall task. There was a discussion of the LBT but no real way to constrain real behavior other than to point to generic outcomes from the modeling.

Reviewer 16:

Suggestions for Improvement

Reviewer 35:

Reviewer 10:
Provide a path for validation.

Reviewer 16:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0301
Presentation Title: Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity
Investigator: Ghassemi, Ahmad (Texas A&M University)

Comments Regarding Relevance/Impact of Research
Reviewer 35:
For the stage of this project it has made good progress. The work lacks field data comparison, so to judge relevance is difficult.

Reviewer 10:
The ability to determine the evolution of permeability resulting from mechanical effects (failure of intact material and on fractures) is crucial in defining the evolution of enhanced geothermal system (EGS) reservoirs. Linking this with observable signals, such as MEQs, provides an important constraint and is feasible.

Reviewer 16:
The project could provide an accurate reservoir response before deciding about the stimulation. Microseismicity cloud will determine the ―created" reservoir.

Comments Regarding Scientific/Technical Approach
Reviewer 35:
The approach presented appears solid. Assumptions were made of insitu conditions, and these assumptions appear reasonable. The data set upon which the code bases its development was not presented, for example, relationships between material parameters and how they vary and interrelate. Scaling from lab data to field data applications was not fully explained.

Reviewer 10:
This is an imaginative approach to attempt to constrain permeability evolution in reservoirs. It is well conceived and well executed. Identifying a definitive linkage between stress and permeability and damage and permeability will be difficult. Anisotropy of that development and also whether it is confined to preexisting orientations of fractures may be important.

Reviewer 16:
The project team applied "known" technology.

Comments Regarding Accomplishments, Results and Progress
Reviewer 35:
The work appears to be on track in terms of progress with good communication of results to the community.

Reviewer 10:
Progress is appropriate with the stage of the project. The method uses a common thermo-poro-mechanical testbed between projects and is a useful vehicle to achieve the desired goals of the project. The PI has some evolving results that show different mechanisms. This is a difficult problem and the project is at a stage to be able to perform hypothesis tests of different behaviors. For example, they may be interested in tryingto reproduce observed MEQ patterns observed in EGS reservoirs. In particular the r = C.sqrt(ct) dependency of locations could be used to define the role of perm change on evolving patterns of MEQs.

Reviewer 16:
The project includes 3D poroelastic finite element, plus damage mechanics, plus stress-dependent permeability. It includes a geostatistical approach with uncertainty analysis. It includes calibration ―after the fact" with laboratory and published field data; needs to be predictive instead. Need to estimate the influence of the full coupling. There is an issue of scaling from laboratory to field.

Comments Regarding Project Management/Coordination
Reviewer 35:
The professor-student relationships appear to work well in that a good deal of work has been completed on what appears to be on budget, etc. The association with industry is stated, but not really demonstrated.

Reviewer 10:
This is a well-managed project.

Reviewer 16:
The project team obtained funds from the petroleum industry. Need more coordination with other DOE field projects.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.
Reviewer 35:

Reviewer 10:
This is an innovative and creative project that is being well executed. It will yield important results and works from data typically available for reservoirs. At present the forward modeling of MEQ locations and timing appears best developed, and less fully developed is discussion of completing the analysis with the geostatistical linkage with permeability.

Reviewer 16:

Comments Regarding Strengths
Reviewer 35:

Reviewer 10:
See above.

Reviewer 16:

Comments Regarding Weaknesses
Reviewer 35:

Reviewer 10:
See above.

Reviewer 16:

Suggestions for Improvement

Reviewer 35:

Reviewer 10:

See above.

Reviewer 16:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0302
Presentation Title: FRAC-STIM: A Physics-Based Fracture Stimulation, Reservoir Flow and Heat Transport Simulator
Investigator: Podgorney, Robert (Idaho National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 35:
The software being developed is attempting to solve real and complex problems—a noteworthy task. This work has the start-from-scratch approach. When the work is complete the software will provide a valuable tool to DOE or industry to evaluate enhanced geothermal system (EGS) reservoir type systems. The evaluation of the code in terms of comparison with field data has not yet been demonstrated.

Reviewer 10:
The ability to provide a variety of models to represent the development of deformations and related permeability evolution and related transport behavior is important in EGS. The project addresses these issues through a variety of interlinked models.

Reviewer 16:
The development of EGS reservoir simulation (both creation and long-term) will make an impact.

Comments Regarding Scientific/Technical Approach
Reviewer 35:
The first principles approach has merit. The data set upon which the code bases its development was not presented, for example, relationships between material parameters and how they vary and interrelate. Scaling from lab data to field data applications was not explained.

Reviewer 10:
This will result in a suite of models available for use within EGS reservoirs. The models have a solid foundation in physics and nascent publications indicate that the work is being accepted beyond the EGS domain and in the mechanics literature. This takes a different and commendable approach compared to some others in developing codes from the beginning. There are intrinsic benefits in this (scalability, parallelization and ability to deal with large problems with a modifyable source code) and also some drawbacks (the lead time is longer than with coupling codes and you don't get the benefit of legacy constitutive models and thermodynamic databases).

Reviewer 16:
This work can be extended to simulate microseismicity. The project solved PDEs simultaneously—not a trivial exercise

Comments Regarding Accomplishments, Results and Progress
Reviewer 35:
The accomplishments listed (publications) demonstrate an adequate level of communicating progress.

Reviewer 10:
The project has shown good progress. A number of codes are operational and able to be applied to problems of merit related to EGS.

Reviewer 16:

A fully coupled solution has been obtained. The project includes a 3D, multiphase, energy transport. The project team is able to consider discontinuities. There are experienced mathematical instabilities which need to be investigated.

Comments Regarding Project Management/Coordination

Reviewer 35:

It appears that the project management and coordination of the work is being well done; all of the participants are near to each other and communicate well as judged by progress to date, etc.

Reviewer 10:

Management of the project is fine.

Reviewer 16:

The issue of licensing needs to be clarified.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 35:

Reviewer 10:

See above.

Reviewer 16:

Comments Regarding Strengths

Reviewer 35:

Reviewer 10:

Strengths include the comprehensive suite of codes to be developed that will be capable of accommodating major phenomenologies anticipated for EGS reservoirs.

Reviewer 16:

Comments Regarding Weaknesses

Reviewer 35:

Reviewer 10:

See above.

Reviewer 16:

Suggestions for Improvement

Reviewer 35:

Reviewer 10:

None.

Reviewer 16:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0303
Presentation Title: Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.
Investigator: Pritchett, John (Science Applications International Corporation)

Comments Regarding Relevance/Impact of Research

Reviewer 35:
This type of model and modeling approach will provide a valuable tool for the U.S. program. The code will eventually be available for anyone's use, but it is unclear how the Department of Energy (DOE) will facilitate use once the product is completed.

Reviewer 10:
This project is developing an approach to define flow and electrical (SP) effects in geothermal reservoirs. These methods could be used to determine the evolution of permeability and throughput within reservoirs.

Reviewer 16:
The project includes 3D-enhanced geothermal system (EGS) simulation with tracer capabilities. The code is able to predict thermal breakthrough.

Comments Regarding Scientific/Technical Approach

Reviewer 35:
The modular approach to developing a software tool is a well-conceived approach that should readily lead to a solid product. The cross fertilization between the U.S. and European programs is a plus in that there is European data to operate from. The reviewer hopes that use of that data for model evaluation is pursued. The data set upon which the code bases its development was not presented, for example, relationships between material parameters and how they vary and interrelate. Scaling from lab data to field data applications was not explained.

Reviewer 10:
Measurements of SP could be useful in determining the evolution of permeability in EGS reservoirs depending on the availability of sensors close to the reservoir that will measure potential, and thereby allow interpretation of fundamental characteristics. This code will enable this to be completed. However, it is not clear whether the coverage of sensors will be adequate to allow interpretation because of issues related to the drop in the signal with radius from the point of action.

Reviewer 16:
The project is limited to single phase flow. It is questionable if the thermoelastic module is fully coupled. There are no new developments; they adapted existing software codes. The influence of the "fracture patches" depends on the size of the –disks”, especially their flowing capability via interconnectivity. This has apparently been overlooked.

Comments Regarding Accomplishments, Results and Progress

Reviewer 35:
It appears that the project "parts" are each on track and consistent with the planned work/goals.

Reviewer 10:
Significant progress has been made. The project appears on schedule. There may be issues related to the readiness of adequate field data at the time this project reaches completion.

Reviewer 16:
The presentation was rather confusing. The project needs a validation effort; this is mainly —controlled" experiments.

Comments Regarding Project Management/Coordination

Reviewer 35:
The project appears to be well organized and coordinated between the two sets of researchers in the United States and Europe.

Reviewer 10:
Management coordination is appropriate.

Reviewer 16:
Project management/coordination is non-existent; this is a single-person effort.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 35:

Reviewer 10:
This project could provide important data in constraining the evolution of permeability in EGS reservoirs. It is not clear whether the strength of the signal, measured at likely access locations to the reservoir, will be adequate to allow this constraint to be applied.

Reviewer 16:

Comments Regarding Strengths

Reviewer 35:

Reviewer 10:

Reviewer 16:

Comments Regarding Weaknesses

Reviewer 35:

Reviewer 10:

Reviewer 16:

Suggestions for Improvement

Reviewer 35:

Reviewer 10:

Reviewer 16:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0304
Presentation Title: Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs
Investigator: Ghassemi, Ahmad (Texas A&M University)

Comments Regarding Relevance/Impact of Research
Reviewer 10:
This project is developing methods to define the evolution of tensile, shear and tearing cracks in enhanced geothermal system (EGS) reservoirs, as extensions of preexisting fractures and the development of new seeded fractures. This is important in defining the evolution of permeability in EGS reservoirs.

Reviewer 16:
The project has the ability to consider all three modes of fracturing, including the mixed modes. Mixed mode fracturing criteria need to be clarified, especially when approaching existing discontinuities.

Comments Regarding Scientific/Technical Approach
Reviewer 10:
The approach is commendable and has been shown capable of effectively recovering the responses desired—validation against mode I, II, and III failures in single and multiple inclined cracks.

Reviewer 16:
This is a new application of the Virtual Multidimensional Interval Bonds (VMIB) technique. It can consider non-linear rock deformation as well as heterogeneities. This is a very smart approach.

Comments Regarding Accomplishments, Results and Progress
Reviewer 10:
Validation results have been presented and the method—representing a significant investment in time—is ready to be used to explore the behavior of EGS reservoirs.

Reviewer 16:
The project was able to implement VMIB into a FEM code. It simulated important test results. This approach has the big advantage that it does not need to consider the particles themselves and can simulate multiple fracture propagation.

Comments Regarding Project Management/Coordination
Reviewer 10:
Project management is appropriate.

Reviewer 16:
Not applicable.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 10:

Reviewer 16:

Comments Regarding Strengths

Reviewer 10:

Reviewer 16:

Comments Regarding Weaknesses

Reviewer 10:

Reviewer 16:

Suggestions for Improvement

Reviewer 10:

Reviewer 16:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0305
Presentation Title: Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems
Investigator: Gutierrez, Marte (Colorado School of Mines)

Comments Regarding Relevance/Impact of Research
Reviewer 35:
Software codes of this type coupled with experimental work is a valid approach; however, it is unclear from the presentation the progress to date and the written material of the solid collection between the two, and thus the impact of the research—albeit valued as a lofty goal, it is perhaps out of reach.

Reviewer 10:
This project is exploring the evolution of hydraulic fractures driven by proppant-laced fluid to define the form of the fractures and to evaluate the distribution of proppant. The model focuses on the generation of a single fracture in a homogeneous medium. The absence of preexisting fractures (dictated by the use of the DD method) may condition the results.

Reviewer 16:
The goal was to develop an "improved" fracturing technology, with laboratory tests to validate; also including proppant transport modeling using PFC3D! That is great, but in reality, nothing new is proposed.

Comments Regarding Scientific/Technical Approach
Reviewer 35:
In the reviewer's opinion, there is too many different topics is/are being attempted (this perhaps is reflected in the lack of progress). The lack of progress is a real detriment to this project and prevents a decent assessment—the data set upon which the code bases its development was not presented, for example, relationships between material parameters and how they vary and interrelate. Scaling from lab data to field data applications was not explained.

Reviewer 10:
The PI is addressing a difficult problem, propagation of hydraulic fractures with a backfilling and propagating fluid. The cross correlation between theoretical, experimental and field data are useful and provide good constraint to the problem. The proposed geometry of failure is perhaps not optimal to addressing the issue for enhanced geothermal systems (EGS), although it is close to the geometry often assumed for Fenton Hill.

Reviewer 16:
Not aware of existing technology and/or pertinent publications.

Comments Regarding Accomplishments, Results and Progress
Reviewer 35:
This work is not well progressed. There are obstacles not yet realized in terms of the planned experimental work. The AE system to instrument, test/collect data, and analyze the data is a formidable challenge (alone). It is not clear that this can be accomplished. The test system (as proposed) is quite complex, as yet it is untested. The software portion is also way behind. This project is somewhat disappointing in terms of accomplishments to date.

Reviewer 10:
The project is moving ahead but with 80% of the derivations completed and 20% of the coding may not be on track.

No data were presented to show the logic to be used, for example for the DD or for PFC fluid and mass transport couplings.

Reviewer 16:
Nil. Having no access to "good" graduate students is not an excuse.

Comments Regarding Project Management/Coordination
Reviewer 35:
The progress on the work is not so great; this points to poor management/coordination of tasking.

Reviewer 10:
Management appears appropriate.

Reviewer 16:
Non-existent.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 35:

Reviewer 10:
This is a difficult project from a technical standpoint but the assumptions related to the propagation of a single hydro fracture may not make results immediately applicable to the relic fractured rocks typical of EGS projects.

Reviewer 16:
This project should be stopped immediately.

Comments Regarding Strengths
Reviewer 35:

Reviewer 10:
See above.

Reviewer 16:

Comments Regarding Weaknesses
Reviewer 35:

Reviewer 10:
See above.

Reviewer 16:

Suggestions for Improvement
Reviewer 35:

Reviewer 10:

See above.

Reviewer 16:

Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1000
Presentation Title: Development of Chemical Model to Predict the Interactions between Supercritical Carbon Dioxide and Reservoir Rock in EGS reservoirs
Investigator: Lu, Chuan (University of Utah)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 2.76

Comments Regarding Relevance/Impact of Research

Reviewer 62:
The new database of thermodynamic data will be useful to the project and to others. This should be beneficial to the program. It is not very clear how the simulations to be performed will be a benefit to the program.

Reviewer 63:
This project involves a two-part approach—improve the descriptions of carbon dioxide (CO2)/water/rock chemical in models, then use the models to evaluate different situations of interest. The chemical reaction rates are important to quantify and have the potential to have a high impact on the basic science. The reviewer is not clear how useful the results from the simulations will be, but incorporating them into this study is important to make sure that the final product will actually be able to be used in a full-scale simulator.

Reviewer 45:
Most reactive transports use geochemical databases not tailored to these conditions. The application of this effort in the West where water is limited is an advantage. Hence, the ultimate goal is to assist in moving the application of geothermal into new areas.

Reviewer 30:
The progress is not substantial but is significant. The P-T geochemical database is commendable in its preliminary version. The objectives are overarching and cover almost the entire area concerning the use of supercritical CO2 in enhanced geothermal systems (EGS). The impact on any individual area will necessarily be limited. The main outcome from this project will probably be a model for optimum design of CO2-EGS systems. The reviewer‘s impression is that the details of such a model may not be made publicly available and this limits the public benefit of the project.

Reviewer 86:
The project is about 50% behind timeline due to loss of the original principal investigator (PI) and change in lead organization. The presenter asserted that the project would have broad impact on EGS development in several types of geologic reservoirs, but the materials presented indicated a specific focus on granites. The presenter was unable to address a question on primary minerals in granites that appeared to have no or incorrect thermodynamic or kinetic data. This reviewer attempted to access the report via the link provided in the presentation to evaluate work done to date but could not access the report due to password protection.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
There is a good synergy between the objectives that have been accomplished to date— development of a database, updating simulators, and testing models for robustness. The remaining plans are not as clearly tied together, and there seems to be a bit of throwing things in to fit different researchers' interests.

Reviewer 63:
The linkage between the model describing the reactions, the experiments at the University of Utah and field studies is heartening. The apparent focus on only granite systems seems limited, and a little unfortunate. The initial discussion seemed to be broad, but the actual applications are limited to just granite.

Reviewer 45:
This project investigates optimal EGS well placement looking at reservoir CO2/water, buoyancy and optimal well placement. TOUGHREACT is an excellent code to link the program with for delivery of results to the community. Work at the University of Wyoming was not well characterized.

Reviewer 30:
Although the objectives cover a broad domain, the investigating team has been able to maintain a focused approach. One of the challenges with this project (and others in this area) is the lack of field data on EGS. This makes it difficult to talk about "typical" conditions. Notwithstanding this, the team has the right approach in accessing the existing field experience and knowledge.

Reviewer 86:
To date, it appears only a literature review has been conducted and nothing was presented to determine what methods or findings from the literature review were addressed in the initial database modifications. No details on the experiments that were represented as being in progress were presented.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
The accomplishments to this point actually probably fit in the fair category, but the reviewer gives them the benefit of the doubt because their PI left, and they got behind.

Reviewer 63:
The compilation of the high P-T geochemical database has been completed and this has been implemented in PFLOTRAN & TOUGHREACT. The 2D model that shows this is functional seems limited, but it is a very nice start.

Reviewer 45:
The first database has been published online. Working with AltaRock, they have licensed the patent for this application and GreenFire (sub to AltaRock). There is a weakness in the database with silica.

Reviewer 30:
In relation to the resources expended so far, the progress has been good. Most of the subtasks are just starting and it is difficult to have a rigorous assessment of the accomplishments at this stage.

Reviewer 86:
As the project is significantly behind schedule, and the new PI was unable to present the work at the review, a poor rating for results and progress is justified. Hopefully, the new PI will quickly get the project on track and make significant progress in meeting the objectives.

Comments Regarding Project Management/Coordination

Reviewer 62:
It is hard to tell how well the project is being managed at this point. Certainly the new PI has the ability to manage this project, and there is a good chance that everything will go okay, but the future plans as laid out in the paper and presentation are very unclear and don't hang very well together at this point. It would be nice to see a clearer plan for the simulations to be performed, what key questions will be used to test, and how they will be used to test these questions.

Reviewer 63:
There have been changes in personnel, but they feel they are staying on target. The coordination between different groups (AltaRock & Greenfire) is encouraging, though they do not seem to be playing a crucial role in the project. It is nice though.

Reviewer 45:
Some key personnel have moved, creating a challenge for keeping the effort on track.

Reviewer 30:
The project appears to be structured well. The broad brief of this project will benefit by closer collaboration with other projects in this area.

Reviewer 86:
Obviously, this project has experienced major difficulties with loss of the original PI and change in lead organization. The team has successfully transitioned to new leadership but with the project behind schedule and very little tangible technical progress presented for review, project management and coordination needs significant attention.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
There is strong linkage between the simulations being studied and the specific locations being evaluated with the lab experiments. This is nice to see, with each portion of the research validating and expanding other parts. But, this also limits the overall scope of what can be studied, hence the focus on just granite reservoirs.

Reviewer 45:
Overall, this is a very reasonable effort. The simulator stills needs refinements so that some effort can be made to optimize conditions.

Reviewer 30:
This was the first presentation under the CO2 heading and it provides a perspective against which the outputs of the other projects can be evaluated. Mechanisms need to be explored to facilitate this, e.g., regular workshops between ALL projects, review of projects by other teams in the same group, etc.

Reviewer 86:
The project has not progressed sufficiently technically or clearly identified the geologies or weaknesses in the

thermodynamic database that are to be addressed, nor has it demonstrated why correcting these data truly impact EGS performance in these geologies (versus just saying that it does). This reviewer is well acquainted with the new PI and has good expectations that this project can improve significantly before the next review, provided the PI can devote sufficient time to this project.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
Focusing on one type of structure (granite) will help to ensure thorough testing of the material. See weaknesses section.

Reviewer 45:
There is a strong linkage with a team that is interested in economic viability. The industrial linkages are excellent. At the same time, the program efforts need to recognize that the publically funded portions of this work must be reported in detail.

Reviewer 30:
The main strength of this project is the practical focus and the quality of the project team.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
Focusing on one type of structure (granite) will limit relevance to other structures. See strengths section.

Reviewer 45:
Some key personnel have moved, creating a challenge for keeping the effort on track. It seems as though the working relations on the program are still in a very dynamic state. If this comes together, this has the potential to be a strong effort. So far, it has not come together.

Reviewer 30:
The main weakness is that the objectives are too broad. The pragmatic and practical orientation of the team will help to keep the project on track but the lack of focus remains a weakness.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:

See comments in project management section above.

Reviewer 63:
Perhaps the scope should be more narrowly defined in the future? Rather than "Determine applicable chemical reactions between water, rock, and CO2" something like "Determine applicable chemical reactions between water, CO2, and granite, a common geothermal reservoir material" would be more palatable.

Reviewer 45:
The project should continue to focus on the flow-through cases and feedback from the industrial partners will help to assure that the effort meets their needs for developing practical applications.

Reviewer 30:
Establish mechanisms through which the project interacts with other projects. If done correctly, this should have two benefits: (a) Provides a practical focus and domain knowledge, missing in some of the other projects, and (b) Enables this project to focus better on CO2-EGS optimization, incorporating the findings from the other projects. This approach would be useful if and only if the results can be captured for public good.

Reviewer 86:
Clearly identify the geologies that the project expects to develop a custom database to represent—don't assert everything is being covered. Identify the specific thermodynamic and kinetic data weaknesses in the current databases and why the van 't Hoff or other extrapolation methods used to estimate these data at high temperatures will lead to inaccurate or poor predictions of EGS performance in these geologies.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1001
Presentation Title: Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water
Investigator: Petro, Miroslav (Symyx Technologies, Inc.)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 2.04

Comments Regarding Relevance/Impact of Research

Reviewer 62:
Some of the experimental work that is being performed will be helpful in terms of determining kinetics of reactions that are relevant for geothermal. They mention "hard-to-get" missing data, but it is not clear what the conditions are under which they will be collecting that data, especially on the flow-through experiments. Also, their experiments seem like they would be appropriate for porous systems, but not fracture-dominated ones.

Reviewer 63:
The impact of this work is apparent; these reactions need to be well understood before they can be implemented in models.

Reviewer 45:
A new dynamic model is the objective for carbon dioxide (CO_2) to supercritical conditions. This is intended to give a more accurate assessment of the power that could be delivered.

Reviewer 30:
About a quarter of a substantial budget has been spent and the progress is difficult to see. While a multi-channel batch system is built, planning for the experimental work has not progressed beyond the initial proposal. There are no results from the project yet that will have an impact outside the project team.

Reviewer 86:
This was a very disappointing presentation. To date, the project has spent about $1 million and basically built a large set of stirred flow-through reactors that are already available at numerous institutions around the country. Moreover, the design of these systems is specifically for water-dominated systems and is poorly suited (impossible really) to get data on the water-wet $scCO_2$ system the PI claimed was of key interest. The list of initial minerals being studied are the most common and well-studied minerals in geochemistry and the PI could not answer a simple question as to why these minerals were selected and what weaknesses exist in the thermodynamic database they would be addressing.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
It's not really clear how far outside of the current envelope of experiments (in terms of P and T) they are going with CO_2 and brine. Much is going on in the CO_2 sequestration area, but not as much at the elevated temperatures. The work seems to be focused on reactions in the aqueous phase, but for situations where CO_2 is a working fluid, it may be more appropriate to look at the CO_2 phase, in terms of what would help the program.

Reviewer 63:
How does one batch experiments different from the flow-through conditions expected to be seen in-situ? Also, when the

material is broken down into 25 to 150 micron particles for flow-through testing, isn't the amount of surface-fluid contact really high, leading to solubility rates that are way faster than would be observed in-situ? The understanding of the speaker towards these and other relevant material questions seemed limited.

Reviewer 45:
The project includes building a batch system for rock solubility. The key technical issue is using ion-HPLC to give mineral composition after a 1000:1 dilution. One can find the data on all the compositions at high temperature and high pressure. They suggest sharing the data after it has been included in the models. The objective this year is to deliver data to the data base.

Reviewer 30:
The 5,000-pounds per square inch (psi) limit on the rig seems to be arbitrary and is not high enough to simulate conditions in most enhanced geothermal system (EGS) reservoirs. At least 10,000 psi would be needed. Some initial planning work would have been good on T and P ranges. The experimental plan is now being put together but it will be limited by the capabilities of the rig. "Pushing the performance of the lab system to represent real situations" is acknowledged as a current issue. One of the justifications for the project is to acquire "hard-to-get" data. It is not clear what this means and should have been identified by now.

Reviewer 86:
Flow-through high-pressure reactors for studying water-dominated geochemical systems have been around for decades. Very little novel or new was presented that would justify an astronomical $4 million investment in repeat studies of halite and calcite among other well-understood minerals. Moreover, the experimental approach presented provides no viable path forward to study the water-wet $scCO_2$ that is key for understanding reactive fracture flow in EGS systems.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
This could be fair or good. It's hard to judge at this point, based on the loss of seven months due to the folding of the initial company. Not much has been done, but they seem to be working hard to get on track and are in a position now to move forward.

Reviewer 63:
The building of the experimental facility is a nice achievement of the group. The actual experiments that have been run show decent results, but without the proper knowledge and understanding of what needs to be looked at, these accomplishments will not further the science or geothermal agenda significantly.

Reviewer 45:
Progress so far includes the construction of the oven facility. The reactors are stirred—5 reactors at 300°C and 5,000 psi upper limits.

Reviewer 30:
There are no results yet to comment upon.

Reviewer 86:
About $1 million has been spent to put together an experimental system consisting of five stirred flow-through reactors in a large oven. The only data that has been collected was for barite dissolution in water and water with dissolved CO_2. Barite has no relevance to the geothermal program directly—its only purported value is as a reference. This is a very large expenditure for development of a system that appears to have a very limited value to the DOE Geothermal Technologies Program (GTP) and overlaps with several other projects in the CO_2 portfolio.

Comments Regarding Project Management/Coordination

Reviewer 62:
This is difficult to judge. Much has changed since the beginning of the project because of the novation. They have gotten Lawrence Berkeley National Laboratory (LBNL)on board, which is a positive step, but how that relationship will work seems to still be in the formation stages. Certainly, they should be able to help prioritize reactions and rocks to work on.

Reviewer 63:
Transition from original group to PARC seems to have been smooth. Good working relationship to LBNL is apparent.

Reviewer 45:
Novation was a major problem. They were forced to rebuild the system, but they did that with improvements; however, the nature of these improvements with respect to yielding credible data was not well established.

Reviewer 30:
The change in management seems to have been positive for the project. However, building the rig to the wrong specifications suggests a possible lack of interaction between the PI and the other members of the team who have geothermal knowledge.

Reviewer 86:
Project spending is in line with the timeline and the team has transitioned from loss of the original lead institution.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
The group has progressed in the sense that the equipment needed to perform tests has been compiled, but the work towards the ―improved model of EGS with supercritical CO2 as a working fluid" and ―New dynamic model of transition from water to supercritical CO2" (the stated project goals) seems quite limited. Further, the three-year plan to 1) build the system, 2) upgrade the system, and 3) generate sufficient data for a model, doesn't leave a lot of room for project mishaps and lost time.

Reviewer 45:
The team does not exhibit technical depth in understanding the thermodynamic complexities needed to deliver data that will add to the community‘s existing knowledge.

Reviewer 30:
The project scope is not well defined. The connection between the experimental schedule and the overall objectives is not clear. There also is a significant overlap with other projects reviewed on the same day.

Reviewer 86:
From the materials presented, this reviewer cannot find sufficient technical depth or probable contributions that would develop from this project to justify an over $4 million investment. The new PI does not seem to have in-depth technical knowledge in aqueous, or more importantly, non-aqueous reactive geochemical systems, so this reviewer is quite

concerned about the prospects for this project succeeding. The PI should decide quickly, given the equipment design and investment already made, to focus on aqueous rock-water systems and make sure the planned experiments address key gaps in the thermodynamic or kinetic data for key minerals critical to the GTP. The PI needs to coordinate better with the other efforts being funded in the American Recovery and Reinvestment Act (ARRA) CO2 project portfolio to minimize duplication.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
The experimental equipment is very nice.

Reviewer 45:
This is not a strong effort.

Reviewer 30:
This is a good team. The PI has the requisite expertise and resources to build the laboratory facilities. Other members of the team are world leaders in geothermal reservoir modeling.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
The goals seem broad and the plan to achieving them seems sparse.

Reviewer 45:
The team needs a member with credible thermodynamics expertise. They are not too specific on the data that will be delivered. Experimental plans were not clearly stated. They did not make a good case for what the innovation with this approach consisted of in specific. The HPLC has a number of limitations. The phase identification will not be characterized. They are not characterizing the sample preparation and this could change things by about two orders of magnitude. They did not make a good case for innovation.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
See comments above regarding fractured formations, reactions in the CO2 phase, and P and T envelope.

Reviewer 63:
Collaboration (strong collaboration) with a group that has more experience with CO2 sequestration and geothermal activities seems like it would make sense. The presentation gave the impression that this group needs to learn more of the basics before attempting to tackle difficult problems.

Reviewer 45:
Add technical depth in understanding the thermodynamics.

Reviewer 30:
Although 25% of the budget has been spent, refocusing the project may be possible by making use of the overlap with other projects. On a side note, since this project is looking into thermodynamic relationships, it would benefit from partnership with a strong thermodynamics group like NIST.

Reviewer 86:
No response entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1002
Presentation Title: An Integrated Experimental and Numerical Study: Developing a Reaction Transport Model that Couples Chemical Reactions of Mineral Dissolution/Precipitation with Spatial and Temporal Flow Variations in CO_2/Brine/Rock Systems
Investigator: Saar, Martin (Regents of the University of Minnesota)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 3.48

Comments Regarding Relevance/Impact of Research

Reviewer 62:
The reviewer believes that this new approach to determining changes in permeability due to chemical reactions is the wave of the future, and where we will have to go to develop an appropriate understanding of how reactive flow changes permeability in porous systems. All of the pieces in their proposal hang together well, though of course, there are other options out there for most of them. The reviewer has two comments on how this work could better serve the program. First, the work focuses on porous media, as opposed to fractured media. Most current geothermal systems are found in highly fractured tight rock formations. Second, the work focuses on chemistry in the aqueous phase, and while that is important, it is also important to assess the reactions in the carbon dioxide (CO_2) phase.

Reviewer 63:
This project involves a great deal of interesting micro-fluidics type research. But the scaling up from pore scale to core scale is tough (especially with LB methods). The scaling up from core to ―relevant field scales” is even tougher. How this will be applicable at this level was not discussed.

Reviewer 45:
This research links into the program needs in an outstanding manner.

Reviewer 30:
Good progress has been achieved in terms of setting the project plans and the linkages but there are no significant results yet.

Reviewer 86:
This project is attempting to address a critical area for enhanced geothermal systems (EGS) using CO_2 with respect to permeability changes in the reservoir. The combined experimental and modeling approach has a good chance of significantly impacting our understanding of these processes and advancing the state of the art.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
No response entered.

Reviewer 63:
Is PIV necessary? It's very interesting, it makes for great insight into micro-scale methods and it appears to be performed very well in this project, but is it needed? The reviewer doesn‘t think so. It's extra fluff on what is a good project. Is LB necessary? It's very interesting, it makes for great insight into micro-scale fluid flow, but it's computationally expensive, even with GPUs. Dr. Saar was asked during the presentation what size domain would be able to be modeled with this

method, but evaded giving a direct answer. It's still useful and is a well-done project, but the reviewer is wary of being overly enthusiastic.
Reviewer 45:
This project uses an alternative to TOUGHREACT and is working on the reconciliation of the various databases to make this more accessible. The thermodynamic approach appears to be more rigorous.

Reviewer 30:
There is a clear connection between Tasks 1, 2 and 5. The connection between these and the remaining two tasks (3 and 4) is not strong. However, it seems to be interesting work and improvements to LB code would be useful. The pressure limit (30 MPa) on the rig is disappointing. Fifty would have given it the capability to simulate typical EGS reservoir conditions.

Reviewer 86:
The PI has demonstrated excellent progress in a short time with setup of a fairly complex flow-through pressure cell, velocimetry system, and start of model development. The in-situ pH probe development is a good extension to commercial probes that have been used for high-pressure pH measurements in the past. Obviously, pH is an aqueous fluid geochemical paramenter and the pH probe will be less useful for experiments in scCO2-dominated fluids where a condensed water phase is either very limited or simply not available for measurements. The PI demonstrated a clear and sound technical approach to validating and potentially improving modeling predictions of permeability changes in reactive chemical systems with CO2.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
No response entered.

Reviewer 63:
The reviewer can't count the PIV as an accomplishment, as he thinks its inclusion is outside the real scope of this project. The database is good, but the reviewer saw no information about the pore level simulations. While the reviewer thinks these will be done and will be interesting when completed, having nothing yet while being so near to the halfway point of the project is worrying.

Reviewer 45:
Overall, the reviewer considered this the strongest talk in the suite of presentations.

Reviewer 30:
Most of the ground work seems to have been completed and the team is ready to start producing results. There are no significant results yet that one can comment on. It would have been good to have plans on where the samples would be obtained from to test EGS-like conditions. At the moment, the experiment seems to be running with CO2-sequestration targets, albeit at elevated temperatures.

Reviewer 86:
So far, experiments presented are limited to an arkosic sandstone that is good for initial system checkout but is obviously not of particular relevance to the Geothermal Technologies Program (GTP). However, the PI has all the pieces in place now to make rapid progress with more relevant systems.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
This is good all around.

Reviewer 45:
The project is looking throughout for opportunities to significantly improve the value of the program and the code to DOE.

Reviewer 30:
The project is being managed well. Most core skills are in the project team and the connections—Lawrence Berkeley National Laboratory (LBNL), for TOUGHREACT mods and Northstar for XRCT—have already been established for others.

Reviewer 86:
The PI did not provide information on project spending to date so it is not possible to determine financial status of the project relative to timeline. Assuming the project is reasonably on track with spending, it appears to be well managed with clearly defined tasks integrated across the project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
The project uses novel techniques—PIV & LB simulations coupled with umCT scanning–to evaluate multiphase flow in pore space. While all the work presented was interesting and appeared to be performed with a high level of competency, the project is nearly half over and has not modeled/viewed fluid flow in pore space yet. The reviewer foresees this to be a big challenge and would strongly urge the researchers to get the geometry into the code as soon as possible.

Reviewer 45:
No response entered.

Reviewer 30:
This is an interesting project. The use of X-ray tomography is expected to deliver sub-micron resolution and this should be sufficient to collect good data on what happens at the pore space level.

Reviewer 86:
This project was one of best of the set of CO_2 projects presented and is addressing a key issue with long-term performance of CO_2-EGS systems.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:

The team has done a good job working together with experiments and simulations to obtain an improved model.

Reviewer 45:
Permeability experiments, even in the early stages, point to obvious challenges. The pressure change was about two orders of magnitude. The reconciliation of the data bases looks like an excellent effort that will be of benefit to the community. Coordinating with Karsten Pruess is good. They will be looking at upcoming issues. The University of Minnesota has a data conservancy center that will serve as the repository. The team is working with strong international collaborators. The pH meter for the in-situ application was an advance for the field. The massively parallel Lattice-Boltzmann simulations are being benefited by the link to the graphic processors. This will work for the X-ray tomography.

Reviewer 30:
The collaboration with the LBNL team (established outside the project) is commendable because this will help the research community access the outcomes of this project through an improved TOUGHREACT.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
The PIV experiments seem a bit like window dressing. The LB code could be verified in much simpler (and less expensive) ways.

Reviewer 45:
The effort needs to move into looking at the dry CO2 reservoir issues.

Reviewer 30:
The provision of typical rock samples to test remains a challenge. Both the choice of the pressure limit and the lack of evidence on thinking for the rock samples suggest a CO2 sequestration bias rather than an EGS focus. There probably is not much that can be done about the pressure but the rock selection needs to be addressed.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
Get the pore geometries as soon as possible.

Reviewer 45:
Well done, but they can add to the community a great deal by looking at fracture issues in the future.

Reviewer 30:

The issue of how to select typical EGS rock samples is a challenge not unique to this project and it is recommended that it is addressed by the DOE program coordinators.

Reviewer 86:

The flow-through cell design provided in the presentation shows separate lines at the column inlet for CO2 and water, with CO2 at the top and water at the bottom. The design would appear to allow the CO2 and water phases to enter the column and remain as separate phases relying only on mixing within the column. The PI needs to consider alternative designs that would permit injection of pre-equilibrated fluids with known water content, especially water-wet scCO2. Also, the water bath preheat constrains the inlet temperature to <100°C, which would introduce cold fluid for hydrothermal experiments in the flow-through cell. Again, a better design would allow for injection of equilibrated fluids at range of temperatures and pressures consistent with the design of pressurized flow cell.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1003
Presentation Title: Laboratory and Field Experimental Studies of CO2 as Heat Transmission
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 2.58

Comments Regarding Relevance/Impact of Research

Reviewer 62:
No response entered.

Reviewer 63:
This is essentially the same project as presentation #1004; as such, the comments are nearly identical. The reasoning for funding both projects is of course questionable. Using only porous media in the lab experiments limits the applicability of the results to non-fractured media. Most geothermal sites, planned or operational, are fractured. Any model that is based on this experimental work is limited from the beginning.

Reviewer 45:
Japan is injecting a brine-carbon dioxide (CO2) mixture where temperature (T)=210°C and pressure (P) = 100 bar. Claims about the heat recovery were not substantiated by an engineering assessment.

Reviewer 30:
This is a very strong team and the objectives are very ambitious and non-trivial. However, it is not clearly explained how the proposed work schedule is linked to these objectives.

Reviewer 86:
Reservoir simulation is of critical importance to enhanced geothermal systems (EGS) so this project is on target. However, with uncertainty over the Ogachi field test, it is not clear that this project will achieve the original objectives. Comparisons with the laboratory column experiments are fine but the design of these experiments did not seem thought out to sufficiently challenge the fundamental physics and chemistry in the reactive flow system that would lead to advancement in TOUGHREACT capabilities.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
No response entered.

Reviewer 63:
One of the two main thrusts of this work (i.e., field level measurements) has not been done, and (it seems) with the pull-out of Ogachi partners and the retirement of Karsten this field testing is in jeopardy of actually being completed. The modeling work on the experimental project needs some fundamental help. Apparently the research student performing the simulations is also doing the experiments, which is nice for continuity between the two, but will probably result in less focused/refined results from both.

Reviewer 45:
The team is looking at CO2 movement and saturation in the field. They are looking at future injection sites and natural

analogues.

Reviewer 30:
The tests with the sand-filled test cell will not produce outcomes that can be used to test TOUGHREACT assumptions on physics of fracture and porespace fluids. The connection with Ogachi is tenuous. The aqueous mixing of the sCO2-spiked river water with the reservoir fluid provides a good case study to model using TOUGHREACT but not enough data to constrain it because Ogachi measurements are limited to the injection well neighborhood. It is likely that further Ogachi testing will not happen within the lifetime of this project. Alternates are offered but it is not clear if the budget has enough contingency to afford them.

Reviewer 86:
TOUGHREACT is a well-established model and the PI is experienced in executing the simulator. Provided the Ogachi field test occurs and some more challenging lab experiments are performed, the modest budget for this project should result in reasonable scientific advancement.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
No response entered.

Reviewer 63:
The progress seems confined to some lab experiments in porous media; simulations of this lab experiment are in the ball park of the right values and some 5-spot TOUGHREACT. There is a great deal more that needs to be done to really make headway in understanding CO2's ability to act as the working fluid in an EGS situation.

Reviewer 45:
Compared to steam/water, CO2 could extract heat at 50% higher rates. However, this claim has not been substantially demonstrated even using available data. Several multi-year research barriers are addressed. An experimental system is up and operating.

Reviewer 30:
The main achievement is the construction of the test rig. However, the model development and the experimental schedule seem to be moving on separate tracks. The present test configuration with flow through a sand-filled cylinder is trivially simple to model and there can even be found analytical solutions for such a problem in the porous media literature. It is not clear how the results from those tests will help with formulating better TOUGHREACT assumptions.

Reviewer 86:
The PI provided no information on spending to date or progress with respect to a planned timeline. The PI presented three simulations conducted over the course of over one year, which seems awfully limited in terms of progress.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
Seems ok, but the reviewer questions the reasoning behind having both the experimental and simulation lab-scale work being done by the same student.

Reviewer 45:
Karstan Pruess is departing and he has been a driving force for this program, providing information on data, reports, and model results. They anticipate close coordination with PARC. However, PARC does not appear to be a strong technical resource.

Reviewer 30:
This is a close-knit and strong team and seems to be working well. However, the fall-back options against the Ogachi testing program failing to get funded in Japan are not realistic because of the expected impact they would cause on the project budget.

Reviewer 86:
Again, the PI provided no information on spending to date or progress with respect to a planned timeline. Also, the retirement of Karsten Pruess is a significant concern with respect to project management and technical direction. The project does seem to be well coordinated with the separate field and laboratory experiments providing data to this project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
The majority of the work presented is numerical; there is not a lot of experimental backing, which seems odd given the title of the project. The ties to the field project were not stressed as much in the presentation of this project as this reviewer had hoped. The goal is noble and seems reasonable, but the progress seems a bit slow and the focus on only CO2 flow in porous media (i.e., no fractures) seems limited. On the plus side, the personnel seem competent and the project goals make sense.

Reviewer 45:
The project did a nice report on the 5-spot test over a multi-year period. They concluded that the fractured reservoirs have good properties for CO2 heat transfer. The project objectives are ambitious.

Reviewer 30:
There has not been significant progress to produce results with significant impact. The findings about Peclet number are not significant and reflect a well- established phenomenon in forced convection. The innovation in the project is not clear. The planned laboratory test schedule and the field observations are not likely to produce results with significant impact.

Reviewer 86:
This project is likely to make a modest contribution to the Geothermal Technologies Program (GTP) given the modest budget and issues with the field experiment in Japan. The 5-spot production simulations are interesting but seem to have been done just to exercise the simulator and are not tied to a possible validation planned for execution in the field (or at least that was not made clear in the presentation).

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
Personnel competency seems strong and the project goals make sense.

Reviewer 45:
Work in an actual reservoir with an international partner is of high value. The well observations have been nicely reconciled with the model.

Reviewer 30:
As already noted above, this is a strong team and has yet chance to produce significant results in terms of a significantly improved TOUGHREACT. The improvements, however, may come not from testing in this project but from tests in other DOE-funded projects. The LBNL team already has linkages established with some of these projects.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
It just seems like this should be a bit farther along. The obtaining field data from Ogachi site seems a little unlikely, though this reviewer hopes it works out.

Reviewer 45:
The interpretation of the reactor experiments still needs to be refined.

Reviewer 30:
The link with the experimental schedule and the model development is not well- established.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
Get another person in the lab to help the poor chap who's doing both the experimental and small-scale simulations.

Reviewer 45:
A stronger engineering assessment would assist in aligning the experimental program goals with the end-user needs.

Reviewer 30:
The DOE Program Management may try to facilitate the collaboration between the Pruess-Xu team and all other projects producing test data. This may provide the team with data more likely to provide constraints for the modeling.

Reviewer 86:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1004
Presentation Title: Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 2.66

Comments Regarding Relevance/Impact of Research

Reviewer 62:
This work could potentially be very helpful to the program. Simulation results (built on modeling work that is of good quality) will help to understand some of the important aspects of a geothermal system with carbon dioxide (CO_2) as a working fluid. One of the most relevant parts of the program is the prediction of the drying out of the aqueous phase from the porous medium. Again, there could be more of a focus on fractures, but this work could help understand important pieces of permeable fractured media.

Reviewer 63:
This is essentially the same project as presentation #1003; as such, the comments are nearly identical. The reasoning for funding both projects is of course questionable. Using only porous media in the lab experiments limits the applicability of the results to non-fractured media. Most geothermal sites, planned or operational, are fractured. Any model that is based on this experimental work is limited from the beginning.

Reviewer 45:
This project includes a test of predictions about heat transfer and fluid flow for CO_2. This should lead to a field test. They are also looking at natural analogue studies.

Reviewer 30:
This is a very strong team and the objectives are very ambitious and non-trivial. However, it is not clearly explained how the proposed work schedule is linked to these objectives.

Reviewer 86:
The CO_2 core flood experiments are targeted at a key issue for enhanced geothermal systems (EGS) using CO_2. There is also a strong need for validation of simulator predictions in these complex systems.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
They are considering fractured media for experimental studies in the future. This would help with relevance of transfer mechanisms to field. There are still some questions of scale-up from the core scale information to the field scale.

Reviewer 63:
The modeling work on the experimental project needs some fundamental help. Apparently the research student performing the simulations is also doing the experiments, which is nice for continuity between the two, but will probably result in less focused/refined results from both.

Reviewer 45:
Experimenter and modeler are the same which is a strength for this effort. The suggestion of investigating the use of a

plugging reaction to create a reservoir cap was not supported by a convincing assessment.

Reviewer 30:
The objectives are very exciting. In particular, the objectives on "water removal mechanisms" and "reservoir stimulation and development using CO2" are very topical. But, how will lab tests of heat extraction from a sand pack help these objectives? The utility of the experiments with dry cold CO2 through the sand bed is very limited. The alluded Peclet-number dependence is well known in porous medium literature. The choice of using a subcritical inlet further limits the utility.

Reviewer 86:
The core flood apparatus being used for model validation does not seem to implement any new design concepts or techniques nor were any plans presented to introduce methods for fluid imaging, in situ chemistry measurements, or other methods to enhance the data set being collected and so enhance the value of the experiments for model validation. Simply measuring temperature changes with a few embedded thermocouples does not seem commensurate with the capabilities at Lawrence Berkeley National Laboratory (LBNL).

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
Progress seemed to be good thus far in the project and headed in the right direction. Work is pretty well defined.

Reviewer 63:
The progress seems confined to some lab experiments in porous media and simulations of this lab experiment that are in the ball park of the right values. There is a great deal more that needs to be done to really make headway in understanding CO2's ability to act as the working fluid in an EGS situation.

Reviewer 45:
Refinements are certainly needed in the model.

Reviewer 30:
The main achievement is the construction of the test rig. However, the model development and the experimental schedule seem to be moving on separate tracks. The present test configuration with flow through a sand-filled cylinder is trivially simple to model and there can even be found analytical solutions for such a problem in the porous media literature. It is not clear how the results from those tests will help with formulating better TOUGHREACT assumptions.

Reviewer 86:
The PI demonstrated completion of a few standard core flood experiments and a single comparison with TOUGH2/ECO2N modeling. Although the first model predictions showed quite significant differences around passage of the thermal shock at each thermocouple, the PI did not comment on these differences or indicate plans to investigate these discrepancies. Again, the very limited results presented after a year of work does not seem consistent with the resources available at LBNL.

Comments Regarding Project Management/Coordination

Reviewer 62:
The project is not too broad, hangs well together, and appears to be managed well. One concern is the resigning of the PI, though appropriate people for replacement seem to have been chosen.

Reviewer 63:
Project management/coordination seems ok, but the reviewer questions the reasoning behind having both the experimental and simulation lab scale work being done by the same student.

Reviewer 45:
There is a new manager eight days into the project with the departure of Karstan Pruess. This began with internal laboratory funding.

Reviewer 30:
The future plans include investigating "the potential use of CO2 for chemical stimulation of water-based EGS." This is a major departure from the project objectives. Why this is required and how it is going to be done needs to be clarified.

Reviewer 86:
Again for this project, the PI provided no information on spending to date or progress with respect to a planned timeline. Also, the retirement of Karsten Pruess is a significant concern with respect to project management and technical direction. The project does seem to be well coordinated with the laboratory experiments even though as stated above, these experiments don't seem to be planned to extract the maximum amount of information that could be used to challenge the simulations.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
The goal is noble and seems reasonable, but the progress seems a bit slow and the focus on only CO2 flow in porous media (i.e., no fractures) seems limited. On the plus side, the personnel seem competent and the project goals make sense.

Reviewer 45:
Develop favorable and unfavorable reservoirs and possible use of stimulants.

Reviewer 30:
While this is a strong team, the innovation content in the project is not clear. The planned laboratory test schedule is not likely to produce results with significant impact.

Reviewer 86:
The project is presently configured to make some advances in reservoir simulations relevant to EGS. However, the experiments do not seem to be designed to take maximum advantage of the resources at LBNL so that key data on fluid saturations, chemistry, relative permeability, and other parameters are obtained to better constrain and advance the model validation task.

Comments Regarding Strengths
Reviewer 62:
No response entered.

Reviewer 63:

Personnel competency seems strong and the project goals make sense.

Reviewer 45:
CO_2 brine flow heat extraction is of high importance.

Reviewer 30:
As already noted above, this is a strong team and has yet chance to produce significant results in terms of a significantly improved TOUGHREACT. The improvements, however, may come not from testing in this project but from tests in other DOE-funded projects. The LBNL team already has linkages established with some of these projects.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
It just seems like this should be a bit farther along.

Reviewer 45:
The data in the literature for equations of the state of CO_2 under high pressure should be explored before developing another model, particularly since this is not the strong expertise of the personnel involved.

Reviewer 30:
The link with the experimental schedule and the model development is not well established.

Reviewer 86:
Integration with the PARC project was claimed in the presentation but that project seems to be focusing on pure mineral systems that are presently largely irrelevant to the experiments done to date. Also, the lack of apparent intent to monitor fluid chemistry in the experiments (temperature only was presented) does not suggest current coordination with the PARC project objectives.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
Get another person in the lab to help the poor chap who's doing both the experimental and small-scale simulations.

Reviewer 45:
The chemical engineering literature should be reviewed in greater depth to provide guidance for the experimental work.

Reviewer 30:
The DOE program management may try to facilitate the collaboration between the Pruess-Xu team and all other projects producing test data. This may provide the team with data more likely to provide constraints for the modeling.

Reviewer 86:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1005
Presentation Title: Synchrotron X-Ray Studies of Supercritical Carbon Dioxide/Reservoir Rock Interfaces (ANL)
Investigator: You, Hoydoo (Argonne National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 3.20

Comments Regarding Relevance/Impact of Research

Reviewer 62:
No response entered.

Reviewer 63:
Understanding how the mineral surfaces react with supercritical carbon dioxide (scCO2) is important for describing the effects of scCO2 in enhanced geothermal system (EGS) situations. By using a synchrotron and a custom flowc ell, this project will provide unprecedented views of how mineral surfaces react under scCO2 at EGS conditions.

Reviewer 30:
This is an exciting project. The results with the static cell show the capability of the measurement method. The scheduled tests with the flow cell should provide very useful data on the dynamic interaction of granite with sCO2 and water mixtures.

Reviewer 86:
This project is developing a new enabling technology to collect synchrotron x-ray data under high-pressure and high-temperature conditions. Such data are very rare and critical to understanding mineral transformation reactions in water-wet scCO2 of key importance to EGS systems using CO2.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
This project includes flow through experiments looking at different CO2-water ratios to see at what conditions things start to happen. It is good to see a group looking at the reactions in the CO2 phase, which will be important for the geothermal systems (at least to determine relevance). The plan will get quantitative dissolution rates on samples, which will be helpful.

Reviewer 63:
This may be the best approach for the small scale. The change to surfaces under these conditions. Everybody else‘s questions focused on how quantitative the results will be, which is valid. This reviewer still feels this is an excellent use of resources and an important method to be utilizing.

Reviewer 30:
The decision to perform separate tests with three fundamental granite minerals rather than testing ―typical EGS rocks" is a good idea and avoids some of the difficulties faced by other testing projects in acquiring representative test samples.

Reviewer 86:
The PI demonstrated good progress toward development of suitable pressure cells for study at the APS. Minerals targeted

for initial study are relevant.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
Accomplishments so far are sufficient, between fair and good. Benefits of the project will be realized this year, if the new cells are able to produce results.

Reviewer 63:
Cell was produced and the static measurements were performed showing that the process works to obtain changes in the mineral surface roughness.

Reviewer 30:
The initial hypothesis that in situ synchrotron X-ray measurements will be accurate enough to detect the nanoscale changes in the mineral interface with the flowing fluids is supported by the static tests. The project seems to be running slightly behind schedule and it will be a challenge to commission the flow cell, perform the flow tests, and issue the final report in the next three months.

Reviewer 86:
The PI has made good progress with cell development and collected data with the batch cell design on orthoclase, quartz, and muscovite. The PI did not note the identity or chemical composition of the corrosion product formed on the orthoclase surface. Changes in the intercalation distance with muscovite are interesting and need further study.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
Everything seems to be going smoothly.

Reviewer 30:
This is not a particularly challenging project in terms of management and it seems to be running well in spite of the small delay in starting the flow cell tests.

Reviewer 86:
This project appears to be well managed with spending and timeline well within tolerance.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
This project uses a novel HPHT flow cell and a synchrotron source to provide unprecedented views of how scCO2 reacts with mineral surfaces and alters the surface roughness.

Reviewer 30:
This is a fundamental research project that has the potential to produce a powerful tool to examine the dynamic interaction between rock and geothermal fluids. The data should be invaluable in developing constitutive relationships for modeling of such interactions.

Reviewer 86:
This project is on track to develop a critical enabling technology for understanding mineral transformation reactions in wet scCO2-rock systems. This reviewer‘s key recommendation is for the PI to consider building in work (or collaborating with work underway at Pacific Northwest National Laboratory or Oak Ridge National Laboratory) on in-situ X-ray diffraction with rotating anode X-ray sources. Beam time at APS is inherently limited and some of these transformation reactions take extended time periods. Raising temperature to speed kinetics does not always result in the same end products. Conducting periodic measurements with the rotating anode machines would provide a critical bridge between conducting more frequent measurements and available APS beam time.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
This is an excellent use of resources and is a unique study that is investigating phenomena that needs to be understood.

Reviewer 30:
These have already been noted above, but the strengths are summarized here: (1) Introduction of a new measurement technique to characterize dynamic interaction between rock and geothermal fluids, and (2) The decision to use granite minerals rather than "typical EGS rocks."

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
With synchrotron work, the limited amount of access of the beamline is always an issue.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
No response entered

Reviewer 63:
None.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1006
Presentation Title: Carbonation Mechanisms of Reservoir Rock by Supercritical Dioxide
Investigator: Butcher, Thomas (Brookhaven National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 2.38

Comments Regarding Relevance/Impact of Research

Reviewer 62:
It is nice to see some work on the supercritical carbon dioxide (scCO2) phase of the subsurface.

Reviewer 63:
What are the benefits of making the powdered samples? This was a different presentation than originally on the lab. The presenter did not seem to have a strong grasp of what the mineral interactions should have been for this experiment a priori.

Reviewer 45:
The static blend exposure tests have not demonstrated that they have been long enough to warrant their providing credible data for the program. The compressive strength tests were unique and controversial; however, no other group conducted such tests and hence this approach was of interest in adding some experimental data to the program.

Reviewer 30:
The innovative content in this project is not clear. Results so far do not offer new insights and some of them may have been assigned significance they do not have, for example, the compressive strength test results where the variation is well within the typical scatter of such tests.

Reviewer 86:
This project is similar to several others in the CO2 set with intentions to address carbonation reactions of key importance to enhanced geothermal systems (EGS) using CO2. However, this reviewer cannot rate the impact of this project above fair due to technical and conceptual problems with the approach presented and discussed below. No novel techniques or approaches were presented to collect the necessary data or improve fundamental understanding of the carbonation reactions in wet scCO2 and technical problems noted below will compromise the impact of this research.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
No response entered.

Reviewer 63:
Evaluating the chemical changes of granite and diorite makes sense and the small-scale imaging does give some insight into the structural changes to the material. The changes to the compressive strength and the porosity are questionable though.

Reviewer 45:
Presented FTIR of before-exposure and after-exposure cases. The timeline running over many days showing the secondary reaction and the chemical reaction with the granite over the long term are of significant interest. This project is

looking at water-sensitive and water-insensitive water carbonation products. The project includes the following: an scCO2-exposure test and follow up analysis for pure minerals, chemical analysis of bore core rock samples from EGS reservoir sites to obtain information on distribution and proportion of various different minerals, an scCO2-exposure test and follow up analysis for bore core samples, and integration of all data and establishment of modeling.

Reviewer 30:
All observations seem to be limited to mechanical data such as the weight of loss, compressive strength, etc. This may reflect the discipline background of the project team but will reduce the value of the findings of the project. In particular, the project team needs mineralogy/geochemisty expertise. This is to avoid statements such as "…between sCO2 and rock minerals, particularly granite, and other minor minerals." Granite is a type of rock, not a mineral.

Reviewer 86:
The technique being employed to study wet scCO2 carbonation reactions is a simple cook and look approach. Only the most basic of data is being collected, which includes weight change, elemental analysis, and porosity (though this was only evident upon questioning the PI). With 66% of the time and $330,000 spent of a $493,000 budget, the PI has apparently managed to run a few batch tests for three months maximum time so far with five rock samples. The PI does not appear to have a clearly formulated scientific hypothesis or experimental plan that would address fundamental questions about scCO2 transformation reactions with these rocks.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
No response entered.

Reviewer 63:
Short-term tests were completed but with (what appears to be) a limited amount of information from them.

Reviewer 45:
Conclusion on two carbonation type mechanisms.

Reviewer 30:
Experimental data have been collected but they are presented in a context that provides useful insights.

Reviewer 86:
The PI did not appear to have the requisite geochemical knowledge to successfully execute this project. For example, the aqueous carbonation reactions shown on the introductory slides represented carbonate anions as the reactive species when under the low pH conditions of scCO2-water systems, aqueous speciation of carbonate is dominated by dissolved CO2 and a little bicarbonate. The PI did not seem to recognize the very strange nature of the results he was reporting with granite samples being carbonated extensively and yet losing weight and gaining porosity. In water-wet scCO2, there should be no continuous aqueous phase to transport mass away from a sample suspended in the supercritical fluid. Both water and any carbonate mineral formed must accumulate as mass on the sample unless spallation or some other process is removing it. Spallation would not remove mass in a real subsurface system so even if this was occurring in the experiments, it would have no bearing on actual processes in the subsurface. The evident failure of the PI to recognize these basic facts casts serious doubt on any significant or reliable results being developed from this project.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
Project management/coordination seems good overall.

Reviewer 45:
The management looks good.

Reviewer 30:
While AltaRock is listed as a project partner, it does not look like this partnership is operating through regular meetings and exchange of views during the conduct of the project. It is a minor point but even the name is consistently misspelled as "AltraRock" in the presented documents.

Reviewer 86:
Although spending and timeline are within reasonable limits, this project appears to be suffering from a lack of PI experience and knowledge in scCO2 geochemistry and reactivity in geologic systems. Retaining a more experienced co-PI could help correct some of the technical and leadership issues that are apparent on this project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
The carbonation mechanisms being sought as part of this project make sense. There seems to be good progress toward making measurements on reacted samples, but there seems to be little work to date on summarizing the models of CO2-rock interactions.

Reviewer 45:
Considering the very modest funding, the program was of benefit.

Reviewer 30:
This is a project that desperately needs input from people with expertise in mineralogy and petrography. The measurements seem to be limited to weight loss. No systematic mineralogy or petrographic study has been conducted of the samples before and after the experiments. The value is limited.

Reviewer 86:
This project does not appear to be on track to produce results that are technically sound or likely to make significant contributions to the Geothermal Technologies Program (GTP).

Comments Regarding Strengths

Reviewer 62:
No response entered

Reviewer 63:
There are important reactions to characterize.

Reviewer 45:
No response entered

Reviewer 30:
No response entered.
Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered

Reviewer 63:
Linkages between small-scale reactions and core-scale changes (porosity, strength) seem tenuous.

Reviewer 45:
Sample preparation is critical and this is not well characterized. The program needs to document that the weight loss in the sample is actually taking place. At the same time, irrespective of this weakness, the program seems to be observing a significant aspect of the reactive performance for these systems.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
Stronger characterization of the sample preparation and the weight loss from the system is needed. In fact, there may be no weight loss; however, there may well be the disappearance of a crystalline phase and here even simple studies would help.

Reviewer 30:
The weaknesses have been noted above.

Reviewer 86:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1007
Presentation Title: Chemical Impact of Elevated CO2 on Geothermal Energy Production
Investigator: Carroll, Susan (Lawrence Livermore National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 3.30

Comments Regarding Relevance/Impact of Research

Reviewer 62:
Rates of reaction at high temperatures are lower than extrapolated rates. This is an important result and an important reason for these results, though in the end it may suggest that the reactions with supercritical carbon dioxide (scCO2) aren't that critical a part of the program.

Reviewer 63:
It is a huge loss not having the field data. But, overall this is the best example presented in this group of not reinventing the wheel. Learning from the geochemical reactions has already been observed in geologic sequestration.

Reviewer 45:
This project is practical rather than innovative (comment from speaker). The project measures realistic rock-water rates for geothermal systems using laboratory experiments to simulate production scale impacts. Experimental results will provide the data needed to constrain reactive-transport simulations used to address the role that mineral alteration will play in the enhanced geothermal system (EGS)-CO2 environment and the feasibility of using CO2 as a heat exchanging fluid.

Reviewer 30:
This is a fundamental study aiming to increase our understanding of sCO2-brinerock interaction by using naturally CO2-rich geothermal fields as analogues. The impact will not be immediately available but will be of significant value in constructing better models as well as will help interpreting the results of the other experimental projects currently funded in this round.

Reviewer 86:
This project is collecting kinetic rate law information on relevant rocks and mineral samples to the GTP. Uncertainty regarding coordination with a field experiment in New Zealand or elsewhere raises uncertainty about achieving the originally intended impacts of this project.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
No response entered.

Reviewer 63:
This project seems to have the best foundation and experience for describing the mineral reaction rates out of the several groups that are currently working on this. The sequestration synergy is an important aspect of this report as well.

Reviewer 45:
Field and laboratory studies are being conducted with sophisticated thermodynamic understanding.

Reviewer 30:
Using natural analogues is a well-established technique. It is also a good idea to use the natural field conditions as a starting point for constructing laboratory experiments where the conditions can be varied over a wider range. This reviewer thought it was an innovative feature of this project to carry out tests in the field to validate the findings of the lab tests. It is a pity to find out that this probably is not going to happen possibly due to time and budget constraints.

Reviewer 86:
The PI is focusing on aqueous-dominated rock-water systems, which although is likely of less significance for most CO2-EGS projects, does constrain the project in a focused technical direction. The flow-through experiments appear to be well designed and the PI is experienced in the interpretation of these data.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
The project team found that the measured rates are orders of magnitude different from the extrapolations. There was unstable chlorite even in rocks where they thought there was not much clay.

Reviewer 30:
The upgrade of an existing hydrothermal test rig to cover supercritical CO2 conditions has enabled the project team to start producing good results. It is disappointing that the project team seems to have decided not to conduct the field experiments even though they were in the initial set of objectives. Even a set of initial tests would provide good insights and help construct a more comprehensive experimental program in future extensions subject to availability of further funding.

Reviewer 86:
The PI has made good progress on experimental system setup and has collected a reasonable data set on chlorite. A key issue going forward is the ability to execute any sort of field project with the time and particularly budget left on this project.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
It is too bad about the field test, but it seems like contact is being kept up between researchers and field operators, as well as laying a foundation for future work (i.e., contact with ORMAT).

Reviewer 45:
The project also linked to other CO2 field demonstration projects, hence, there is a good opportunity to cross-compare results.

Reviewer 30:
The project involves contributions from New Zealand and the collaboration seems to be working well. There is no evidence that the cancellation of the field experiments is due to poor management. It is also commendable that the PIs are able to use leveraging from the CO2 sequestration project investment.

Reviewer 86:
The project appears to be significantly overspent with 50% of the timeline expired but 75% of the budget spent. This is particularly severe since planned field activities have not occurred to date. Given time and funding constraints, focusing remaining resources on completing the laboratory experiments may be the best use of funds.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
This project demonstrates excellent crossover from sequestration to geothermal. This working from both sides has really enabled a greater understanding of the most relevant chemical relationships from the beginning of this project, rather than ―reinventing the wheel."

Reviewer 45:
This was one of the strongest presentations and a job well done.

Reviewer 30:
This is a good project. As already noted above, it will bring new understanding to the way sCO2 and brine interact with the reservoir rock by using naturally CO2- rich geothermal fields as analogues. Starting with observations from actual geothermal sites, lab tests that start from the natural field conditions but cover a wider range of CO2 compositions, and finally, validating the results of the lab tests by going back to the original field and performing field tests on the in situ reservoir brine are innovative features. A possible improvement would be increasing the range of the natural CO2 in the brine by considering other geothermal fields with higher natural CO2 content, e.g., some Turkish geothermal sites as well as some sites in Tuscany.

Reviewer 86:
This project is likely to make solid contributions to kinetic rate law data for several key mineral-rock systems. The PI is encouraged to think through the feasibility of field work participation given time and funding constraints on this project.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
Links with the overall hydrodynamics of a specific reservoir are a strength of this project.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
The development of rate equations would also benefit from a review of the extensive engineering literature and broadening the base beyond Geochimica et Cosmochimica Acta.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
The reviewer would really like to see some data from a field site to better guide both this and other projects in identifying the most important aspects to be modeling/studying in the lab.

Reviewer 45:
Future work will look at recovering the dissolved water and using it in an NMR cell. Look again at field experiments and re-submit.

Reviewer 30:
A possible improvement would be increasing the range of the natural CO2 in the brine by considering other geothermal fields with higher natural CO2 content, e.g., some Turkish geothermal sites as well as some sites in Tuscany. It is also recommended that the brine compositions used in this project be made available to the other experimental projects (e.g., the two projects using X-ray tomography) in a timely fashion so that they can perform at least some limited testing to see the difference from the artificially constructed brine without the complex reservoir geochemistry.

Reviewer 86:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1008
Presentation Title: Properties of CO2 Rich Pore Fluids and their Effect on Porosity Evolution in EGS Rocks
Investigator: Cole, David (Oak Ridge National Laboratory)
Panel: Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: 3.58

Comments Regarding Relevance/Impact of Research

Reviewer 62:
This could be fair or good. This research is mostly relevant to very tight granite rocks. In such rocks, micropores *may* be relevant to movement on the field scale. For other types of formations, this data is not as useful. If the program imagines using carbon dioxide (CO2) for very tight granite rocks, then the work is good.

Reviewer 63:
No response entered.

Reviewer 45:
Relevance/impact of research includes small-angle neutron scattering to examine bulk vs. pore fluid properties. This reviewer considered this one of the two strongest presentations on the program.

Reviewer 30:
This a very innovative project introducing new experimental techniques to better understand the behavior of pore-confined fluids and pore-space processes. In spite of the novelty of the idea, it looks like the techniques have already been well established and the team has been able to produce good results.

Reviewer 86:
This project is developing two unique experimental techniques to evaluate pore fluid properties and transport behavior in fractured/porous rock systems under relevant in-situ conditions. These techniques represent a significant advance in the present state-of-the-art.

Comments Regarding Scientific/Technical Approach

Reviewer 62:
This is a very well put together technical program.

Reviewer 63:
No response entered.

Reviewer 45:
Project includes first measurements for compositions in the pores using a novel technique. For field measurements from geysers, the normal temperature zone and the high-temperature zone are quite different. The project team is using a neutron imaging facility in the first application. They will use neutron flow tomography at actual geothermal conditions. They are showing both the saturated and unsaturated zones. They observed that porosity is not evenly distributed but seems to fall into planes.

Reviewer 30:

The strength of this project is in combining the considerable talents and the experimental infrastructure at Oak Ridge National Laboratory (ORNL) with the substantial geothermal energy domain experience and knowledge of the numerous collaborators from Lawrence Berkeley National Laboratory (LBNL) and the industry stakeholders. The use of the high-temperature flow vibrating tube densimeters (HTVTD) to measure the pore-confined fluid properties is a world-first and is one of the most innovative features of this project. The neuron tomography also seems to be working well although it is early days yet in the use of this latter tool.

Reviewer 86:
The experimental techniques are novel and appear to be well suited to collect data that is difficult or impossible to collect by other means.

Comments Regarding Accomplishments, Results and Progress

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
The first measurements are over seven orders of magnitude of pores. The project includes HTVTD. Trying to clarify what to believe regarding the discrepancies in the phase equilibria data. Other absorption methods do not get total porosity as measured by this technique.

Reviewer 30:
Quantitatively establishing the dependence of the pore-confined fluid on the pore size is a significant achievement. The neutron tomography results as presented do not seem to be bringing new insights yet but validate the technique. More results and really exciting insights are bound to come out from further extension and development of this technique.

Reviewer 86:
The PI is making good progress in equipment development and has demonstrated operating principles on model systems. The PI does need to transition quickly into measurements with samples more relevant to the Geothermal Technologies Program (GTP) enhanced geothermal systems (EGS) program.

Comments Regarding Project Management/Coordination

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
The project also linked with fluid behavior in confined pores.

Reviewer 30:
One of the several strengths of this project is the substance of contributions from the research collaborators, with field samples for testing as well as geothermal domain knowledge. A complex testing program schedule seems to have been carried out on schedule and on budget and was also able to produce very exciting results. This is a commendable

achievement.

Reviewer 86:
The project is on track with spending and timeline and is making good progress on technique and equipment development.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 62:
No response entered.

Reviewer 63:
This is a nice presentation and a good body of work. As this project is coming to an end in the not too distant future, it would behoove both the researchers and the geothermal community to get more of this information published.

Reviewer 45:
This is a very strong team with a vision to see through the effort.

Reviewer 30:
This reviewer has already commented on many innovative features and exciting achievements in this project. This a very innovative project introducing new experimental techniques to better understand the behavior of pore-confined fluids and pore-space processes. In spite of the novelty of the idea, it looks like the team has managed not only to establish the validity of the techniques but also has produced good results.

Reviewer 86:
This project was one of the best of the set of CO2 projects and is poised to make critical contributions to the GTP EGS program.

Comments Regarding Strengths

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
Well done.

Reviewer 30:
The strength of this project is in combining the considerable talents and the experimental infrastructure at ORNL with the substantial geothermal energy domain experience and knowledge of the numerous collaborators from LBNL and the industry stakeholders. The use of the HTVTD to measure the pore-confined fluid properties is a world-first and is one of the most innovative features of this project. The neuron tomography also seems to be working well although it is early days yet in the use of this latter tool.

Reviewer 86:
No response entered.

Comments Regarding Weaknesses

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
No response entered.

Reviewer 30:
No response entered.

Reviewer 86:
The vibrating tube densitometer (VTD) tests are very interesting but so far only conducted with either pure fluids or fluids confined in aerogel. The fractured and porous rock systems of interest for EGS will have far lower porosity than aerogel and density that is much higher than supercritical CO2 (scCO2). Both of these factors will make detecting fluid density changes much more difficult. This reviewer is concerned about the sensitivity and resolution of the VTD to detect fluid density changes with real rock samples. The PI needs to quickly demonstrate that capability and continue the work, or if the results do not appear promising, then focus more effort on the neutron imaging task.

Suggestions for Improvement

Reviewer 62:
No response entered.

Reviewer 63:
No response entered.

Reviewer 45:
Include diagrams for use at SNS at lower costs vessels than for the current titanium. Address tasks 1, 2, and 3.

Reviewer 30:
No response entered.

Reviewer 86:
No response entered.

Systems Analysis, Resources Assessments, Data Systems Development and Population

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0100
Presentation Title: Systems Engineering Analysis (SNL)
Investigator: Lowry, Thomas (Sandia National Laboratories)

Comments Regarding Relevance/Impact of Research

Reviewer 43:
There are assumptions that may limit the classes of reservoir models that may be used with this code. This reviewer cannot tell if this tool will have sufficient credibility so that others will use it. One reviewer suggested finding data sets to test the complete tool on, and that is a good idea. The risk analysis will be quite valuable if the model is believed.

Reviewer 29:
The full-field simulator is a useful tool for scenario analysis and relevant for DOE's systems analysis program. The target audience is also clear.

Reviewer 27:
No response entered.

Comments Regarding Scientific/Technical Approach

Reviewer 43:
This reviewer ranked this only "fair" because the PI has not convinced him that combining system dynamics (SD) into the reservoir models is going to work in a meaningful way. Perhaps that is the reviewer‘s problem and not his.

Reviewer 29:
The strong link and integration into GETEM is particularly good and represents a very consistent approach. Scenarios can be modeled well, but decisions to be taken along the way, evaluating the value of information (VoI) of choices made at certain decision points appears to be a complex, but doable undertaking. This reviewer thinks the water/steam gathering systems and separation facilities warrant some attention.

Reviewer 27:
No response entered.

Comments Regarding Accomplishments, Results and Progress

Reviewer 43:
The project has spent about half the money, and is about halfway done.

Reviewer 29:
Progress towards Beta 1 version appears to be good. The model would benefit greatly from some benchmarking—fit-for-purpose for each version. Test-cases or benchmarks derived from real field developments may provide highly valuable quality control and assurance.

Reviewer 27:
This is notably one of the presentations reviewed that actually included timelines and accomplishments/decision points that made the results and future task clear and understandable.

Comments Regarding Project Management/Coordination

Reviewer 43:
None.

Reviewer 29:
Rescoping of this fairly complex project does not help. Intermittent flow of funds does not help either. The project would in all likelihood benefit highly from industrial partners.

Reviewer 27:
The previous GRC publication (Lowry et al, 2010) outlined the following program goals: 1. An economic parameter space for different geothermal technologies as a function of location, heat extraction technology, geologic conditions, power plant type and configuration, available resources, and economics; 2. Identify the key gaps in understanding and technology that pertain to exploration, site selection, site development, heat extraction, and heat conversion; 3. Identify the integrated technical and economic bottle necks and uncertainties associated with developing a geothermal resource; and 4. Incorporate spatial variability in the evaluation of a geothermal resource. The publication also suggests the following functionalities: 1. Heat extraction systems beyond enhanced geothermal systems (EGS); 2. Linking to and/or utilizing ongoing work in detailed reservoir modeling; 3. Developing the spatial, economic and institutional modules; 4. Continued development of the graphical user interface; and 5. Soliciting and gathering stakeholder input and involvement. The presentation does not directly address progress toward these specific goals and (presumably) generalizes for simplicity, but would these stated project goals be addressed in the final documentation?

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 43:
This project is combining SD modeling , analytical modeling and risk assessment to produce a tool to estimate physical and economic performance uncertainties. SD assumes that connected systems can be connected by "causal loops" that can be represented by first-order differential equations, and that a geothermal production facility can be represented adequately by a set of these systems and "causal loops." The PI indicates that this approach can expand on the economic information contained in GETEM, and can provide risk/reward curves for various parameters of the operation. This reviewer‘s main concern about the project is that he does not see how realistic reservoir models can be incorporated into the SD models. The PI suggested that this would be accomplished by generating a lookup table in a dimensionless parameter space. That seems possible to do for simplistic models, such as Gringarten's, but for a realistic well field model using TOUGH with interfering wells and variable injection rates and temperatures, this reviewer doesn‘t think one could get a dimensionless representation of the output. This reviewer may not understand this aspect correctly and encourages the PI to explain in more detail why this is not a reasonable criticism of the project.

Reviewer 29:
This is a comprehensive project with a clear methodology.

Reviewer 27:
This and complimentary Sandia efforts are important and necessary tools for unraveling the complexity and evaluating the economic viability. Much of the focus is on EGS applications but the stated need is to identify "realistic, physics based simulations at the component level to simulate total system performance." Where in the program is there a reality check using current producing hydrothermal systems (see reservoir modeling above) before applying the methodology to EGS where analogs do not exist?

Comments Regarding Strengths

Reviewer 43:
If all these things can be tied together in a meaningful way, it would be very useful. The PI appears to have a good understanding of the process.

Reviewer 29:
No response entered.

Reviewer 27:
This is important and excellent work with strong development of theory and practice.

Comments Regarding Weaknesses

Reviewer 43:
How will the model be tested? Can realistic reservoir information really be incorporated? Given uncertainties in EGS exploration and heat-exchanger development, can any meaningful uncertainties for EGS systems be obtained?

Reviewer 29:
No response entered.

Reviewer 27:
The stated goal is DOE deployment. Need to move toward more general application and testing in the current working geothermal world. Acceptance by financial institutions is not assured.

Suggestions for Improvement

Reviewer 43:
Clarify the assumptions used in combining the SD models and realistic reservoir models. Identify industrial partners who have expressed interest in the tool. Find a dataset to demonstrate, validate, or calibrate the model.

Reviewer 29:
This reviewer suggests reaching out to an industry player willing to provide a test case. This may, of course, be a difficult task but it's worth trying out.

Reviewer 27:
The summary and presentation presume a familiarity with the researcher's program and the complementary research at Sandia. Better explanations are available in previous GRC and Stanford Geothermal Technologies Program (GTP) publications but readers should not be forced to waste time searching for explanations elsewhere.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0101
Presentation Title: Energy Returned on Investment of Engineered Geothermal Systems (Mansure)
Investigator: Mansure, Arthur (Arthur Mansure)

Comments Regarding Relevance/Impact of Research

Reviewer 43:
The perception that enhanced geothermal systems (EGS) geothermal may have a poor energy return on investment (EROI) could be a barrier to EGS geothermal development. This narrowly defined project will provide quantitative information that will probably dispel that perception, which will provide arguments in favor of developing EGS.

Reviewer 29:
The project is highly relevant to DOE's targets. Results will have high impact owing to the prominent position of EROI when discussing sustainability issues. Links to related and complimentary studies like LCAs are very clear. Outstanding.

Comments Regarding Scientific/Technical Approach

Reviewer 43:
This is a sharply focused project that appears to be using a sound technical approach. (Reviewer comment to managers: it is a lot easier to get excellent results with a small, focused project than with a big, multi-organization project).

Reviewer 29:
There is hardly anything to fault the approach; past work is clearly reviewed, with the focus on process analysis. A minor/minute point is the energy expense of abandoning the site and wells—the reviewer might have missed this.

Comments Regarding Accomplishments, Results and Progress

Reviewer 43:
This reviewer sees no areas for improvement in the progress made, although it is difficult to assess if all the needed data are actually in hand.

Reviewer 29:
Considering the scope of the project and the resources dedicated to delivery, the accomplishments are very good / outstanding.

Comments Regarding Project Management/Coordination

Reviewer 43:
Although this reviewer is not suggesting any management improvements, he is rating this only as "good" because this is a single PI project, so the management is easy. The project appears to be on target, and the PI has presented his results in appropriate places. The PI has coordinated with others to avoid duplication of efforts.

Reviewer 29:
There is a clear focus on publications (including online). The whole project is very "track-able" and the PI is to be congratulated on good integration with ANL (despite no funding). Sometimes single PI projects are most efficient.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 43:
This project is calculating the EROI for EGS systems. Papers published in the 1970s suggested that if geothermal energy was produced from wells greater than a certain depth, then the EROI would be too small, and geothermal production could not be viable without subsidies. The purpose of this project is to update those calculations, and provide a defensible estimate of the EROI so that the value of geothermal energy can be communicated to the public, etc. The energy cost depends on the embodied energy in materials and processes and on the amounts of materials and processes that are necessary at a particular geothermal site. Although the project is not yet complete, the PI asserts that he will calculate EROIs that are higher than previous research, and that cost, rather than EROI, will limit EGS utilization.

Reviewer 29:
This is an outstanding project with excellent value for money. It uses a straightforward, clear and transparent approach to the analysis and solution to the problem with clear messages. EROI is a very useful metric for arguing sustainability and comparing geothermal energy utilization with other types of energy sources.

Comments Regarding Strengths

Reviewer 43:
The PI has developed current estimates of the embodied energy in materials and activities needed for geothermal production, making good use of the work of others to avoid duplication of effort. The use of "closing the loop" to illustrate value is clever. The PI says that all assumptions will be online, so future updates will be easy.

Reviewer 29:
No response entered.

Comments Regarding Weaknesses

Reviewer 43:
It appears that the energy cost of exploration may not be included. The author may wish to clarify this.

Reviewer 29:
No response entered.

Suggestions for Improvement

Reviewer 43:
1. The author may wish to add the option of including exploration costs, probably dominated by "dry holes", in the energy cost. 2. This reviewer would like to know if the "online" documentation will just be a document, or if there will be a "program" that users could run with their own assumptions. The latter would be preferable.

Reviewer 29:
Sometimes it is useful to keep track of energy pay-back with a simple graph—vertical axis (energy in (negative) and energy out (positive)) plotted versus time on horizontal axis without discounting.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0102
Presentation Title: Analysis of Low-Temperature Utilization of Geothermal Resources (WVU)
Investigator: Anderson, Brian (West Virginia University)

Comments Regarding Relevance/Impact of Research

Reviewer 70:
The presenter mentioned earlier in his presentation the potential of low-temperature (90-150°C), but all of the analysis is at 110°, 130° and 150°C. Direct use can be used at lower temperatures. An example is Pagosa Springs which has a district heating system using 60°C water.

Reviewer 42:
As presented, the project will result in little or no impact on DOE's mission and goals. The work being carried out will have no impact on geothermal development. The PI could have done a better job to communicate the relevance or importance of this project to the objectives of the Geothermal Technologies Program (GTP), but that is not the real problem with this project.

Reviewer 29:
This project is important for DOE, but maybe even more so for individual states and counties. The relevant states for this study appear well involved and connected. Thus, support of this type of project would appear highly relevant for concerted efforts of federal and state governments to promote the uptake of geothermal.

Comments Regarding Scientific/Technical Approach

Reviewer 70:
The presenter mentioned earlier in his presentation the potential of low-temperature (90-150°C), but all of the analysis is at 110°, 130° and 150°C. Direct use can be used at lower temperatures. An example is Pagosa Springs which has a district heating system using 60°C water.

Reviewer 42:
There is no problem with the technical approaches for the district heating or the biomass work as separate and independent research; however, the PI was not able to discuss or provide real convincing, tangible benefits to the West Virginia University (WVU) campus or Cornell. Not enough information was provided by the PI to conclude that the WVU campus would retrofit an old campus building to accommodate a district heating system. No location or design specifications were provided for WVU or any other facility or building. The price of coal is very cheap—2-3.5 cents per kilowatt hour (kwh)—and natural gas is cheap so why install a geothermal district heating system?

Reviewer 29:
This is a clean systematic approach to resource assessment, identification of prime targets, the development of supply curves and the integration into DOE models. The approach is adapted to local conditions prevailing in the states/counties/communities of the region. Relevant boundary conditions are well captured, e.g., link to carbon dioxide (CO_2) emissions, integration of CCUS solutions. A minor point may be establishing a connection to ground source heat pumps / energy structures if they are deemed of relevance.

Comments Regarding Accomplishments, Results and Progress

Reviewer 70:
The presentation and summary do not really summarize what stage the project is in and what has been accomplished.
Reviewer 42:
The project has met its first year's work statement goals but the accomplishments and outcomes will be marginal. There is an insignificant gain in knowledge.

Reviewer 29:
Accomplishments are on track and adequate. Good on the integration of low-T geothermal and biomass.

Comments Regarding Project Management/Coordination

Reviewer 70:
The project was not able to get the students at the beginning. The presentation was not available to the reviewer until the week before the review. Also the summary was not available until the day of the review.

Reviewer 42:
The PI and contributing partners have demonstrated the necessary managerial skills to keep this project on schedule and meeting objectives. The PI appears able to able to maintain communication with other researchers.

Reviewer 29:
This is a fairly complex project with three universities and one national laboratory. It is well structured and appears well managed. Some of the program delays are out of the control of the PI but are not surprising (lack of students and their time).

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 70:
No response entered.

Reviewer 42:
This project has minimal value. The project as presented appears to be an attempt by the three institutions to obtain DOE funding via the DOE GTP. This project is really four separate projects. There is no apparent benefit other than the assistance from the National Renewable Energy Laboratory (NREL). The biomass portion has no need for geothermal. This portion of the project can operate independently, more efficiently and economically. The PI did not provide enough evidence or data to make the argument that using geothermal for biomass gasification or pyrolisis will work. The PI did not describe or provide a flow chart or provide any cost data.

Reviewer 29:
This is a very useful project for local and state-wide resource assessment and possible synergies. Both DOE and the PI must be commended on the project in all aspects, but notably so by identifying options and opportunities for local states, counties and communities.

Comments Regarding Strengths

Reviewer 70:
No response entered.

Reviewer 42:
No response entered.

Reviewer 29:
The impact for local/state energy policies and strategies and plans is exceptionally high; it is particularly useful for states that do not have high-grade resources. The project is geographically well distributed, has efficient project management and split of work packages, and has great potential to integrate with CCUS and CO2-emissions management efforts.

Comments Regarding Weaknesses

Reviewer 70:
No response entered.

Reviewer 42:
This does not appear to be a good use of DOE research funds. It is keeping two researchers busy and five graduate students employed. The project will provide very little benefits other than keeping the PI and associate researchers employed. No discussion was provided to explain how the distinct data generated by WVU, Cornell and ISU would be integrated by NREL. No discussion was provided on how and who would integrate the geothermal data into the National Geothermal Data System (NGDS) and databases. There was poor explanation of the base-case reservoir simulation with the proposed district heating system. The PI did not identify where the WVU campus is located within the geothermal resource.

Reviewer 29:
No response entered.

Suggestions for Improvement

Reviewer 70:
No response entered.

Reviewer 42:
No response entered.

Reviewer 29:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0103
Presentation Title: Co-Production Risk Assessment (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 42:
This research project has made very good progress in meeting DOE goals and objectives. The PI provided a reasonable, well laid out case for assessing the risk and costs associated with geothermal co-production.

Reviewer 72:
The project and its results seem very detailed and complete, but in a very narrow purview. If the view is contingent on continued funding, how important could it be?

Reviewer 87:
This project has resulted in estimates for the capital and operations and maintenance (O&M) costs for geothermal energy co-production. These estimates are for current and future potential costs where the future costs are based on DOE funding levels. These estimates are very valuable to the Geothermal Technologies Program (GTP) in guiding the funding for geothermal co-production.

Comments Regarding Scientific/Technical Approach

Reviewer 42:
The technical approach taken is valid and based on solid engineering principles. A very positive aspect of this is the fact that the PI included GETEM for calculating costs and performance analysis. However, model variables should have included permitting, electrical connection, and system integration costs.

Reviewer 72:
Again, similar to comments on #1, this would be good to have the added context of the market.

Reviewer 87:
The approach taken was to rely on a small group of experts' knowledge as to the capital and O&M costs for geothermal energy co-production. These experts were mostly suppliers of the equipment involved and are thus an excellent source of the information sought. It would be better still if at least the baseline set of costs developed was compared with the costs developed from a bottoms-up design and cost estimate for this technology and/or by examining costs for commercial power plants that utilize much of the same process and equipment. The costs are for the plant only. Since this is co-production, the costs of below ground operations are assumed to be carried solely by the oil and gas producer. This should be investigated. The oil and gas producer might charge the geothermal power production for some services, capital, etc. The use of probability distributions and Monte Carlo techniques is very useful within this project‘s approach.

Comments Regarding Accomplishments, Results and Progress

Reviewer 42:
The project has made good progress in reaching its milestones and initial results. The project results will provide DOE and other research staff a baseline on evaluating risk assessments for geothermal co-production.

Reviewer 72:
The scope and milestones are clear. Why not go for the gusto and make the impact of this really big, rather than so modest?

Reviewer 87:
The project has been completed with the exception of the final report. The results are very useful to the GTP and have been achieved with a very small amount of funding.

Comments Regarding Project Management/Coordination

Reviewer 42:
The PI appears to have achieved the project objectives and within budget. Project management in general appears to be effective.

Reviewer 72:
It sounds like it would have been very hard to have managed these experts and know that you are getting the right opinions. The program is well managed and seems to have met its goals, even if the goals were not outstanding.

Reviewer 87:
The management of this project has been very good. However, since the vast majority of the work was completed last summer and fall, one would expect the final report to have already been completed.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 42:
This reviewer‘s general impression of the project is a favorable one. While the expert pool was too small, it will provide DOE staff and other researchers the appropriate tools for assessing the potential for geothermal co-production.

Reviewer 72:
This is a good solid look at this co-production, but if the market is hesitant, why not target some really key market barriers?

Reviewer 87:
This is an excellent project that has been well executed for a very modest amount of funding and the results should be very useful for the GTP. The approach of utilizing true experts has enabled achieving valuable results at a minimal cost. If time and funding allowed, comparing the experts‘ results with a bottoms-up design and/or with the costs of commercial power plants that utilize most of the equipment and process in a similar fashion would have added value to this effort.

Comments Regarding Strengths

Reviewer 42:
This is a needed tool for assessing geothermal co-production. The PI has met its objectives as described. The management team is a positive and the project is proceeding on schedule. There is a very high probability of success. The project is based on sound information management principles.

Reviewer 72:

The structure of the assessment is solid. The outcomes are clear.

Reviewer 87:
This is an excellent project that has been well executed for a very modest amount of funding and the results should be very useful for the GTP. The approach of utilizing true experts has enabled achieving valuable results at a minimal cost.

Comments Regarding Weaknesses

Reviewer 42:
The pool of technical experts was too small. No analysis or discussion was provided to factor in electrical distribution system or grid interconnection inter-tie. Usually these kinds of installations are part of a larger energy picture. How do these small binary systems affect the overall bottom line for the owner?

Reviewer 72:
A willingness to have taken on some of the uncertainties regarding the market would have strengthened the conclusions. In a way, it is as though the conclusions were known prior to beginning.

Reviewer 87:
Considering that the vast majority of the work was completed last summer and fall, one would expect the final report to have already been completed. If time and funding allowed, comparing the experts‘ results with a bottoms-up design and/or with the costs of commercial power plants that utilize most of the equipment and process in a similar fashion would have added value to this effort.

Suggestions for Improvement

Reviewer 42:
Recommendations: 1) Expand the pool of industry experts, 2) Associated permitting, electrical connection, and system integration costs may vary from state to state or perhaps even county to county but there should be a mechanism in the methodology to factor in these associated costs.

Reviewer 72:
In the future it would be wise to spend limited government dollars in a way that addresses some of the risks the market is challenged with.

Reviewer 87:
If time and funding is available, comparing the experts‘ results with a bottoms-up design and/or with the costs of commercial power plants that utilize most of the equipment and process in a similar fashion would add value to this effort.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0104
Presentation Title: Market & Policy Analysis (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 51:
While the budget allocated to this project activity is modest, the project design and focus makes little progress on the Geothermal Technologies Program's (GTP) mission and goals and does little to advance geothermal energy development. Financing any aspect of a geothermal project is a highly sophisticated proposition which rarely occurs in the current energy marketplace. The project's audience, so-called new entrants (developers and financiers), could not reasonably be expected to effectively use this project's information to finance and build a geothermal project. To be relevant for this audience, the project should instead identify the primary sources of industry participants (e.g., banks, institutional investors, private equity, developers, real estate leasing companies (landsmen), state natural resource offices, construction companies, operators, geologists, etc.) and allow these experts to provide firsthand information. However, the focus on policy makers as an audience for some of the information is a much better suited endeavor. Again, the breadth of project finance information, such as financing costs, debt/equity ratios, loan terms, etc., is of very little value to a policy maker. Instead, trends in the industry that are buried in the project information, should be extracted, emphasized and periodically distributed to federal employees, Congressional staff members, political appointees and industry association representatives. By way of example, the use of the Section 1603 Treasury Department Tax Grant is currently exclusively used by geothermal project developers instead of the investment tax credit (ITC) and production tax credit (PTC). Congress should know this and be asked to extend the program. In addition, the project reports that market investment returns expected for resource verification and drilling activities are prohibitively expensive. Few developers can afford such costs and as a result, geothermal development is limited to a small number of companies and investors. Policy makers should be actively debating the best methods for supporting and subsidizing geothermal drilling efforts across the country.

Reviewer 72:
This is exactly the role the federal government should assume in helping grow renewables, beyond merely pursuing research and development (R&D). Prior to this, there was no objective, third-party source for centralized info for geothermal project financing. This is a bold approach and brings geothermal up to par with the rest of the renewable energy programs.

Reviewer 87:
This project is focused on obtaining and tracking information relative to financing options and availability for renewable energy (RE) and in particular geothermal energy commercial projects. This information is usually readily available to the private sector through their own companies' efforts, through venture capitalists (VCs) and through other means. Each company has its own viewpoint on acceptable returns and types of financing it is willing to utilize. It appears that the only significant value of this information would be for policy makers and possibly some new small entrants to this market. Policy makers also have other sources, data, and analyses available to them relative to these issues. It would appear that effort by DOE RE technology programs in this area would only have limited value. It is useful for DOE RE technology programs to understand and utilize a baseline consistent set of financing parameters in its own RE cost analyses. A minimal effort through survey and/or workshops could help establish a set of baseline parameters for each DOE RE technology program to use.

Reviewer 29:

This is relevant to DOE's targets and useful in that information is presented in a well-structured and useful manner.

Comments Regarding Scientific/Technical Approach

Reviewer 51:
On the one hand, it is difficult to establish a qualitative set of metrics that would provide clear indications as to whether this project is succeeding or effectively advancing stated objectives. A handbook, website and database are tools and resources to be utilized by the target audience, so by the nature of the project design, it is hard to determine whether these tools are being put to good use. As a result, a quantitative approach is instead implemented that tracks the number of users who have downloaded the handbook and visited the website. Further detail is discerned by determining how many of the total users are returning to the source and how many are first timers. In addition, the organization from which the user works or is affiliated can ostensibly be obtained from website or email addresses. Hence, we are told that thousands of site visits coming from hundreds of users have been steadily tracked since project inception and this provides the primary indication of success. In reality, such statistics only indicate that more people from differing groups are visiting the website and downloading the handbook. As there is no information pertaining to the actual number of geothermal projects being financed coinciding with the project launch, there is no relevant correlation being drawn. Further, no information relating to new bank financing products is provided, nor is there any discussion of new federal or state legislative proposals initiated. The fact is that only one 50megawatt (MW) geothermal project financing occurred in 2010 in a market where no project financing in the United States had occurred in several years (note, tax equity financing of wind projects does not constitute project financing). No new federal or state laws or regulations have been passed of any material import, and no new investor group has supported geothermal projects outside of the DOE Loan Guarantee Program. Far too many variables are at play that influence the prospects for a successful geothermal project financing. Only the most sophisticated and experienced participants are surviving in this industry right now and they will not be visiting the website or downloading the handbook. If there is going to be a quantitative method used, the project should specifically provide the number of federal and state congressional staffers that have utilized the resource and cited the information in their reports to elected officials.

Reviewer 72:
This project is technical in a manner that is not customary for our technology programs--in terms of information technology (IT) and in terms of its comprehensive approach to the information.

Reviewer 87:
The approach of surveying a large number of private and other organizations in an anonymous manner to gather the financing information being sought is excellent. They would not normally provide such information but the ability to do so anonymously allows them to share such information. The use of the internet to provide this information to the entire RE community is excellent. The creation of the financing guide is a very useful way to communicate the information. Gathering new data as often as every quarter would appear to be overkill by a wide margin. Once per year or less or only when there is a reason to believe there might be a significant change in financing of RE projects, or when new policies are issued by the federal or state governments would be much more appropriate.

Reviewer 29:
The approach is straightforward. One stakeholder community that appears to not be well represented is the insurance company, less in a financing role but more in an industry branch that is adept at managing risk (exploration risk and negative impact on estimated monetary values of projects, i.e., risked NPVs) and potentially offering solutions that lower financial barriers. Very useful is the approach to track performance of financial instruments as far as possible, and an analysis of their efficiency and impact.

Comments Regarding Accomplishments, Results and Progress

Reviewer 51:
Again, this reviewer notes and emphasizes that only $180,000 was spent in drafting the Geothermal Project Finance Handbook and only $145,000 is slated for the website and database. In light of this, it is possible to say that the accomplishments, results, and outcomes have been adequate in relation to the minimal resources expended. Nevertheless, the remaining unspent budget for the website and database should be redirected to another, more worthy endeavor. The quality of the project accomplishments made toward project objectives cannot be reliably determined. It seems, however, that the quantity of project recipients has steadily increased and the use of an internet resource makes availability of the project information virtually limitless. The level of productivity in work underway appears to be quite good in that the collection of information and its packaging and distribution through a published handbook and url and blog postings on the worldwide web has been done in accordance with scheduled timelines. However, insofar as discerning the quality and productivity related to the collection of confidential financing information related to completed geothermal projects that is then posted on a government website, this reviewer must admit deep skepticism in both the purpose and precepts. The reviewers were told that quarterly written inquiries are sent to industry participants on a confidential basis. The collected information is then combined into an aggregated form and reported anonymously to protect the various sources of information. With no attribution to the sources and no accountability for false or misleading statements, the veracity of these reports is marginal at best. Even if such information could at least be deemed to constitute a general indication of market trends and demands on project financing terms and conditions, the relevance such information has on the heavily negotiated agreements actually concluded between investors/lenders and developers is nonexistent. The scrutiny employed and due diligence conducted on project locations, quality of geothermal resource, credit quality of power off-takers, engineering, procurement, and construction (EPC) contractors and operations and maintenance (O&M) operators and the experience of the sponsor management team makes every project financing in this current market a one-off transaction for the very limited group of lenders and investors playing in this arena.

Reviewer 72:
Does the presenter mean November 2010, not November 2011 on the slide? Is the presenter able to get information from other finance sources like Bloomberg New Energy Finance and Cleantech Group? Has he checked whether his products are superior to theirs? Is he able to share this information with other programs or with LGPO?

Reviewer 87:
It appears that all of the data sought by this project has been obtained and made available on the internet. By having it on the internet it should be available to all the target audiences. A financing guidebook has also been completed. It would be better if more information was provided in the presentation material showing more clearly what the content of the internet website is and how the data has been analyzed and presented.

Reviewer 29:
There has been fair and good progress on the three principal deliverables. Websites are a useful fairly good way to impact the community, collect useful additional information and provide valuable insights. Estimating the value of the renewable energy finance tracking initiative (REFTI) / terms and conditions to DOE is probably difficult owing to issues surrounding nondisclosure. But, this is a very good effort to capture data!

Comments Regarding Project Management/Coordination

Reviewer 51:
As this project has been designed, NREL has managed project deliverables in a very effective manner and has logically structured its schedule and staffing plans to meet future performance milestones. However, this project is focused solely on the collection and dissemination of information related to geothermal project financing—a basic task for which the Geothermal Technologies Program should expect only the highest level of performance from such a prestigious national laboratory. This reviewer knows from personal experience that NREL has or has had in its employ the likes of Dan Arvizu, Marty Murphy, Doug Dahle, and Jeff Dominick to name a few, who all have significant current market

knowledge and can provide insightful input on much more effective methods for applying market research toward desired policy outcomes. Again, the project budget is less than a half million dollars and hardly rises to the top of the priority list for NREL. Unfortunately, geothermal base-load energy is pathetically underutilized in this country and our best government resources are not being asked to address basic development and financing impediments in the current market place. This reviewer commends Karlynn and Chad for the work they have done as it has exceeded the goals and objectives presented. This reviewer only wishes that the exceptional brain trust that is NREL would have been asked to suggest alternatives for influencing the use of collected financing information to drive and accelerate geothermal project market penetration.

Reviewer 72:
Why is the information not released in real-time? Why wait and release quarterly? Who is vetting the information? How can this information be collected and the sources not be public? Is it free from Freedom of Information Act (FOIA) concerns? With whom is the team checking in at DOE Headquarters (HQ)? NREL Analysis is missing the opportunity to bring its clients together. This has been noticed this a few times with the Analysis function at NREL—that information is only being shared with a few key people and not used as an opportunity to convene and educate HQ.

Reviewer 87:
It appears that the project has been very well managed and has achieved its objectives in a timely fashion. Based on the comments under Relevance and Approach, the frequency and effort planned to continue to gather data and information does not appear warranted.

Reviewer 29:
Project management and coordination seems to be functional (good data sharing, well presented), but on occasion a "heap of unstructured information". Looking forward to an analysis of various instruments and policies.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 51:
"Drill baby. Drill"—the controversial mantra suggesting widespread access to U.S. oil resources. It should be the theme phrase for the Geothermal Technologies Program. The project presentation quoted the Geothermal Energy Association‘s Karl Gawell as saying that financing is the greatest barrier to U.S. geothermal development. What should be understood is that the 50-MW Hudson Ranch Project in the Imperial Valley of California was able to raise $400 million in project financing in 2010 (just 18 months post financial institution meltdown) in large part because of its proven geothermal resources. If the resource can be proven, the financing will come. The NREL reports and collection of information have cited the expensive costs associated with resource verification and drilling, but they do not make any recommendations to address this issue. Instead, they expose the misread of market obstacles to accelerated geothermal utilization and distract the new entry developers and investors with simplistic observations of project finance strictures and requirements. The initial impetus for launching the project is its primary strength. That is to say that the recognition that geothermal development in the United States faces numerous impediments and the availability of affordable financing is one such barrier. The weakness was in assuming that a government laboratory should be commissioned to write a handbook and create a website resource on how financing is conducted instead of simply gathering the names of the people and organizations that conduct financing for a living and providing a platform that efficiently distributes that information to the industry.

Reviewer 72:
If respondents appear to reflect fatigue with the same survey over and over each month, switch it up a little. Maintain the

same core set of questions, but ask something new as a lead-in—something that reflects current events. As another reviewer asked, make insurance a category unto themselves.

Reviewer 87:
It is not clear that DOE RE technology programs and GTP should be putting a significant effort towards the objective of this project. The type of information being gathered should be available to the private sector and most likely, policy makers through other sources. Financing choices and parameters are different for every company. A minimal effort to establish baseline information on financing options and parameters for use by the DOE RE programs and others could be sufficient with updates only when warranted. Posting new federal and state RE policies on a website as they are issued would also be useful. Having said that, this project has been well managed, has utilized a good approach to achieve its objectives, and appears to have successfully gathered and disseminated the desired information.

Reviewer 29:
No response entered.

Comments Regarding Strengths

Reviewer 51:
Throughout the information provided in this project's handbook, website and database are very important nuggets of information that require careful consideration by the Geothermal Technologies Program. This information should also be presented in a meaningful and concise way to government policy makers. For example, there is reference to royalty rates associated with the lease and property rights required in every geothermal transaction. The terms and conditions requiring payment of such royalties under each lease are critically important to each geothermal project sponsor and its investors. Those states that have legislated the fairest balance between protection of their respective natural resources and incentivizing project development are leading the country in geothermal project activity. The project should take further steps to analyze these successes and make the information available to all of the states and the Bureau of Land Management (BLM). In addition, as mentioned before, cursory observations have been made on the costs and challenges associated with resource verification and drilling. The oil and gas industry dominates the use of available drilling rigs in the United States and because of the inflated revenue streams flowing from oil in this current market, geothermal projects can hardly hope to negotiate reasonable and affordable terms with drilling companies. The project should look deeper into the drilling barriers it has identified to prompt informed discussion within the Geothermal Technologies Program and various legislative bodies to directly address this matter. Finally, and perhaps of most immediate importance, the project identified the exclusive current reliance on the Section 1603 Tax Grant. This point must be emphasized in dramatic fashion. Little, if any, meaningful tax equity investments are being made in geothermal power projects under the ITC and PTC regimes. In contrast, 1603 has been a game changer for this industry for many reasons. If Congress was aware of this impact and of the potential impact the continuation of the tax grant will have on geothermal power project development, there would be a much a better chance that this grant program would be extended.

Reviewer 72:
This is bold for its approach. This reviewer wishes more folks at DOE knew about this. Consider making a splash of this not just at Geothermal Energy Association (GEA) events, but also at American Council on Renewable Energy (ACORE) and Cleantech events.

Reviewer 87:
This project has been well managed, has utilized a good approach to achieve its objectives, and appears to have successfully gathered and disseminated the desired information on RE and geothermal commercial project financing.

Reviewer 29:
No response entered.

Comments Regarding Weaknesses

Reviewer 51:
The previous comments and observations have adequately addressed project weaknesses.

Reviewer 72:
The question is whether this is an appropriate use of federal funds. If DOE does not engage in financial education, then DOE is patently uneducated in terms of finance. It is about education from within.

Reviewer 87:
It is not clear that DOE RE technology programs and GTP should be putting a significant effort towards the objectives of this project. The type of information being gathered should be available to the private sector and most likely, policy makers through other sources. Financing choices and parameters are different for every company.

Reviewer 29:
No response entered.

Suggestions for Improvement

Reviewer 51:
The Peer Review forum is a wonderful gathering of government, academic, science, and private sector industry experts. The GTP's outreach to this community is commendable and should be continued. The Peer Review should, however, have an additional important track included. All reviewers should also be asked to review new GTP goals, objectives and related contemplated projects before they are funded and implemented. The Federal employees and lab contractors working for and with GTP are very talented and certainly quite committed in their work. The time and effort applied to existing GTP projects should not be criticized. However, we all need to work much more closely in establishing new projects that will meaningfully contribute to the rapid expansion and use of geothermal resources in the U.S. marketplace.

Reviewer 72:
This reviewer would suggest a dashboard of "hot topics," snazzy specific items that are easily remembered as tidbits of great information.

Reviewer 87:
Reduce any additional effort in this area to only update RE financing information when there might be a significant change to RE and geothermal energy financing and when new federal or state RE financing and other RE policies are issued.

Reviewer 29:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0105
Presentation Title: Decision Analysis for Enhanced Geothermal Systems (MIT)
Investigator: Einstein, Herbert (Massachusetts Institute of Technology)

Comments Regarding Relevance/Impact of Research

Reviewer 60:
The project's approach uses fundamental concepts of probability to assess risks associated with geothermal development. Embodied in this effort is the enhancement of an existing Massachusetts Institute of Technology (MIT) fracture population model, GEOFRAC. The reviewer is not certain, but suspects much of what is being done is already available in industry (e.g., FRACMAN). The reviewer suggests that the PI articulate what is different between GEOFRAC and other commercially available codes for geologic discontinuity modeling. In addition, the reviewer is not convinced that tunnel cost codes are applicable to drilling and the PI should be careful in making adopting the DAT model for well construction applications.

Reviewer 92:
Regarding decision and uncertainty analysis, there is fair coverage of all aspects of geothermal development. The focus on including mostly subsurface methodologies as part of the scope is a notable effort.

Reviewer 87:
This project is designed to develop an analysis tool capable of modeling and evaluating enhanced geothermal system (EGS) energy exploration, development and operations including the degree of uncertainty resulting in a risk analysis for cost and time. Such a tool would be of tremendous benefit to geothermal energy, making it far more effective and cost efficient to explore for and develop EGS energy. It is clear that significant progress has been made and the project is on track to be completed on schedule. The Fracture Pattern Model and Drill Cost and Time Model have been completed. The other tasks are in progress.

Reviewer 29:
The goal is clear as is the relevance. However, the theoretical decision analysis system which is developed in the project is rather remote from the actual scoping, definition, planning and execution of an EGS project. The relevance of this project will— on its current trajectory—contribute at best to modest progress towards an impact on DOE's missions and goals.

Comments Regarding Scientific/Technical Approach

Reviewer 60:
Work to date is primarily on the first two tasks and the work appears solid and well-focused given the limited progress to date (with the caveats noted above relative to the need for improvements to GEOFRAC). Tools to formally assess the uncertainties of the subsurface associated with geothermal development are needed, but to ensure the end product is useful for geothermal development, the PI should carefully consider the differences between the tunnel construction and drilling in high-temperature environments.

Reviewer 92:
The methods ignore the value of dynamic data. If the technical approach could address the importance of dynamic data when an EGS project begins and the data used going forward in decision making, it could help address a key research focus area of DOE which is to better understand risks of EGS. This piece was missing/not communicated.

Reviewer 87:
This effort is taking a very sophisticated state of the art fundamental stochastic modeling approach to the fracture process. The modeling of drilling cost and time is utilizing real data and includes uncertainties and uncertainty interactions. It includes a detailed cost breakdown and full activity profile. The overall modeling effort will also include a subsurface cost and time model and exploration decision analysis. Overall the complete modeling effort should be scientifically sound, robust and account for many of the uncertainties involved.

Reviewer 29:
The approach appears overly theoretical; a classification of decisions during an EGS project with respect to their impact on cost and yield with respect to the objectives may justify the approach taken. While one recognizes certain parallels to a tunneling project, a comparison to an oil and gas development project (be it green or brownfield) may yield more relevant insights.

Comments Regarding Accomplishments, Results and Progress

Reviewer 60:
Project appears to be on budget and progressing well. Work to date seems to be primarily limited to improving the GEOFRAC. As additional tasks are completed a more refined assessment of progress will be possible.

Reviewer 92:
Only Tasks 1 and 2 are in progress. Are there any collaborations? Cost breakdowns are readily gathered by other groups.

Reviewer 87:
It is clear that significant progress has been made and the project is on track to be completed on schedule. The Fracture Pattern Model and Drill Cost and Time Model have been completed. These have value on their own. The EGS circulation model is in progress and should be complete in December 2011. It is expected that the remaining tasks will be completed on schedule.

Reviewer 29:
The project has achieved a number of milestones and associated deliverables.

Comments Regarding Project Management/Coordination

Reviewer 60:
This is a relatively small project and the PI is managing the program well. As a university project, the PI is challenged to ensure there is continuity of student support to this activity, but it appears this is being handled well.

Reviewer 92:
Fair project management practices are noticed.

Reviewer 87:
This project is being done by a close nit group at MIT. It has a well-defined schedule and is on track following the schedule. Quarterly meetings are held for data sharing and there is interaction with industry, federal labs and other universities. The future plans are well defined.

Reviewer 29:
The project appears to be on track. Project management and coordination are as can be expected by a project executed by a single institution.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 60:
With uncertainly being a major factor limiting geothermal development, tools that address uncertainty are good for the industry. The PI does, however, need to better articulate what this approach (both individual tasks as well as the entire project) will provide relative to what is currently available.

Reviewer 92:
Overall the project seemed to have a good handle on building the framework for decision analysis. However, the cost and the other analytical assumptions used need to be benchmarked. This will allow DOE to set a baseline for future initiations in this line of research. Use of GeoFRAC and time spent on it (redesigning it) over other existing models was not clearly understood. The driving force behind the decision remains to be reevaluated.

Reviewer 87:
This project is designed to develop an analysis tool capable of modeling and evaluating EGS energy exploration, development and operations including the degree of uncertainty resulting in a risk analysis for cost and time. Such a tool would be of tremendous benefit to geothermal energy making it far more effective and cost efficient to explore for and develop EGS energy. This is an outstanding project and is utilizing state of the art geothermal fundamental science and modeling. Significant progress has been made and the project is well managed and on track for completion on schedule.

Reviewer 29:
The development of EGS systems from initial scoping, definition, and planning to execution and operation encompasses many decision points of a technical, economic, commercial, organizational and political nature. The ones that are developed to date in this project focus on the development of the subsurface reservoir, the value of which is not entirely clear. Very little mention is made of other decision points in the course of standard project maturation up to FID and beyond (execution). Value of onformation evaluation of various decisions on the estimated monetary value of a venture and an overall increase in understanding cost drivers to achieve or improve on cost targets for proved, probable, and possible available geothermal resources (P10/P50/P90) are at best alluded to or implied. A strong link to EGS projects which are actually scoped, defined, planned and executed is recommended to test the validity of the project's approach to decision analysis.

Comments Regarding Strengths

Reviewer 60:
The PI has command of the subject area and is attempting to bring in concepts and tools that are employed outside the geothermal development industry.

Reviewer 92:
Excellent focus on subsurface systems. Good team to execute the project. All aspects at the systems level of approaching an EGS project are well covered.

Reviewer 87:
This project is designed to develop an analysis tool capable of modeling and evaluating EGS energy exploration, development and operations including the degree of uncertainty resulting in a risk analysis for cost and time. Such a tool would be of tremendous benefit to geothermal energy making it far more effective and cost efficient to explore for and develop EGS energy. This is an outstanding project and is utilizing state of the art geothermal fundamental science and

modeling. Significant progress has been made and the project is well managed and on track for completion on schedule.

Reviewer 29:
No response entered.

Comments Regarding Weaknesses
Reviewer 60:
There is nothing glaring, but as noted above, it is not clear how much of the work needs to be done versus what is being used today by industry.

Reviewer 92:
How is the cost of delay accounted for in the analysis? How are the results from the fracture stimulation model included as inputs for decision analysis? Is there a method to consider qualitative inputs that could affect the outcomes of decisions?

Reviewer 87:
It is not clear how the Fracture Pattern Model can/will be tested against real data.

Reviewer 29:
No response entered.

Suggestions for Improvement

Reviewer 60:
Suggestions for improvement are noted in the body of this review.

Reviewer 92:
There is room for improvement in using or referring to work already done by other groups in the community. Overall, the project has distinct goals and it seems that it is on track for successful completion. Benchmarking the cost assumptions is a critical success factor and should be considered for the rest of the duration of the project.

Reviewer 87:
Determine how best to test the Fracture Model against real data.

Reviewer 29:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0106
Presentation Title: Geothermal Supply Curve Development (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 61:
The main goal of this project is to relate available geothermal resources to the cost of development by generating supply curves. It is therefore very relevant to the mission and goals of the DOE Geothermal Technologies Program (GTP). Supply curves are needed in many areas to better guide industry and provide critical data for potential outside investment in geothermal development. This project would have greater impact, however, if low-temperature systems were considered for direct-use applications, where feasible--although the present budget does not allow for this.

Reviewer 42:
The relevance of this project may be more important to DOE staff than to the developer or investor. This could be a very expensive training tool for a small number of users and/or DOE staff.

Reviewer 87:
The objective of this project is to develop supply curves that relate available resources to cost of development for geothermal energy technologies. Co-production, and geopressured supply curves will be developed and hydrothermal, enhanced geothermal system (EGS) and permeable sedimentary supply curves will be updated. Once completed, the results would be of great value to the development of geothermal energy. A co-production resource database and cost model have been developed. A methodology for estimating geopressured resource estimates has been developed and resource estimates for the Texas Gulf Coast have been completed. These accomplishments are useful on their own.

Reviewer 77:
This project is ambitious yet seems to be on track. As the work is still in progress impact can only be evaluated in the future.

Comments Regarding Scientific/Technical Approach

Reviewer 61:
This project seems sufficiently focused with accomplishable goals. The strategy for building databases for co-production and geopressured systems appears to be well organized with interesting results. For other types of systems, the approach is more difficult to evaluate with the submitted documents. For hydrothermal systems, distinguishing between magmatic and amagmatic systems will be important. Future work should include evaluation of low-temperature systems for direct use.

Reviewer 42:
The scientific/technical approach is reasonable.

Reviewer 87:
The project is finding and utilizing the best resource availability data on geothermal energy that exists. The data available is not as complete as desired but this effort will provide the best estimates on geothermal energy potential to date. There are other projects developing geothermal technology cost models and this project is using their results where possible. Thus the best cost data available will be utilized. Synthesizing all of the best available geothermal energy resource and cost information to be able to look across these geothermal technologies relative to cost and potential energy supply will

be very valuable. It will be necessary of users to be cautious in their conclusions since the best information available is still less accurate than desired.

Reviewer 77:
The approach is generally appropriate considering the timeline and scope of work. Considering the number of poorly quantified variables involved, this reviewer wonders if the "mass of data" approach to the co-produced resource will actually provide information that is directly relevant to local conditions. It would be useful to compare a standardized National Renewable Energy Laboratory (NREL) approach to specific results from the Rocky Mountain Oilfield Testing Center (RMOTC) co-production effort.

Comments Regarding Accomplishments, Results and Progress

Reviewer 61:
Good progress has been made on co-production and geopressured systems. The compiled databases (mainly well data) for these types of systems appear to be robust. The completed analyses have yielded very interesting results for understanding the potential of co-production systems, which appear to have been over-estimated by some previous studies. This reviewer has some concerns over the evaluation of permeable basins, as the PIs are in the process of obtaining qualified personnel for these studies, but there appears to be ample time to line up the appropriate research team.

Reviewer 42:
The project is on schedule and the results and data generated may be useful, principally for policy makers and not necessarily for the investors or venture capitalists.

Reviewer 87:
A co-production resource database and cost model have has been developed. A methodology for estimating geopressured resource estimates has been developed and resource estimates for the Texas Gulf Coast have been completed. These accomplishments are useful on their own. There is a good deal of work left to do on this project and it appears to be somewhat behind its aggressive schedule. There is significant work left on geopressured and updates for hydrothermal and EGS have not been started. Existing limitations on available resource data and cost modeling will hamper the project's ability to produce robust and credible results.

Reviewer 77:
The project is meeting deadlines and addressing tasks according to schedule. The project is highly productive considering the small size of staff.

Comments Regarding Project Management/Coordination

Reviewer 61:
The project has been well focused to date with significant progress on two major types of systems (co-production and geopressured). The spend plan seems appropriate. As stated above, some concerns exist about staffing for subsequent studies but there appears to be sufficient time to assemble a good team for analyzing other types of systems.

Reviewer 42:
The PI has properly managed and completed the tasks specified in the scope of work. The project is on time and accomplished within budget.

Reviewer 87:
There is insufficient information provided on the project team and specific project management approach but the management seems to be quite good. However, the project appears somewhat behind schedule considering the aggressive

project plan timing and the amount of work completed to date. There appears to be good collaboration with state agencies, U.S. Geological Society (USGS), and Southern Methodist University (SMU). Resource databases are being consolidated and updated and will be made available through the internet. The future plans are good but somewhat lacking in detail relative to the updates for hydrothermal and EGS.
Reviewer 77:
This reviewer would be inclined to give this project an outstanding in this area, but is modestly concerned about the scale of the task relative to the number of people available to work on the project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 61:
This is a critical study for understanding the economics of various types of geothermal systems for comparative purposes and development investment.

Reviewer 42:
This project should perhaps be renamed and used as a training tool for DOE or regulatory agencies that do not have access to financing data available to the developers and venture capitalists. Just make sure that this material is actually used. The probability of this report ending up on the bookshelf could be very high. The workbook may not serve any purpose for developers or investors.

Reviewer 87:
The objective of this project is to develop supply curves that relate available resources to the cost of development and operation of all of the primary geothermal energy technologies. Co-production and geopressured supply curves will be developed and hydrothermal, EGS and permeable sedimentary supply curves will be updated. Once completed, the results should be of tremendous value to the development of geothermal energy and to the GTP to set priorities and direction of R&D. A co-production resource database and cost model have been developed. A methodology for estimating geopressured resource estimates has been developed and resource estimates for the Texas Gulf Coast have been completed. These accomplishments are useful on their own. There is a good deal of work left to do on this project.

Reviewer 77:
Overall, this reviewer considers this project close to, but not quite, outstanding, for the reasons that are discussed below.

Comments Regarding Strengths

Reviewer 61:
1. Study is focused and accomplishable in the noted time frame. 2. Important databases have been compiled for co-production and geo-pressured systems. 3. Results on co-production systems are intriguing and more thorough and realistic than previous estimates.

Reviewer 42:
No response entered.

Reviewer 87:
The objective of this project is to develop supply curves that relate available resources to the cost of development for geothermal energy technologies. Co-production and geopressured supply curves will be developed and hydrothermal, EGS and permeable sedimentary supply curves will be updated. Once completed, the results would be of tremendous

value to the development of geothermal energy and to the GTP to set priorities and direction of R&D. A co-production resource database and cost model have been developed. A methodology for estimating geopressured resource estimates has been developed and resource estimates for the Texas Gulf Coast have been completed. These accomplishments are useful on their own.

Reviewer 77:
Considering the scope of the task, the project is making tremendous progress and to date has been very successful at keeping to its timeline. Project personnel have demonstrated great skill in deriving useful information from extraordinarily large datasets in a short amount of time. The supply curve work is clearly of critical importance to the DOE program.

Comments Regarding Weaknesses

Reviewer 61:
1. Does not include low-temperature systems for direct use, but budget and scope would clearly increase significantly if this were added. 2. Does not include analysis of different types of hydrothermal systems (magmatic vs. amagmatic). An adjustment here could possibly be made without a huge impact on scope or budget. 3. Research team not assembled yet for some aspects of the study. 4. No publications appear to have resulted from this work to date and yet the study has clearly yielded important results.

Reviewer 42:
No response entered.

Reviewer 87:
There is a good deal of work left to do on this project. It appears to be somewhat behind its aggressive schedule. The future plans are good but somewhat lacking in detail relative to the updates for hydrothermal and EGS.

Reviewer 77:
A large portion of the project remains to be completed by the end of September, and this reviewer questions whether there is sufficient time to complete the tasks without compromising the quality of the work. Considering the importance of this work, this reviewer wonders if it wouldn't be better to stretch out the project timeline to ensure the quality of the resulting products.

Suggestions for Improvement

Reviewer 61:
1. Publish results. 2. Consider different types of hydrothermal systems in the analyses.

Reviewer 42:
No response entered.

Reviewer 87:
No response entered.

Reviewer 77:
The project staff have become very skilled at producing results for DOE in a very short timeframe, but, given the uncertainties involved in much of the analysis, this reviewer would like to see some longer-term methodology studies added to the project objectives to provide a firmer foundation for future supply curve updates.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0107
Presentation Title: National Geothermal Resource Assessment and Classification (USGS)
Investigator: Williams, Colin (U.S. Geological Survey)

Comments Regarding Relevance/Impact of Research

Reviewer 23:
This work will have a tremendous impact in advancing geothermal energy in the U.S. portfolio of renewables. The expanded coverage, geographically, as well as in terms of new resource types, will be a high value resource for policy makers, researchers and developers within the geothermal community. This additional coverage will fill significant gaps to tell "the rest of the story" about the potential for geothermal energy production in the U.S.

Reviewer 61:
This project aims to develop new geothermal resource classification standards and assist in establishing the National Geothermal Data System (NGDS). The project is clearly very critical for enhancing reliable information on geothermal resources. Existing information must be categorized and synthesized to enhance our understanding of geothermal resources and reduce the risks in geothermal development.

Reviewer 42:
This relevance or impact of the research will be immediate and have long lasting effects to the geothermal industry. The work conducted will have a significant impact on DOE's mission and goals.

Comments Regarding Scientific/Technical Approach

Reviewer 23:
The approach is based on well-founded assessment approaches, extended through new, innovative techniques and greater application of data. It ambitiously covers a broad swath of geothermal resources. The focus is clearly on electric power generation potential, which is in line with stated DOE objectives. The approach to developing the new resource classification system is rigorous, incorporating concepts from existing literature and remaining open to revision based on comment from the geothermal community. Coordination with NGDS efforts appears to be effectively implemented.

Reviewer 61:
This is an ambitious project that requires a systematic approach to evaluating and classifying geothermal systems. Understandably, the budget is large to address these challenging tasks. Presumably, a large team of researchers is needed to evaluate the many types of geothermal systems (e.g., conventional, EGS, and sedimentary basins). Unfortunately, the supporting documents and presentation appear to leave several important questions hanging. Who is on the geophysical and geologic teams, for example— is this staffed internally from within the U.S. Geological Survey (USGS) or does it include various collaborators? Limited information was provided on the team members. Although certain areas have been selected for detailed study, it is unclear why such areas were selected over others. For example, is northeast Nevada (one of the study areas) representative of conventional or EGS systems in some way? If so, how? Also, the geophysical studies involving gravity and magnetic data seem overly simplified. An attempt is being made to distinguish areas dominated by plutonic vs. volcanic rock. Yet, much of the region contains both volcanic rocks and underlying plutons. The relevance of these geophysical studies to geothermal resources is not well explained. The specific ways in which the various components of this project will be used to assess undiscovered resources is also not well defined.

Reviewer 42:
The technical approach taken by the PI and respective researchers is excellent in design and implementation. The approach was well conceived in the beginning and is outstanding in its execution.

Comments Regarding Accomplishments, Results and Progress

Reviewer 23:
Given the late start, the progress to date has been commendable. Initial reports and provisional classification definitions have been published and feedback has been received, and progress has been made on resource modeling. There has also been notable progress in integrating with the NGDS, both to incorporate the resource classification scheme and to make existing USGS data and publications accessible through NGDS. There is some concern that given the ambitious scope of this project, its objectives may not be fully realized.

Reviewer 61:
To date, a preliminary classification scheme has been completed, fulfilling one of the major milestones. However, this classification scheme was not shown in the supporting documents, making this evaluation more time consuming than necessary. On another note, estimates of resource potential from this and related projects should be fully supported in future publications.

Reviewer 42:
The project has achieved all the milestone accomplishments to date. The preliminary results and progress are of high quality and verifiable.

Comments Regarding Project Management/Coordination

Reviewer 23:
The late start (not a fault of this project) was dealt with in a very effective way and the project appears to be on track to deliver. No issues with project management are apparent.

Reviewer 61:
As mentioned above, staffing is a major question for such an ambitious project. It was not entirely clear from the supporting documents that researchers for geologic, geophysical, geochemical, and other critical disciplines have been assembled to accomplish the stated goals.

Reviewer 42:
The PI has demonstrated outstanding skill in project management and coordination between numerous collaborators.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 23:
This is an impressive and ambitious effort, and this reviewer is certain the result will prove to be an outstanding authoritative resource for a complete view of the future U.S. energy picture.

Reviewer 61:
This may be one of the more important projects currently being supported by the DOE Geothermal Technologies

Program (GTP). Significant milestones have been met, but major questions exist about staffing and level of systematic approach to this ambitious project.

Reviewer 42:
Excellent work.

Comments Regarding Strengths

Reviewer 23:
No response entered.

Reviewer 61:
1) Known members of the research team have ample experience in the geothermal arena. 2) The project is very relevant. 3) Initial milestones have been met.

Reviewer 42:
This project is what DOE should fund. This project lays foundation for future work in undiscovered resource methodology. The PI has met its objectives as described. The management team is a positive and the project is proceeding on schedule. There is a very high probability of success. The project is based on sound information management principles.

Comments Regarding Weaknesses

Reviewer 23:
No response entered.

Reviewer 61:
1) A more systematic approach to data analysis and synthesis may be needed to accomplish stated goals. 2) More effort is seemingly needed in assembling research teams or perhaps including a better explanation in the review documents if this has been done. 3) Explanations for selecting certain study areas are needed. 4) Reduced scope of field activities may compromise some aspects of this project. 5) Relevance of geophysical studies to geothermal resource evaluation should be more fully explained in the context of the geologic framework for particular regions under study.

Reviewer 42:
No response entered.

Suggestions for Improvement

Reviewer 23:
Just a few suggestions: -1) Ensure coordination with other assessments and analyses underway, especially by the National Renewable Energy Laboratory (NREL). 2) On the way to estimating electric generation potential of a resource, estimates of thermal energy in place will inevitably be made; it would be useful to publish these estimates along with the power generation potential. 3) Clarify the USGS role in relationship to NGDS; will the USGS be operating a data "node" and contribute catalog metadata and web service interfaces, or will USGS be transferring its publications and data to NGDS? That is unclear from the write-up and presentation.

Reviewer 61:
Suggestions for improvement are essentially listed under "comments regarding weaknesses."

Reviewer 42:

This reviewer appreciates the benefits of this research and can see an expanded resource assessment to oil and gas fields in Los Angeles, Orange, Kern, Santa Barbara and Ventura Counties in California. These are not sedimentary basins and the geology is more complex but there are sufficient geothermal resources that may be exploited. Expanded geothermal resource assessment would: 1) Identify where geothermal energy co-production from oil and gas wells can address current and future problems such as availability, capacity, congestion, power quality and reliability of California's electrical system while providing high public benefits. 2) Identify where geothermal energy co-production can complement or enable other renewable electricity systems to address current and future problems facing California's electricity system. 3) Establish collaboration for future geothermal energy co-production and oil and gas research and development projects with federal, state, and local governments, industry, academic institutions and community stakeholders. Benefits include: 1) More baseload electrical generation from geothermal resources, 2) Displacement of fossil fuels, 3) Development of underutilized renewable energy resources, 4) Reduction of greenhouse gases emissions, 5) Postpone or significantly delay construction of additional transmission and distribution lines in highly urbanized neighborhoods and coastal areas, 6) Minimal pipeline infrastructure redevelopment in highly urbanized neighborhoods, 7) Address social justice concerns, 8) Local job creation, 9) Local community economic multiplier effect, 10) Addresses legislation such as AB 32 Renewable Portfolio Standards, AB 118 and Commission policies, 11) Research and possible deployment of enhanced geothermal systems, 12) Distributed generation deployment, 13) Facilitate development of other renewable energy technologies, and 14) Development of technologies that address the variability and power quality issues of wind and solar, via hybrid generation, storage or other innovative approaches.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0112
Presentation Title: GETEM Development (INL)
Investigator: Mines, Greg (Idaho National Laboratory)

Comments Regarding Relevance/Impact of Research
Reviewer 100:
This is one of the potentially most useful of the DOE-funded projects. It is important for standardizing across projects and in providing relative cost components across and within projects and for ensuring projects report on the same basis. It ensures important factors are not overlooked as it can be used as a checklist of factors which must be considered.

Reviewer 87:
The objective of GETEM is to provide a tool to evaluate the cost of hydrothermal and enhanced geothermal system (EGS) power production in a consistent, transparent, user-friendly manner. Such a tool has tremendous benefit to the Geothermal Technologies Program (GTP) by providing at least consistent relative power costs for these geothermal energy technologies and variations within these technologies as well as a better understanding of the key cost factors and relative potential cost improvements. This can help the program set its research priorities and direction. The recent work to improve the exploration and well drilling modules, and to add economic evaluation tools are significant improvements to the model.

Reviewer 29:
The project is highly relevant for DOE's strategy development and planning its implementation. GETEM is a key tool to track technology development and quantify results with respect to technical unit costs, specific capacity costs, levelized costs of electricity, etc. GETEM has a well-developed granularity in individual modules.

Reviewer 27:
No response entered.

Comments Regarding Scientific/Technical Approach
Reviewer 100:
This is a detailed, comprehensive approach which incorporates continuous improvement and has and is actively incorporating feedback from industry and users. The creators have already incorporated substantial improvements and have shown intent to continue to do so as they receive feedback.

Reviewer 87:
The overall structure of the model using individual modules to represent the various aspects of developing and operating geothermal energy makes the model easier to use and understand. It also makes it easier to improve and expand the model's capabilities. The model structure allows the user to define different scenarios based on a specific power production or number of wells. This is very helpful. The model is being improved on a continuous basis as additional and more accurate cost modeling information becomes available. It could be helpful if the GTP collaborated with other EERE programs on certain aspects of energy cost modeling to provide an improved level of consistency and transparency across EERE. The model uses a fixed charge rate approach. It would be better if a more rigorous discounted cash flow rate were utilized.

Reviewer 29:
The approach appears robust and straightforward both in terms of inputs, outputs and tools used to generate results.

Accounting of the exploration program in terms of probability of success and the impact on estimated monetary values—for example, . risked NPVs—is probably a more conventional approach, but difficult to implement in GETEM. The PI described a practicable work-around.

Reviewer 27:
The summary notes that the original hydrothermal model development was completed in 2006 but makes no note if that modeling actually matched the known history of developed hydrothermal systems. This is alluded to in the Key Issues section noting insufficient data and industry feedback to assess the personableness of estimates.

Comments Regarding Accomplishments, Results and Progress
Reviewer 100:
Progress towards the project objectives has been outstanding. The accomplishments are bordering on outstanding as the creators recognize that there is necessarily some compromise between more detailed input/output for those who need it and more simplification for those who don‘t need it. Overall it is very impressive.

Reviewer 87:
The exploration module has been improved to explicitly include a number of exploration tools/methods and their associated costs. The cost of failed explorations can also now be included. The well drilling cost model has been made significantly more robust by including a methodology to estimate the well cost based on the well depth and the bottom hole configuration. The model steps up through each casing/liner interval, sizing the hole and casing based on vendor information and calculating costs based on time and material costs. Additional spreadsheets have been added to allow for supplemental cost analyses for the levelized cost of electricity for a given internal rate of return (IRR) or the IRR for a given price for the electricity sold. The user interface has been improved and all required inputs consolidated on one tab. All of these improvements add to the utility of GETEM.

Reviewer 29:
This project incorporates exploration, has economic worksheets, is relatively comprehensive and complete, has no POS approach to EMV, has optimization to some extent, has sensitivities, and -technology improvements are captured.

Reviewer 27:
No response entered.

Comments Regarding Project Management/Coordination
Reviewer 100:
Project management has been very good with collaboration with DOE. The developers have taken industry feedback into account and also accepted input of metric units as an option. It suffers from limited industry feedback but this is not the fault of the developer of GETEM which is requesting more feedback from industry.

Reviewer 87:
The project appears to be well managed with an explicitly defined schedule. The project is kept on schedule. There appears to be good interaction with industry, Sandia National Laboratories (SNL), and the National Renewable Energy Laboratory (NREL). Future plans are well defined.

Reviewer 29:
Project management and coordination appear to be very good. The PI is to be commended for his responsiveness to DOE reprioritization, level of cooperation and efforts on dissemination.

Reviewer 27:
No response entered.

Overall
In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 100:
This project has had outstanding achievements overall. The main weaknesses are recognized by the developers themselves, namely the requirement for a simpler model for those that need a quicker scoping model and also for a more detailed model for those professionals and industry who may want to analyze sensitivities of other factors on project economics.

Reviewer 87:
The objective of GETEM is to provide a tool to evaluate the cost of hydrothermal and EGS power production in a consistent, transparent, user friendly manner. Such a tool has tremendous benefit to the GTP by providing at least consistent relative power costs for these geothermal energy technologies and variations within these technologies as well as a better understanding of the key cost factors and relative potential cost improvements. This can help the program set its research priorities and direction. The recent work to improve the exploration and well drilling modules, add economic evaluation tools, and improve the user interface are significant improvements to the model. The overall structure of the model using individual modules to represent the various aspects of developing and operating geothermal energy makes the model easier to use and understand. It also makes it easier to improve and expand the model's capabilities. This effort is well managed with an explicit future plan and schedule.

Reviewer 29:
No response entered.

Reviewer 27:
This is excellent and important work. Its use in evaluating conventional operating hydrothermal developments is alluded to but not documented. Will the final report include this important validation of the methodology?

Comments Regarding Strengths
Reviewer 100:
This is the only publically available format for this type of geothermal project evaluation. It provides a common basis which can be used for relative ranking of cost components of a project and against other projects and could help a company prioritize project expenditures. It is a valuable tool for industry to check their own models to ensure they are not overlooking some key factor. The developers are actively making improvements by incorporating industry feedback. Using Microsoft Excel makes it accessible to everyone. Allowing exploration cost components and failed exploration is excellent. Allowing input in metric units is excellent.

Reviewer 87:
The objective of GETEM is to provide a tool to evaluate the cost of hydrothermal and EGS power production in a consistent, transparent, user-friendly manner. Such a tool has tremendous benefit to the GTP by providing at least consistent relative power costs for these geothermal energy technologies and variations within these technologies as well as a better understanding of the key cost factors and relative potential cost improvements. This can help the program set its research priorities and direction. The model is being improved on a continuous basis as additional and more accurate cost modeling information becomes available. This effort is well managed with an explicit future plan and schedule.

Reviewer 29:
No response entered.

Reviewer 27:
No response entered.

Comments Regarding Weaknesses
Reviewer 100:
They would like more feedback to assist with the process of making improvements. This is not a weakness but could help to improve the model further. It only works with Excel (Office 2007) due to inbuilt macros but the developer recognizes this and aims to fix it.

Reviewer 87:
The model uses a fixed charge rate approach. It would be better if a more rigorous discounted cash flow rate approach were utilized. There is insufficient knowledge of all of the costs of geothermal energy systems. The GTP is trying to develop this knowledge over time. GETEM is only as good as the data available. Significant additional effort should be put into trying to get additional and better data from industry and related industries (e.g. oil and gas).

Reviewer 29:
No response entered.

Reviewer 27:
No response entered.

Suggestions for Improvement
Reviewer 100:
Having an option for outputting results (not just inputs) in metric units (e.g. liters vs. gallons) would be most valuable to enable U.S. projects to be compared directly to overseas projects in Europe, Iceland, Australia, New Zealand, Japan, etc., where metric units are used. The plan for future maintenance of the model is strongly recommended and this reviewer would encourage DOE to provide funding for this in the future so the model can be adapted for future changes in information or policy or government fees or taxes. Fix it so it works with office 2010 as well. Having inputs for different causes for problems/flat time for drilling would be useful for a more robust version.

Reviewer 87:
It could be helpful if the GTP collaborated with other EERE programs on certain aspects of energy cost modeling to provide an improved level of consistency and transparency across EERE. There is insufficient knowledge of all of the costs of geothermal energy systems. The GTP is trying to develop this knowledge over time. GETEM is only as good as the data available. Significant additional effort should be put into trying to get additional and better data from industry and related industries (e.g. oil and gas).

Reviewer 29:
No response entered.

Reviewer 27:
As noted, the Key Issues section mentions insufficient data and industry feedback to assess the personableness of estimates. This is a model application to GTP needs but little mention is made of addressing this key issue and obtaining industry input or calibrating the results with known geothermal developments.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0113
Presentation Title: Life-cycle Analysis for Geothermal Power Systems (ANL)
Investigator: Wang, Michael (Argonne National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 100:
This work in principle is relevant and a valuable input for policy decisions. It is important to know what resources are required to reduce carbon dioxide (CO2) emissions and how geothermal ranks against other energy sources. It is useful or even necessary for industry to have this sort of data when talking to government or local governments or the public about the relative benefits a geothermal project can bring versus the costs or nuisances to the community. If an industry proponent does not know the possible impacts it may have relative to other energy sources then the public may be suspicious about whether or not the proponent cares or is trustworthy. This project has made good progress but could improve by getting more information from existing geothermal plants.

Reviewer 29:
This project is highly relevant for DOE's ability to assess, evaluate, rank and communicate sustainability questions and issues. The project has already made substantial progress and is and continues to be one of the key studies in the field.

Reviewer 27:
No response entered.

Comments Regarding Scientific/Technical Approach

Reviewer 100:
The scientific/technical approach seems OK, but the actual presentation contained a lot of technical jargon which made it harder to assess all aspects. It was hard to assess the robustness of the information obtained about other power industries. This reviewer suggests they obtain more information from major industrial geothermal power plant producers such as Ormat as they have a lot of information on power plant developments of various scales of output developed over two decades of continuous improvements for both air-cooled and water-cooled organic Rankine cycle (ORC) plants.

Reviewer 29:
The project has sharp focus and extremely experienced professionals working on a comprehensive life-cycle analysis and comparison to other energy technologies.

Reviewer 27:
No response entered.

Comments Regarding Accomplishments, Results and Progress

Reviewer 100:
It has already produced some good results concerning energy consumptions and emissions on a life cycle basis. Valuable information has been produced already (e.g., construction has low relative effect) but it is hard for this reviewer to assess objectively against industries that he knows not much about (e.g., nuclear and how much cement it may use relative to EGS).

Reviewer 29:
Data have been carefully cross-checked and referenced to Bertani and Thain 2001. Careful data collection in the U.S.. Authors confirm various difficult/impossible to obtain data yielding a not perfectly complete picture, but probably close enough. Link to GETEM is highly welcome.

Reviewer 27:
No response entered.

Comments Regarding Project Management/Coordination

Reviewer 100:
Project management/coordination seems OK as it has delivered results and aims to improve certain aspects of the study as set out in the tasks in slide 5 of the presentation.

Reviewer 29:
Project management appears to be highly efficient. A minor, but annoying gap is the lack of a project summary sheet. This would have been rather useful.

Reviewer 27:
No response entered.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 100:
This project develops useful numbers for energy inputs and emissions for geothermal power relative to other power sources. It has already developed useful results. It could get more up-to-date information from major geothermal power plant developers such as Ormat for ORC plant to improve its accuracy and relevance.

Reviewer 29:
This is an excellent, highly relevant study, also benchmarked against foreign studies. It is money well worth spent.

Reviewer 27:
The importance of these analyses should not be understated. If renewable in general and geothermal particularly are to compete with other generation technologies, this type of analysis is critical and may represent the principal selling point for continued development of geothermal power.

Comments Regarding Strengths

Reviewer 100:
This project tries to take account of existing and future developments. It uses GETEM to assist the evaluations. It has recognized the importance of availability of water supplies and has collaborated on water usage.

Reviewer 29:
No response entered.

Reviewer 27:

No response entered.

Comments Regarding Weaknesses

Reviewer 100:
This project has made good progress but could improve by getting more information from existing geothermal plants. There may be a substantial difference between air-cooled and water-cooled plants in regards to some major factors such as cement requirements for site works, cooling units, and pumping requirements. In some EGS projects and conventional projects (e.g. Landau, Germany), the geofluid is kept under pressure and reinjected into the reservoir so there is no degassing of CO2 because this can cause cavitation in the production pumps. The researchers identified the key issues as insufficient data partly due to limitations of industry feedback. They identified the need to explain more about stimulation costs for EGS vs. reservoir size. They may not have taken into account the remoteness of a development, i.e., if it is built near existing infrastructure such as roads or high-voltage power lines.

Reviewer 29:
No response entered.

Reviewer 27:
The summary and presentation presume a familiarity with the researcher's program and the complementary research at Sandia National Laboratories (SNL). No fewer than six undefined acronyms are used in the project overview slide and the problem persists throughout. Some of the results seem counterintuitive but previously published documentation clarifies.

Suggestions for Improvement

Reviewer 100:
This reviewer suggests they should obtain more up-to-date and relevant information from major industrial geothermal power plant producers such as Ormat as they have a lot of information on power plant developments of various scales of output developed over two decades of continuous improvements for both air-cooled and water-cooled ORC plants. They should continue with their plans to include hot sedimentary aquifer geothermal projects which should differ substantially in some ways from conventional hydrothermal geothermal and EGS.

Reviewer 29:
No response entered.

Reviewer 27:
Define terms. Establish the viability of analogs. Slide 8 notes that a range of information for U.S. plants (including other generation methods??) would be valuable. The project summary does not provide a plan for addressing identified key issues or what efforts are being made to get that information.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0114
Presentation Title: Water Resource Requirements for Geothermal Energy Production (ANL)
Investigator: Wang, Michael (Argonne National Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 100:
Knowledge of requirements and impacts of water use quality and quantity for geothermal technologies is a key aspect of geothermal energy production especially in locations where water is relatively scarce or valuable as it is required for competing uses. The study is providing useful information especially to those not experienced in water requirements for geothermal projects. Water use issues are likely to become even more important in the future.

Reviewer 29:
The relevance is clearly established—water resources are a major issue. The study will provide fact-based information of high-value to address this concern, also in comparison to other energy technologies.

Reviewer 27:
No response entered.

Comments Regarding Scientific/Technical Approach
Reviewer 100:
A key challenge recognized by the researchers is data availability and collection. In this respect they could have gathered more information from power plant developers like Ormat which has built, installed and operated numerous plants over decades. Water use can vary substantially over time with continuous plant improvements and according to the type of plant utilized.

Reviewer 29:
Thorough approach on defining system boundaries, data collection and data analysis. Good integration with GETEM and other national laboratories.

Reviewer 27:
The stated challenges (slide 3) are to address data availability/collection, develop suitable surrogates for missing data and (compare?) existing vs. future technology. If comparing to existing technologies, why jump immediately to enhanced geothermal system (EGS) processes (the only example in slide 4)?

Comments Regarding Accomplishments, Results and Progress

Reviewer 100:
Reasonable results to date but this could be improved with more information from a range of organic Rankine cycle (ORC) plants installed in different locations (not just the U.S.). This reviewer would like to have seen information on the use or losses of water in the subsurface, particularly in EGS systems where there may be losses in the subsurface in non-closed systems (GETEM assumes water losses of less than 10%). Experience at Soultz EGS project shows no losses due to subsurface inflow but in EGS projects in Japan there were a large percentage of water losses in the subsurface making the projects technically and commercially nonviable. The project seems to be on schedule.

Reviewer 29:

Good track record on deliverables, results and dissemination.

Reviewer 27:
No response entered.

Comments Regarding Project Management/Coordination

Reviewer 100:
Seems to have made reasonable progress against its objectives and the researchers have sought and had some industry input.

Reviewer 29:
Project appears on schedule, the coordination and cooperation with national labs is well-established and strong, and the team is to be commended for their good link to the Geothermal Energy Association (GEA). It is a pity and annoying that the PI did not include a project summary—a useful document for a reviewer.

Reviewer 27:
No response entered.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 100:
Overall it is a worthwhile project to provide base data for developers of new geothermal projects. The researchers have recognized that growth of geothermal energy may be slowed by limitations on water supply. The researchers have estimated water demand resulting from expanded geothermal energy production, based upon future growth scenarios. They have recognized that binary plants may offer some advantages. This reviewer would have liked to have seen water use requirements analyzed for injection well/production well couplets at an initial stage for both a hydrothermal project where water is not circulated between the wells and an EGS project where it is circulated between the wells and for later larger scale geothermal developments requiring multiple injectors and producer wells.

Reviewer 29:
No response entered.

Reviewer 27:
No response entered.

Comments Regarding Strengths

Reviewer 100:
This project aims to take into account both existing and future technologies and assess future demand requirements. To do this the researchers should consult with geothermal power plant developers, such as Ormat, who have installed numerous plants over decades with continuous improvements in efficiency.

Reviewer 29:
No response entered.

Reviewer 27:
No response entered.

Comments Regarding Weaknesses

Reviewer 100:
The assumption of using ESP for temperatures above 170°C is not viable as current ESP technology does not allow pumping of the high-flow rates required for geothermal power plants compared to the much lower hydrocarbon flow rates obtained from ESPs used in the petroleum industry. That is why line shaft pumping is used at the higher temperature projects such as at Landau, Germany. The Soultz project in France has shown that ESP pumps are not currently suitable for temperatures above 170°C and need further development. The study does not take into account the effect of possible water losses in the subsurface. The study should take into account the pricing, proximity or remoteness of available water sources as this can be a key factor in remote or desert areas. The study should take into account that emissions from geofluids will not occur where the geofluid is kept under pressure below the bubble point to ensure that it remains in the liquid phase and that gas is not emitted in the well bore or at the surface to avoid cavitation in the pumps and the plant.

Reviewer 29:
No response entered.

Reviewer 27:
No response entered.

Suggestions for Improvement

Reviewer 100:
The study recognizes that reuse of non-fresh water is an option but should also consider that geothermal energy has the potential to provide a base load 24/7 energy source to purify water via multi-effect distillation and therefore could be part of the solution to improving water quality (even to potable quality) and making it available for other uses such as drinking water or process water in the future and not just be a consumer of water.

Reviewer 29:
No response entered.

Reviewer 27:
Expand comparison or calibration against existing operations before making the EGS leap.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0115
Presentation Title: Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems (ADI)
Investigator: Turaga, Uday (ADI Analytics, LLC)

Comments Regarding Relevance/Impact of Research

Reviewer 82:
The five tasks listed for this project do not appear that they would have a large impact on program goals since they do not do much to address knowledge gaps. Most of the tasks pertain to areas that have either been covered by past projects or are being addressed by current projects also presented at the Peer Review. The project appears to have too large of a scope, attempting to cover subjects ranging from cost drivers to the impacts of new technologies to outreach and education. The biggest potential impacts from this work would likely come from Task 2 (evaluating cost impacts of new technologies) and Task 3 (Patent Analytics). There should be some overlap between these two tasks.

Reviewer 42:
The project appears to have made important and significant progress in meeting DOE's mission and goals. This research looks at critical components of enhanced geothermal system (EGS) costs and levelized cost of electricity (LCOE) modeling that need to be properly analyzed and scrutinized for a given field.

Reviewer 87:
The objective of this project is to get an independent assessment of the cost of EGS power for current technology and possible cost reduction for the future. They are eliciting experts for information to input into GETEM to validate, augment and improve on EGS cost estimates. An independent assessment is good but there are other projects also doing this. It is not at all clear that this effort will be worth the $1.6 million cost of the project. It is still relying heavily on the costs in GETEM.

Reviewer 29:
The project is relevant with its three primary goals of providing an independent assessment of EGS cost, understanding how cost structure will evolve, and education and outreach. The project is particularly high value for forecasting the impact of technology development and allowing for prioritization.

Comments Regarding Scientific/Technical Approach

Reviewer 82:
It was hard to evaluate the technical approach of such a wide-ranging project with so many tasks in the space provided for the presentation and summary sheet. For the expert elicitation, this reviewer worries that talking with experts one-on-one about their technology would lead to overestimates of the potential cost reductions and performance improvements. Since they are proponents of their technologies, they are likely to give inflated values. Experts should also be interviewed in areas in which they are knowledgeable but not actively involved to give a tempered viewpoint of the emerging technologies. Using this as input for Task 2 brings the credibility of the results into question. For Task 3, the rate of patent applications is increasing, but no comparison to patent growth in other industries or a methodology for translating these growth rates into actual technology advances is shown. Has the rate of patents in all fields (or the overall rate of patent applications, for that matter) grown at a similar rate? The same is true for Task 4. From the figures shown, it's hard to tell how the numbers were derived.

Reviewer 42:

The technical approach taken by the PI and Penn State is appropriate and reasonable. There is question about the participation of SciTech in relation to just how beneficial their participation is. Other than that, the PI has provided very interesting insight on the estimate and analysis of EGS.

Reviewer 87:
The project is eliciting information from experts, utilizing GETEM, and trying to use patents to develop improved EGS cost estimates for current and potential new technology. It is a reasonable approach but is unlikely to add enough information to what is already known through GETEM or being uncovered in other projects to warrant the $1.6 million cost for this project. It is unclear how the patent search will add viable quantifiable information on current and future EGS costs. The project will try to construct learning curves based on the patent search and looking at other industries such as the oil and gas industry especially for the more recent advancements in shale oil and gas. This could be useful if done well. The project also has a task on combining IGCC with EGS to look for synergies and lower cost EGS. This is interesting but it is not clear this project team has any unique skills and qualifications for this part of the effort.

Reviewer 29:
The combination of the four principal tools used—expert elicitation, cost modeling, patent analytics, and exploring synergistic/hybrid use of EGS—is excellent. Data collection appears to be very thorough and complete. A minor, but rather difficult to overcome weakness is the relatively small number of expert interviews (the PIs have suggested, though, that more of them will be performed).

Comments Regarding Accomplishments, Results and Progress

Reviewer 82:
The results shown to date are not unique or that insightful. EGS cost category ranges and values are similar to what this reviewer has seen from other sources. The cost reduction requirements to reach near-field EGS goals seem obvious, as do the impacts of new technologies. As mentioned above, this reviewer can see that there are more geothermal patents, but doesn‘t know how that can be used to quantify technology advances. The CO2 analysis in Task 4 doesn't appear that in-depth. It would have been better if the presenter had gone into more detail about the methodology and results for a few tasks rather than trying to cover them all.

Reviewer 42:
The PI presented a quality presentation on the accomplishments, results and project progress to date. The real work has yet to be completed. Specifically, the Task 4 related to the feasibility of IGCC/CO2-EGS.

Reviewer 87:
The results to date are centered on information gathered from experts, other previously done studies, and GETEM on EGS costs and necessary cost reductions to achieve the DOE EGS goals. It is not clear that substantial information has been uncovered that either was already known or being established in other projects. The patent search has been completed and analyzed. It is unclear what new information pertinent to the GTP program was uncovered through this effort.

Reviewer 29:
The project execution appears to be on track with deliverables and milestones delivered as promised. The quality appears very good. The dissemination efforts are good; the educational outreach appears to be focused on one or very few institutions.

Comments Regarding Project Management/Coordination

Reviewer 82:
Given the large number of tasks, the team is doing a good job of moving the work along.

Reviewer 42:
It appears that the PI and team have effectively managed this project considering the complexity of the scope of work. Provisions for future management were described. The project itself is well planned and is proceeding on schedule.

Reviewer 87:
The project is well managed with a defined schedule.

Reviewer 29:
Good project management! This is a particularly well executed and controlled project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 82:
Overall, the project appears spread thin. It is trying to do too many things at once. In part because of its breadth, the tasks tend to mimic or rely heavily on previous studies rather than perform new analysis in a novel way or diving deep into an issue. The patent analytics and expert interviews show promise, but a better methodology to get an accurate appraisal of new technologies is needed, and the patent analytics needs its methodology better defined.

Reviewer 42:
Initial impression of this project is a positive one. The results of this project will be very useful in exploring the use of CO_2 as working fluid for power production. This research will by no means be definitive on this issue. However, there are several major concerns regarding this topic. It's a very interesting concept that is being presented, using CO_2 for enhanced geothermal as a working fluid. Not enough discussion was provided by the PI regarding whether the research considered a naturally porous and permeable formation or low permeability crystalline rock. There are definitely some issues that will need to be scoped out. Here are a few thoughts that come to mind. This reviewer has not fully thought these through; they are just rough thoughts. 1) The potential for migration of the CO_2 beyond the project areas and contamination of any ground water resources would like be significant in the naturally porous, permeable formations. The proposal is not all that different from the concept of enhanced oil recovery with CO_2. Containment in natural geothermal environs might be more difficult than in oil and gas fields, where there are known traps, etc. 2) The concurrent sequestration argument is not well supported, especially when the intent is that the PI will assess using the CO_2 as a working fluid that will be pumped back up and recycled again and again. The PI states that 10% of the CO_2 is lost (more than 10% actually); then where is it going? How much is being sequestered? The likelihood is that it is migrating somewhere else (given the buoyant nature of the CO_2) and not getting entrained in the formation. There would be a need for a very rigorous monitoring program to demonstrate that the CO_2 is staying where it should. There would also be a need for contingency plans for when it goes offsite. Will the income from sale of the electricity be sufficient to offset the costs for all the site characterization and monitoring that will be needed? 3) There are also issues with how the CO_2 moves in the subsurface and there may be requirements for increased water use to allow for injection of the CO_2 as a working fluid. In enhanced oil recovery it has been shown that the CO_2 creates channels or pathways in the subsurface if injection of the CO_2 isn't alternated with a water flood. (This is called water alternating gas or WAG). So there might be an increased demand on water resources in an area where this type of project operated. 4) In California, environmental review and permitting of such projects would be a significant issue. Any scoping would need to look at permitting issues as well as the multiple technical issues. Injection of CO_2 under Class V—geothermal Underground Injection Control (UIC)—requirements and the role of the Division of Oil, Gas &

Geothermal Resources (DOGGR) would need to be evaluated. The permitting of CO2 under DOGGR Class II authorities is unclear, so there may be institutional issues or a need for new legislation in order to allow the activity under Class V DOGGR authorities as well.

Reviewer 87:
The objective of this project is to get an independent assessment of the cost of EGS power for current technology and possible cost reduction for the future. They are eliciting experts for information to input into GETEM to validate, augment and improve on EGS cost estimates. An independent assessment is good but there are other projects also doing this. It is not at all clear that this effort will be worth the $1.6 million cost of the project. It is still relying heavily on the costs in GETEM.

Reviewer 29:
It is worth emphasizing that the approach put forward by the PIs is very useful for assessing, ranking and prioritizing the development of technologies.

Comments Regarding Strengths

Reviewer 82:
Good job making progress on many tasks in the time given.

Reviewer 42:
The PI is meeting objectives as described. The management team is a positive and is on task. There is a very high probability of success. The project is based on sound engineering principles.

Reviewer 87:
It is good to get an independent assessment of current and future potential costs of EGS power. The development of possible learning curves for EGS from patents and the oil and gas industry would be very useful if done well.

Reviewer 29:
No response entered.

Comments Regarding Weaknesses

Reviewer 82:
Tasks lack depth and uniqueness. This reviewer doesn't see a lot of new information coming from this project.

Reviewer 42:
No response entered.

Reviewer 87:
It is not clear that this effort will add $1.6 million of value to the Geothermal Technologies Program (GTP). Other projects are doing similar work. The team does not appear to have any specialized skills to make their results significantly better than what has already been done or is being done in other projects.

Reviewer 29:
No response entered.

Suggestions for Improvement

Reviewer 82:
Suggest the project concentrate on a few tasks and delve deeper into them.

Reviewer 42:
No response entered.

Reviewer 87:
A decision should be made as to whether to continue this project or not.
Reviewer 29:
No response entered.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0116
Presentation Title: Baseline System Costs for 50.0 MW Enhanced Geothermal System (GEECO)
Investigator: Dunn, Paul (GEECO)

Comments Regarding Relevance/Impact of Research

Reviewer 82:
The results of the study to date have interesting conclusions, namely that carbon dioxide (CO_2) systems, even when the CO_2 must be purchased, are preferable to water-based enhanced geothermal systems (EGS). These conclusions would be important factors to ponder for the program if it were to consider a larger effort in "ultra-deep" EGS resources. The study would also be of immediate use to the program if at some point in the future a policy, such as a carbon tax, were enacted that assigned value to sequestering CO_2. It would quickly allow the Geothermal Technologies Program (GTP) to point to this technology as having significant potential of being an economic way to do this. This reviewer would have liked to have seen the study look at such a scenario, and believes the results are somewhat limited in their application. The study looked primarily at very deep (7-10 km) resources, where drilling costs dominate and pumping power required to circulate the geofluid (if water) becomes a major issue. The conclusions should include more caveats and stress that the results do not necessarily apply to shallower EGS resources. Also, the results assume that CO_2 power plant generation equipment is technically available. This is mentioned, but should be stressed more in the final report.

Reviewer 42:
This project has made significant progress in fulfilling DOE goals and has successfully demonstrated that it is addressing knowledge gaps and barriers.

Reviewer 29:
This reviewer does not see the relevance of the project, other than exploring the implication of a highly disadvantaged (from a subsurface point of view) resource base and scoping out hybrid EGS+ projects. Does DOE need to spend US$ 1.2 million on a fairly obvious conclusion right from the get-go? One redeeming aspect in terms of relevance is linking EGS development to CCS and adding a study that evaluates the question, but of highly limited relevance.

Comments Regarding Scientific/Technical Approach

Reviewer 82:
The project appears to have taken a rigorous and methodical approach to answering a complex analysis question with many unknown variables. The project proposed several scenarios, including multiple working fluids and multiple surface plant configurations, to demonstrate potential for a range of potential solutions. For each scenario, a consistent level of analysis and evaluation was applied. Key factors affecting end-project cost were identified and addressed. The project also examined "novel" concepts such as onsite hybrid plants for CO_2 generation to address key factors they had found during their analysis. The presentation did not allow enough detail to assess the legitimacy of component costs. This reviewer would like to have seen one slide with details on drilling cost and power plant cost assumptions, especially drilling costs since they have such a huge impact on total project costs.

Reviewer 42:
The technical approach taken by the PI is well devised and will be an effective tool for future geothermal research and eventual geothermal development.

Reviewer 29:

The WBS to costing is standard to achieve the stated objectives.

Comments Regarding Accomplishments, Results and Progress

Reviewer 82:
The ranking applies more to productivity than quality. The amount of work and depth of the results is very impressive given the time frame of the project. The quality of the work is very good, but may be confined to the location and scenario considered. This reviewer has concerns about applying the results broadly.

Reviewer 42:
The project has made significant progress and has achieved better than expected results and outcomes. They have made excellent progress in compiling massive amounts of paper and electronic data, and geothermal resource data in many incompatible formats and integrating them into a cohesive understandable and workable format.

Reviewer 29:
The results achieved in each of the WBS appear reasonable. But, little was revealed on the input into the model.

Comments Regarding Project Management/Coordination

Reviewer 82:
The project appears to be very well managed and coordinated, given the large number of team members/groups that collaborated on the project. The team has done a great job staying focused on the task and objectives and staying on schedule.

Reviewer 42:
The PI and staff have provided convincing evidence that they have done a formidable job in effectively managing their project. The project has evolved and has progressed according to schedule, and appears to have the proper checks and controls. It appears that the project is able to handle most deviations without compromising the schedule.

Reviewer 29:
The project management and coordination was that of a typical scoping study for an infrastructure engineering project.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 82:
Overall, the project appears to be a very thorough case study of deep (7-10 km) EGS potential that would include sites not typically considered geothermal resources. The analysis is rigorous and thorough and identifies key factors that impact project costs. The results can be used by the program to assess the potential and promise of funding deep EGS and CO_2 as working fluid projects in the future.

Reviewer 42:
This is a very good investment of DOE funds. The ground work being laid by this massive data collection effort will provide geothermal developers and future research work important resource information.

Reviewer 29:
No response entered.

Comments Regarding Strengths

Reviewer 82:
- Thorough analysis. - Wide range of scenarios addressed. - Identifies key barriers to projects. - Strong focus on project costs. , Ggood identification of key metric ($)

Reviewer 42:
The PI has met its objectives as described. The mangagement team is a positive and the project is proceeding on schedule. There is a very high probability of success. The project is based on sound information management principles.

Reviewer 29:

Comments Regarding Weaknesses

Reviewer 82:
- The Aapplication of results is somewhat limited to the area and scenarios studied. It Ddoes not address CO2 use in shallower EGS resources. - Financing assumptions (4% cost of capital) are not realistic. Other funding levels not considered. - It Ddoes not consider future scenario where CO2 sequestration is wide-spread/mandated.

Reviewer 42:
The real weakness in this project is that the PI has no real contingency plan to keep the data collection, cataloging and storagte operation going once DOE funding runs out. It was mentioned by the PI that the individual nodes would be self-sufficient. While this may be a their plan, no evidence was provided by the PI to indicate that other funding sources would be available to keep the Arizona U.S. Geological Survey (AZ USGS) effort going. There was no discussion on how to protect the integrity of the AZ node and the larger system from cyber attacks.

Reviewer 29:

Suggestions for Improvement

Reviewer 82:
Adding a few more scenarios where cost of money or cost of working fluid is varied would help the study. Since the majority of work on pricing out wells and surface equipment is already down, expanding analysis to include this does not seem like it would be particularly difficult.

Reviewer 42:

Reviewer 29:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0117
Presentation Title: Economic Impact Analysis for EGS (EGI)
Investigator: Gowda, Varun (University of Utah)

Comments Regarding Relevance/Impact of Research

Reviewer 82:
The tool that this project is developing could be useful in helping decision makers consider the economic impacts of supporting geothermal deployment. The task also appears to be addressing knowledge gaps in terms of component costs, especially in terms of developing drilling cost estimates.

Reviewer 23:
Assessment of the broader economic impact of enhanced geothermal systems (EGS)— - the point of this project— - is of great importance in informing decision making by policy and other government groups as they consider the means to achieve the "right" future energy portfolio for the United States.

Reviewer 42:

Reviewer 29:
In theory the project is highly relevant for demonstrating the economic impact. However, the PIs were not able to demonstrate any real progress. The Q+Aquestion and answer session revealed that some tools had been developed to assess the impact.

Comments Regarding Scientific/Technical Approach

Reviewer 82:
The project has developed and explained a sound methodology for each phase of the project, in particular in the strategy they've developed for obtaining or estimating component costs and in using public data (which can be easily updated) to calculate the "ripple effect" from geothermal projects.

Reviewer 23:
Use of the input-output methodology described is entirely appropriate as the basis for the economic impact model. It will be very interesting to see the results as the project continues. It seems the project's approach to developing a cost basis for the model is reasonable given the sparseness of available real-world data about EGS. It will be interesting to compare and contrast the results with other economic modeling approaches being applied internationally.

Reviewer 42:

Reviewer 29:
The phased approach appears reasonable, but no clear indication was made whether this is a standard approach to assess the eEconomic impact.

Comments Regarding Accomplishments, Results and Progress

Reviewer 82:

The accomplishments presented appear in line with where this type of project should be. The GETEM runs using the Monte Carlo tools are is interesting, but only inform where the major cost drivers are and are not a major goal of this project. The supplemental slides note that these runs do not include parasitic power losses, which is troubling. It's good that they have a basic model for the U.S. US "Make Use" tables, but this reviewer I would have liked to have seen some results from it in the presentation or summary document.

Reviewer 23:
Progress seems reasonable to date, but it is difficult to assess fully until the project begins producing results from application of the model. If a more iterative approach were being used it might have been possible to show preliminary economic impact results at this point.

Reviewer 42:

Reviewer 29:
Considering the approach of the project, the accomplishments, results and progress appear fair, - but focus on EGS cost only.

Comments Regarding Project Management/Coordination

Reviewer 82:
The project appears to be well organized, on schedule, and within budget, with plans and a schedule for moving forward.

Reviewer 23:
The Project appears to be on track and managed well. It might have been useful, as noted above, to apply a bit more iterative/incremental project management approach in order to show preliminary results sooner, - leading to more confidence in ultimate project success.

Reviewer 42:

Reviewer 29:
There appears to be a poor vision on how to achieve a clear, transparent assessment of the economic impact for EGS.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 82:
Overall, this project seems to be going well and should result in a useful model of economic impacts from geothermal that contains some interesting features and is available to the public.

Reviewer 23:

Reviewer 42:

Reviewer 29:

Comments Regarding Strengths

Reviewer 82:
The efforts to develop a drilling cost model and estimates is admirable. It shows initiative from the team in finding a solution when data was not readily available. Since drilling costs have a large impact oin geothermal project economics (especially for EGS), this could be a very useful bonus tool from the project. This reviewer is I am interested in seeing the results from this portion of the project.

Reviewer 23:

Reviewer 42:

Reviewer 29:

Comments Regarding Weaknesses

Reviewer 82:
Viewing the supplemental slides, I amthis reviewer is concerned that the parasitic loads have not been factored into the hydrothermal and EGS models. These can have significant impacts on costs and power output. The cost of the injection and production pumps alone could have a large effect on economic impacts. These units require frequent replacement and will impact operations and maintenance (O&M) costs (and plant jobs) over the lifetime of the plant. The team should focus on getting these added. Like many of the analysis projects, this reviewer worries I worry about heavy reliance on GETEM for building additional models and doing analysis.

Reviewer 23:

Reviewer 42:

Reviewer 29:

Suggestions for Improvement

Reviewer 82:
As mentioned above, adding parasitic power estimates to model runs is key. Otherwise, the results can not be taken seriously.

Reviewer 23:
G- get some early economic model results out sooner, even if they are not entirely validated. - Ddo some additional discovery concerning other efforts to model the economic impact of geothermal, e.g., ... NREL, international, etc. It would seem there is some of this going on elsewhere.

Reviewer 42:

Reviewer 29:

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0118
Presentation Title: Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment and The Potential Employment, Energy, and Environmental Impacts of Direct Use Applications (BLA)
Investigator: Battocletti, Elizabeth (Bob Lawrence & Associates, Inc.)

Comments Regarding Relevance/Impact of Research

Reviewer 11:
This project has the potential to have an impact on the Geothermal Heat Pump (GHP) Roadmap goal of 1 million GHPs installed by 2016. The project objectives, "to measure the costs and economic, social, and environmental benefits of nationwide geothermal heat pump (GHP) deployment" and "to survey selected states as to their potential employment, energy use and savings, and environmental impact for direct use applications, and to provide technical assistance" do serve an important niche in evaluating the overall impacts of widespread GHP deployment. The project materials provided (presentation and summary document), however, make it very difficult to evaluate the progress of the project toward having an impact on the GHP Pprogram's mission and goals. The project would be strengthened significantly if there was would be a portion of the analysis devoted to the potential barriers to widespread deployment of GHPs. Simply analyzing the costs and benefits may be useful; however, the impact to the program would be much greater if barriers were identified.

Reviewer 64:
This project supports the goal of installing 3 gigawatts electrical (GWe) of low-temperature geothermal capacity by 2020 by examining the costs and benefits of geothermal heat pumps and direct use.

Reviewer 74:
The project addresses the large- scale implementation but to this reviewer‘s my knowledge the study is confined to technology cost evaluation of the installation of heat pumps which is fairly well established in other countries such as Sweden, for instance. This reviewer I misses relevant issues such as the impact on the power profile, the possibility of gas- driven heat pumps to mitigate this,. the compatibility of the systems in the buildings and the buildings themselves, etc. The emphasis on thermal conductivity of soil is, to this reviewer‘s my knowledge, a secondary issue with high local variations.

Reviewer 88:
This study addresses known market barriers for ground- source heat pumps. The PI has done a good job at networking within the technical community to identify good sources of information. The project has also identified, reviewed, and responded to the most recent publications relevant to their effort.

Comments Regarding Scientific/Technical Approach

Reviewer 11:
The Scientific/Technical Approach was rated "Fair" because of limited information regarding how the data collected will be analyzed. In the presentation there were five slides devoted to data collection and only half 1/2 of a slide devoted to data analysis. For the GHPsRUS project, the objective is to not only measure the costs, but to also measure the economic, social, and environmental benefits. There are no details on how the latter will be accomplished. This is a significant omission, considering the importance of the quantification of these benefits. Additionally, the project would be

significantly strengthened if the details of the analysis plans were included. The analysis of the data collected represents a significant portion of this project and there is no clear pathway toward the data analysis.

Reviewer 64:
The approach for the ground- source heat pump assessment appears to be thorough. The technical approach for the direct use work is less clear. Specifically, itt is not clear (1) what type of technical assistance will be conducted, and (2) what aspects of the bulletin are considered technical assistance (the articles or the project described in the article).

Reviewer 74:
The project has good scientific/ technical resources within the defined scope. What is missing is input on energy system issues.

Reviewer 88:
1. Excellent idea to try to gather data online via a crowd source type approach, but I this reviewer doesn‘tdon't see that the study has thought through the implementation. Results to date indicate that the approach for gathering installer data may not be successful. , This reviewer doesn‘t I don't see evidence that they recognize this. Change in approach would be good. 2. The analysis approach and assumptions for the building analysis in various locations was not well enough defined. This reviewer is I am concerned that they have underestimated the challenge and may not be able to complete the scope with credible results.

Comments Regarding Accomplishments, Results and Progress

Reviewer 11:
The materials provided make it difficult to evaluate the progress of the project. At this point of the project (%40% completed, 34% of funds spent) it would be expected that significantly more progress would have been made. Slide 15 (the single Accomplishments, Results, and Progress slide) provides only information on the reports that have been written, but no information about the actual progress toward data collection and analysis (Steps 1-4). It appears from the review materials and from the presentation that only one of the surveys of the "who" listed on Slide 10 has been created. There were 15 constituent groups listed, therefore if only one group has been surveyed, there is a significant amount of work remaining. In short, for a project that has expended over $500,000 of DOE funds thus far, one would expect to see many more results than presented on Slide 15 and in the Summary Document. There is not enough evidence to support the assertion on Slide 22 that data compilation is on schedule considering there was no schedule provided and no data collection timeline.

Reviewer 64:
Progress seems appropriate although no preliminary results were presented. The direct use task has completed two 2 surveys out of seven 7 and appears to be on track. The data compilation appears to be on track for the geothermal heat pump task as well.

Reviewer 74:
The project has progressed well with its planned tasks.

Reviewer 88:
This reviewer I was disappointed with the progress shown for data collection and the analysis results for various locations.

Comments Regarding Project Management/Coordination

Reviewer 11:
The project coordination and management seems reasonable; however, there are no details of how the project is being

coordinated—, only who the project leaders are. This is not sufficient. The project leaders need to define a project management plan that outlines how the various aspects of the project are being coordinated.

Reviewer 64:
Task responsibility is clearly laid out among Bob Lawrence & Associates, Inc . (BL&A), CGEC, and GHC-IT. They are coordinating with many organizations as part of their effort.

Reviewer 74:
As the relevance matrix has not been established in forehand it is fair to say that for the management for the project according to the work plan is OK.

Reviewer 88:
Downgraded from good to poor because I this reviewer felt that the PI did not recognize the challenges of modeling and had not gotten the team far enough along on that activity.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 11:
One might assume that the project is making sufficient progress; however, the materials that were provided (both the presentation and the summary document) do not provide enough details to verify this assumption. Overall, from the information provided it seems that the project has not obtained enough results to justify the resources that have been expended thus far. It is also not clear what the path forward will be.

Reviewer 64:

Reviewer 74:
The scope should be measuring the cCosts and Eeconomic, Ssocial, and Eenvironmental Bbenefits of Nnationwide Ggeothermal Hheat Ppump Ddeployment and the Ppotential Eemployment, Eenergy, and Eenvironmental Iimpacts of Ddirect Uuse Aapplications. This is a very wide scope which is not well reflected in the actual plan and execution of the project.

Reviewer 88:
This is a valuable project and the general scope is well thought out. The project would benefit from help at DOE to make mid-course corrections.

Comments Regarding Strengths

Reviewer 11:
The project has the potential to contribute significantly to the understanding of the potential benefits of widespread GHP deployment. Additionally, the barriers to this deployment may be identified, allowing for the GHP pProgram to assess potential remediation methods to overcome any barriers.

Reviewer 64:
The project team is competent and experienced, which will serve the project well through completion.

Reviewer 74:
The strength of the project is that it is collecting actual data on the preconditions, technologies and performance for the installation of heat pumps. For these aspects the data should be of good quality.

Reviewer 88:

Comments Regarding Weaknesses

Reviewer 11:
The major weakness of this project may be the review materials provided to the reviewers. It is very difficult to assess the progress, technical approach, and future path when these details are not provided.

Reviewer 64:

Reviewer 74:
The weakness of the project is that it does not deal with the compatibility of heat pump installations with the grid, the housing stock nor the contemporary technologies for buildings and building service.

Reviewer 88:
Poor answer to a question raised about the net jobs if GHP installed; some competition does exist—, market growth will take away jobs from other heating, ventilation, and air conditioning (HVAC) industry. There will be push-back from non-ground-source heat pumpGSHP industry of study results. Should be anticipating and thinking about how to deal with it. More thought needed on building analysis.

Suggestions for Improvement

Reviewer 11:
The project would be improved greatly if there was a clear path for data collection and analysis was identified.

Reviewer 64:
More details on the type of technical assistance provided for direct use and how that furthers the low-temperature goal through education, reducing perceived and real barriers, etc., would be helpful.

Reviewer 74:
In the final report,ing the questions of system aspects and compatibility should be addressed and if they can not be treated thoroughly a road map for complementary research should be provided. Also alternative strategies like gas- driven heat pumps and other heat exchange configurations other than drilled holes should be considered. Also, a chapter on established experience in other countries should be added

Reviewer 88:
More direction from DOE technology program.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0119
Presentation Title: National Geothermal Student Competition (NREL)
Investigator: Geiger, Jesse (National Renewable Energy Laboratory)

Comments Regarding Relevance/Impact of Research

Reviewer 11:
The importance of bringing future engineers and scientists into the geothermal field cannot be overstated. This project has made significant progress toward introducing a large number of students to a relevant geothermal research topic. However, the impact might be greater using a different approach instead of focusing on one specific geographic area. The impact might be increased if a sustainability plan would be developed. While this might be out of the scope of the current project, the experiences gained from this first competition will be useful in informing a sustainability plan for the competition.

Reviewer 91:
This is Aa good project in an experimental phase. It is Ddifficult to quantify its measurable outcome as it is the case with any educational project. The program is attracting like-minded students with interest in geothermal energy. This group should be widened to, a pool of potential leaders in the field. Their extended technical knowledge will be critical to DOE's R&D goals as well as to commercial success.

Reviewer 90:
This project has huge relevance to advancing the knowledge base among future geo-scientists, with particular attention to geothermal energy. While the project has accomplished the goals, the time period to accomplish such goals is unrealistic. The student group's should have an entire academic year to work on this type of a group project, understand the issues/barriers, and make some recommendations based on their understanding and future needs. Of course, this is not the fault of the PI or DOE. This is something that needs to be worked out in terms of matching fiscal years and academic years and the funding cycle.

Reviewer 46:
As this is an education project it is difficult to assess in terms of the programmatic goals. I do think tThis project makes an important contribution to the program, as it is energizing the geothermal industry at the grass roots level. The students you are involveding today will be the professionals and decision makers when enhanced geothermal systems (EGS) begins to make an impact into the U.S. energy mix.

Reviewer 75:
The idea of a geothermal student research competition is excellent and very timely. It is time to attract more students into the field of geothermal and renewable energy science from all aspects. Unfortunately, the time frame of advertising the program and project submission was extremely short and only reached a fraction of programs and mostly programs that already have geothermal programs (although there were exceptions). In any case, this is an excellent idea, but with flaws in execution.

Comments Regarding Scientific/Technical Approach

Reviewer 11:
The approach was good, as evident by the large number of participants. It might be improved if the timeline was revisited. Many more schools might be able to participate if it spanned a full academic year. The project participants

should examine other national-level competitions (see EcoCar and others).

Reviewer 91:
The approach is highly recommended. The project helps provide examples of open-ended solutions to new geothermal energy extraction problems associated with a given geologic area.

Reviewer 90:
The approach is scientific and seems to be technical. It was not very obvious nor did the reviewer' s have access to see the proposals from each university to the PI. I This reviewer would have liked to have seen those, especially, when some teams had faculty oversight and the university proposals to the PI were submitted by the faculty, whereas, a couple universities had student- initiated teams. It seems, a few universities have been able to make significant advances by being able to incorporate their research findings into a class as a module or introduce a new class, spreading the geothermal energy future to more students. I amThis reviewer is not sure if a multidisciplinary approach was used in selecting the teams or not. It will be important to have these teams comprised of engineer's, geoscientist's and business/economics majors. That will be a truly multidisciplinary team working on an open- ended problem.

Reviewer 46:
This reviewer I liked the open- ended approach that the National Renewable Energy Laboratory (NREL used);, while they didn't present the mix of student backgrounds, coming at the in a prescriptive manner would more than likely exclude participation rather than focus the project.

Reviewer 75:
Not having access to any of the student presentations or results, the assessment is limited to the logistical evaluation of the program (see above). Over all, this reviewer likes the geographic, rather than the methodological/thematic approach, but is I am not sure how learning is ensured and evaluated. Having dealing with tracking of student learning, this reviewer was what somewhat disappointed by those efforts. What were the expectations? I think Tthe expectations and the outcome need to be better defined.

Comments Regarding Accomplishments, Results and Progress

Reviewer 11:
The results presented illustrated that there were a large number of schools that were able to participate. Three schools tailored a class around the competition and the topics spanned a wide range of expertise. The project's results and progress was rated "Good" and not rated "Outstanding" due to the utilization of the DOE funds awarded. It is not clear where the $231,000 was spent when only $96,000 went to the uUniversity awards.

Reviewer 91:
The project is achieving its goals as planned. The productivity is excellent, judged from the overwhelming interest from the participants.

Reviewer 90:
Considering the time frame, the students have done a remarkable job. They will be able to compete and present their research findings in a technical conference. Unfortunately, these presentations are yet to occur (late June 2011), so the reviewer' s do not have an opportunity to see that material. The students had to have a high level of productivity to come up with these presentations in such a short timeframesmall duration.

Reviewer 46:
I think tThey are on track, while truly defining a measurement metric for success is a bit dubious. The major question is "How will they truly measure success?" I don't think Tthe answer isn‘t in holding the competition, but I think the

answer really would be in how many students go on to geothermal- related degrees, how many enter industry, etc. How to track this is an entirely different issue....

Reviewer 75:
I think oOverall this well-intended program has itsthe heart in the right place and is a much needed effort. However, the costs appear to be prohibitive and not well spent. The time of the advertisement and, the lack of response from a wider audience leave much room for improvement. As stated above, not having access to any of the student presentations or results, the assessment is limited to the logistical evaluation of the program. One of the major issues not addressed in the review is program sustainability. Clearly at the cost of the current program this is not sustainable. What could be changed? What about industry buy- in for the entire program?

Comments Regarding Project Management/Coordination

Reviewer 11:
The project appears to be running smoothly. Monthly coordination calls have been held, the projects were disseminated on time. The only negative aspect of the coordination were was the delays that were due to contracting delays. While these may be due to a number of factors out of the control of the project organizers, it is also partially due to the truncated timeline that was under the control of the project organizers. The participant schools were selected in December and it should not be unexpected for contracting to extend into the spring semester.

Reviewer 91:
This is Vvery good and successful as a first effort. The project is on schedule with a larger than expected group of participants.

Reviewer 90:
The project has been well managed by the PI. Again, the time frames were extremely tight and I believe the PI has done a great job in steering the universities in the right direction and keeping them focussed on the deliverables.

Reviewer 46:
NREL's management is competent. Should this competition be repeated, it would be best to make the announcement well in advance of the school year, so senior/class design projects could be aligned with the competition.

Reviewer 75:
It is difficult to evaluate the management/coordination of the program. However, the costs appear prohibitive and do not represent a good or sustainable model. The technical staff was at the students' disposal, but went unused. There was no attempt to remedy that.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 11:
Overall, this project is performing very well. It is good to see so many schools participating, especially those that are not commonly associated with geothermal research.

Reviewer 91:
The project helps provide a better-educated work force for geothermal energy production. A higher quality in the work force will accelerate the long-term development of the geothermal energy industry.

Reviewer 90:
Overall, it has been a novel concept by the PI to engage the future geoscientists and engineers in to a unique multidisciplinary team, that has accomplished it's goals of advancing and spreading the knowledge about geothermal energy.

Reviewer 46:
Most of this is covered above. , I feel Tthis is an important project that makes an important contribution, yet that contribution is difficult to quantify.

Reviewer 75:
The comments here reflect many of the comments above, ranging from advertisement to tracking of student learning. I think Tthe program could and needs to be improved to be more effective in terms of learning and more cost-effective to be sustainable. The boundary conditions for proposals and budgeting need to be tightened up, so that we get the most education per dollar spent/$. . One idea, might be to link up with a company or companies for students to independently tackle real life problems. IThis has have seen this been done successfully in the oil and gas industryO&G.

Comments Regarding Strengths

Reviewer 11:
Many of the strengths have been discussed under the individual criteria. I feel that iIt is very important to engage students across the country in the geothermal field.

Reviewer 91:
Very good concept, very good experimental execution and management.

Reviewer 90:
The project deliverables are well defined and focussed. The student teams have a clear and concise goal and extremely tight schedules to deliver, which is a reality in real life.

Reviewer 46:
Getting the student involvement, and also engaging industry. The final workshop/presentations in Santa Fe should be captured and distributed.

Reviewer 75:
See above.

Comments Regarding Weaknesses

Reviewer 11:
One weakness of the project is the large price tag associated with the coordination of the project. In order to establish the future sustainability of the project, it is important to identify a mechanism that will minimize the overall cost of the central competition coordination.

Reviewer 91:
Try to increase the duration of the project;, one year may be too short for students and programs. Project money should support student work instead of faculty especially if the work is done during the academic year.

Reviewer 90:
In order to do a meaningful job, the time needs to be more realistic. The student teams should have at least two academic semesters to work as a team. While the concept is novel, there is no plan for sustaining and building this concept to the next level. Also, this should somehow needs to be tied up with Senior Capstone Design classes held at most universities.

Reviewer 46:
Regarding Ttiming, -if this program is continued it needs to be advertised well in advance of the academic year.

Reviewer 75:
See above.

Suggestions for Improvement

Reviewer 11:
The project can be improved by lengthening the timeline of the project. This reviewerI would assume that the number of participants would be increased if the funding opportunity announcement (FOA) was released prior to the start of the fall semester (perhaps even early in the summer). Additionally, options to have the project be run for a full academic year might also increase the project's effectiveness of the project.

Reviewer 91:
Advertise the project wider,; increase the duration from start to finish,; ask for budget plans and set some target rules for directing the financial support to students.

Reviewer 90:
The scientific community and DOE's goal should be able to sustain this kind of program. Having said that, the funding should all go the student teams and not to faculty salary. Also, this should somehow needs to be tied up with Senior Capstone Design classes held at most universities.

Reviewer 46:

Reviewer 75:
Advertise more broadly, establish a geothermal student database or social site to encourage communication and effective capture of the next generation, better use of funds, proposal for long-term non-DOoE funded sustainability of the program.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 0120
Presentation Title: National Geothermal Academy (UNR)
Investigator: Calvin, Wendy (University of Nevada -- Reno)

Comments Regarding Relevance/Impact of Research

Reviewer 46:
This project, like the other education one, doesn't directly align with the Geothermal Technologies Program (GTP) programmatic goals, yet it is an important consideration.

Reviewer 75:
The National Geothermal Academy is a wonderful idea that deserves to be supported. Training of the next generation as well as continued education of the current generationl of geothermal explorers,ationists etc., is a critical investment into the future. The PI and her team have put together an excellent syllabus and an excellent line-up of instructors/speakers. The program is well organized and structured and hits all the hight points students should be exposed to.

Reviewer 88:
Continued education and workforce development will be important to expansion of geothermal in the United States.

Comments Regarding Scientific/Technical Approach

Reviewer 46:
This reviewer is I am not sure if this is the best technical approach to educate the workforce. It almost seemed like more of an investment in developing the University of Nevada -- Reno (UNR). The comment made by the presenter that some of the material will be proprietary and not distributed outside the course is simply ridiculous! For efforts like this to have a real impact any and all materials must be fully available to the entire community, not the 50 or so attendees of the course. I do This reviewer questions if this method will reach a large enough audience given the amount of investment required. If the goal is to "train new undergraduate and graduate students" then the courses need to be available not only during the summer months, but also during the academic year. Could some type of outreach/cooperative learning model be developed with any degree- granting university, perhaps using the materials developed with DOE seed money? I feel that Tthe short- course format is much better suited to working professionals that either need to hone their skills, or migrate into this field from other areas.

Reviewer 75:
This category seems somewhat oadd for the evaluation of the National Geothermal Academy as it's mostly course development, course creation, advertisement, etc. I think also pPoints are very well handled by the PI and her team. This reviewer‘s My only concerns are related to the wider -availability of the course materials and the longevity/sustainability of the program. First of all, tax-payer created course materials need to be open- source and should be shared and proliferated on-line. Creation of an on-line course or availability of the course on-line will help long- term -stustainability and will allow better access for continued education (people that work and don't have weeks to attend a course at UNR, -coupled with travel costs).

Reviewer 88:
This is Nnot really an applicable category for this project.

Comments Regarding Accomplishments, Results and Progress

Reviewer 46:
The goals/evauluation metrics, using the last bullet from Slide 3 as the criteria, should be met for the course attendees. The bigger picture, i.e., training undergraduate and graduate students, is unlikely to have a very large impact, as you simply cannot reach a large enough audience by relocating people for 8 eight weeks at a time to the course location.

Reviewer 75:
As stated above, the program has created a cutting-edge program in a ver short time with an excellent modern syllabus and a line of contributors/instructors. The prototype mode of the program is well conceived and flushed out and should create a model for future courses and on-line teaching.

Reviewer 88:
Very good progress shown in establishing the program and having a successful launch.

Comments Regarding Project Management/Coordination

Reviewer 46:
Given the number of instructors, travel, materials, housing etc., this reviewer I can only imagine the project management nightmares the PI must be dealing with! The true evaluation of this issue can't be made until the course is completed. Good lLuck!

Reviewer 75:
Management and organization are excellent. The PI has done a wonderful job, despite personnel discontinuities, to organize and launch this program as an official class through UNR.

Reviewer 88:
This reviewerI was particularly impressed with the PI decision to divert funding from a staff position to funding fellowships. Leadership as well as management—: bravo.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 46:
I This reviewer elaborated on strengths and weaknesses individually above, and won't repeat them here, but overall I thinks the education and workforce development is an important aspect of the GTPgtp. While this reviewer is I am uncertain of the potential rewards that may come from this project, and how far reaching they will be, I do think the project as defined is being well executed and is on task for successful completion.

Reviewer 75:
As state above, this is a wonderful program that needs to spread. This reviewer's So as state above, my only concerns are related to the wider- availability of the course materials and the longevity/sustainability of the program. First of all, tax-payer created course materials need to be open-source and should be shared and proliferated on- line. Creation of an on-line course or availability of the course on-line will help long- term -stustainability and will allow better access for continued education (working people or people that lack the mobility to travel and stay at UNR for a summer).

Reviewer 88:
This is a well thought out project.

Comments Regarding Strengths

Reviewer 46:
Reviewer 75:

Reviewer 88:

Comments Regarding Weaknesses

Reviewer 46:

Reviewer 75:

Reviewer 88:
It is always easy to cut educational expenses when budgets are tight. And they will always be tight. I don't This reviewer doesn‘t see a path to sustainability for the program laid out.

Suggestions for Improvement

Reviewer 46:

Reviewer 75:
See above . Overall statement.

Reviewer 88:

Tracers and Tracer Interpretation

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1200
Presentation Title: Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics
Investigator: Tang, Yongchun (Power Environmental and Energy Research Institute)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 2.15

Comments Regarding Relevance/Impact of Research

Reviewer 99:
No Response Entered

Reviewer 89:
Seems like good lab work, and the detection limits look promising, but there does not appear a method in place (or the capabilities) to develop their ―user friendly interpretation tools …”. Interpretation was missing from the Integrated Approach discussion as well. The PI was specifically asked about a path forward to develop interpretation methods and did not respond adequately. Without a clear understanding of how tracers can estimate fracture properties, which were not spelled out in the document, presentation, or Q&A, chances of success of this project are not high.

Reviewer 68:
Tracers can delineate the following important parameters of a geothermal reservoir: (1) porosities, (2) migration distance, and (3) fracture spacing. However, this project is not likely to yield those results before completion.

Reviewer 76:
The development and characterization of variably partitioning tracers should be useful in characterizing swept volumes in complex, heterogeneous systems. The inclusion of field trials should establish the usefulness of this work. The focus on enhanced concentration is perhaps less critical for this application, where many low-cost, low-toxicity tracers are available (and most geothermal systems are not used for human water supply).

Reviewer 53:
Nice mixture of theory, experiment, field trials and interpretation tools that should help achieve project objectives. An approach that can put all these things together and provide a useable product might make significant impact on industry. The project may add smart tracer arrays to advance current tracer functionality.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
No Response Entered

Reviewer 89:
The project seems to have focused on identifying tracers for EGS application, but is leaving many fundamental questions for later in the workflow. No discussion of what adsorption mechanisms were relevant in geothermal rocks (so far looking at silica). Again, no interpretation discussion, or how this work will allow field operations to estimate fracture properties such as spacing, area, etc. There are lofty goals, without a clear discussion of how we get there.

Reviewer 68:
Balanced laboratory, theory, and field approach. I question the value of functional density calculations unless completely validated by experiment. It is only the coarsest of sifters.

Reviewer 76:
The use of high P/T experiments and procedure seem very good. However, use of overly idealized Ottawa sand systems, and naive generic discussion of "clay" may limit the applicability of results to real mineralogies.

Reviewer 53:
The four broad tasks appears to be a viable approach for achieving project objectives. There is a good balance between the various tasks. Project is only about 30% along the funding path but the approach seems appropriate and reasonable.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
No Response Entered

Reviewer 89:
The significant progress reported on was in pre-concentrating the tracers and reducing detection limits by three orders of magnitude. Given the project ends next fiscal year, there are significant pieces missing, including adsorption on realistic rock surfaces, an understanding of how measuring adsorption will lead to property estimates, how much adsorption would be optimal and which if any of the tracer candidates exhibit that amount, etc.

Reviewer 68:
The project is meeting the milestones it set for itself except the most important one -- field validation.

Reviewer 76:
Progress is on schedule and satisfactory.

Reviewer 53:
Good progress with respect to planning and studies are needed prior to field work. These include tracer selection, pre-concentrations, tracer surface interactions and theoretical model. The hollow-fiber, micro-extraction method appears to be novel. The research approach appears to be very innovative and creative.

Comments Regarding Project Management/Coordination

Reviewer 99:
No Response Entered

Reviewer 89:
Overall the project has focused on a single important--but not the only important--part of the project tasks, and is not coordinating the pieces appropriately. I would predict there is a strong possibility that the tracers may be developed, but the project will fail to deliver on the integrated project goals stated, for reasons stated above.

Reviewer 68:
Getting sub awards in place is not sufficient. Is the PI actively managing decision points and integrating sub award results?

Reviewer 76:
No Response Entered

Reviewer 53:
Project management is appropriate for the level of effort represented by this project. There is a good mix of collaborators from different institutions.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
Too much effort in trying to develop a "pre-concentration" technology with little evidence that it will be proven in the field. No data was presented that would indicate the calibration of the pre-concentration slim-tube technology would be effective under the widely variable chemical and physical conditions possible in geothermal reservoirs, such as varying salinities, ionic strength, pH, temp, and pressure). Perhaps this research is still to come, but it seems a great deal of effort has been expended on laboratory research rather than field research.

Reviewer 89:
For the reasons stated above, the information provided in the project summary vs. the presentation material, and Q&A answers given.

Reviewer 68:
The jury is out with regard to whether or not the laboratory and theory tasks have any relevance to the yet-to-come field trials.

Reviewer 76:
No Response Entered

Reviewer 53:
My opinion is that this project has a good possibility of advancing tracer availability. Some of my concerns may be related to where the project is on its funding trajectory and will be addressed in later phases of the project.

Comments Regarding Strengths

Reviewer 99:
Interesting methodology presented on pre-concentration of a specific class of tracers.

Reviewer 89:
No Response Entered

Reviewer 68:
Validating up to 29 tracers has value. It is development rather than research.

Reviewer 76:
The program is apparently very strong in the areas of basic chemistry and use of microfibers for concentration. Collaboration with a hydraulic fracturing service provider may increase the validation and value of this research.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
Applicability of pre-concentration technology not yet shown to be effective in a field setting. The technology is specific to a certain class of tracers, therefore not broadly applicable. Lab experiments conducted on packed sand in columns which does not represent the real fractured rock reservoir. It is questionable whether modeling based on these lab experiments will be transferable to real reservoirs.

Reviewer 89:
No Response Entered

Reviewer 68:
Not clearly integrating different tasks.

Reviewer 76:
Naive mineralogy and insufficient knowledge of interwell-scale tracer flows in realistic geologic settings.

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
Too much emphasis on modeling and laboratory experimentation. Field data and results are needed.

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
This project involves geoscientists and/or geothermal engineers with field experience.

Reviewer 53:
No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1201
Presentation Title: Quantum Dot Tracers for Use in Engineered Geothermal Systems
Investigator: Rose, Peter (University of Utah)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 2.42

Comments Regarding Relevance/Impact of Research

Reviewer 99:
The project's focus has been on the development of particulate "quantum dot" tracers, with little work to date to demonstrate that these tracers will be effective at meeting the stated goals of the project.

Reviewer 89:
Identifying tracers which can be applied to estimating surface area of fractures is a good set of goals. However, this project differs from the PI's 2nd project only in that this looks at nanotechnology. In fact, when asked about the relevance and need of this project, the PI said to _wait – the relevance of this project will be made clear from my other talk…' If he cannot provide relevance to this without invoking the other, I would combine those two, remove redundancies to reduce cost.

Reviewer 68:
Although the relevance is high, the current project results =are marginal in terms of application. Yet, developing a novel new tracer will take time, particularly in the 100s of kilogram quantities required.

Reviewer 76:
The usefulness of this high-cost, difficult to engineer trace compound is questionable.

Reviewer 53:
This project may add tracers to the geothermal characterization tool box. There is much work that needs to be done in this area to create a fully field deployable nanoparticle for use in geothermal industry. This project seems to be making significant advances in this area.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
Quantum dot tracers are expensive to develop and manufacture. Field comparison with performance of cheaper, readily-available tracers (e.g., fluorescent dyes) need to be conducted.

Reviewer 89:
1. Looking at temperature is part of a different Geothermal Technologies Program-funded project, and because of that should not be discussed herein, . 2. Expecting diffusion to estimate surface area in EGS doesn't seem feasible if EGS targets are still crystalline rock. 3. The project would benefit from studies on what sorption mechanisms can be induced to provide field data to then estimate field data. I didn't see this in the write up other than numerical modeling. 4. It is not clear why we should be estimating near-well surface area. Is that thought to be representative of the EGS-systems performance / fracture properties? Why?

Reviewer 68:

Using laboratory tests and models to predict field results for a fracture area is sound.

Reviewer 76:
The material-science-rich approach seems poorly suited to address the geologic variability such as variable rugosity, intergranular apertures, adsorption site density, etc. Difficulties in dot manufacturing were not considered adequately.

Reviewer 53:
The approach appears to be reasonable given the project objectives. There is a good use of a combined laboratory and modeled approach with final a field test using quantum dot tracers. It is not clear on progress relative to milestones and schedule. It appears to be a logical, well thought-out project.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
There have been only mostly modeling results to date. The tracer development is still ongoing, even with the project 60% complete. Tracer development is less than 50% complete, as goals of reversible sorption have not yet been achieved in tracer development. It is =doubtful that the project will provide adequate field tests given limited remaining funds.

Reviewer 89:
1. It is unclear if the researchers have developed non-sorbing tracers, since the flow properties are not shown in support of that statement. A reviewer asked that of the PI during his secondtalk and the PI didn‘t know if they had proven the candidates didn‘t sorb. 2. It would have been useful to have reviewed, however briefly, the methods for estimating surface area adjacent to an EGS wellbore, although the PI did say that was reported last year. 3. There is some concern regarding using sorbing tracers to estimate surface area, including representative sorption sites, etc. The PI mentioned ―we have ideas on how to modify sorptivity" but did not address questions regarding interpretation. 4. In the technical accomplishments discussion, the PI states they ―Test the performance of the first-generation nonsorbing quantum dot tracers…" but it seems they injected naphthalene disulfonate, lithium, and bromide- none of these are quantum dots, despite the implications of the PI‘s ―Accomplishment" note.

Reviewer 68:
Good for 50% mark, but jury is out as field tests conducted in March 2011 are still being analyzed.

Reviewer 76:
No Response Entered

Reviewer 53:
This project is about 60% complete and seems to be progressing nicely. Tasks seem to be on schedule and there is good collaboration with industry.

Comments Regarding Project Management/Coordination

Reviewer 99:
No Response Entered

Reviewer 89:
I don‘t see any Go/No Go decision points, and useful interpretation seems to hinge on successful inverse modeling of a dataset,which is an unconstrained problem. There was little discussion on how to constrain it, and in the absence of meaningful interpretation, quantum dots are no better than the 8-10 tracers already in existence. The interdependence on other projects was somewhat alarming.

Reviewer 68:
Unreadable Gantt chart.

Reviewer 76:
No Response Entered

Reviewer 53:
The project management seems to be adequate for scope. Nice collaboration and leveraging of funds from other projects.
Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
Interesting and perhaps ultimately useful development of quantum dot tracers; however, progress toward meeting stated goals of reservoir characterization by quantifying 1) reversible sorption, 2) resistance to thermal decay, and 3) contrasting diffusivity of tracers is slow. I am doubtful these tracers will prove to be greatly superior to traditional tracers, such as fluorescent dyes.

Reviewer 89:
See comments above.

Reviewer 68:
The field tests are the best part, particularly if the earlier laboratory work and modeling prove out. I find it hard though to see how this ground truth links to obtaining results of fracture area relative to the earlier laboratory work and modeling work.

Reviewer 76:
No Response Entered

Reviewer 53:
This is a good project and is progressing appropriately. Field work will be important to move to the next step. This should be done even without finding perfection in the tracers in laboratory work.

Comments Regarding Strengths

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
Interesting idea.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
The quantum dots are colloids and that aspect was not discussed in the modeling. The experiments so far are on Ottawa sand, which is not realistic for the goal of estimating fracture surface area.

Reviewer 76:
Investigator seemed unaware of colloid transport work, which is highly relevant to dot transport in fractured porous media.

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
More collaboration with geoscientists.

Reviewer 53:
No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1202
Presentation Title: Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems
Investigator: Kennedy, Mack (Lawrence Berkeley National Laboratory)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 2.76

Comments Regarding Relevance/Impact of Research

Reviewer 99:
Changes in reservoir permeability due to water-rock reaction is worth investigating, however it is doubtful that laboratory experiments will help in characterizing real reservoir characteristics. Transferability of results from the laboratory (or model) to field is an issue that has not been demonstrated.

Reviewer 89:
Innovative tracers or tracer proxies that can be applied to estimating surface area of fractures are a good set of goals; one that hasn't been considered in previous Geothermal Technologies Program-funded projects. In particular, looking at the evolution of reactions to identify surface area is promising. A drawback to the approach is their observation that Brunauer-Emmett-Teller (BET) surface area, which is what they measure with reaction chemistry, differs substantially from ―geologic" surface area, which is what heat transfer depends on. The extent that the PIs can understand that relationship will dictate the ultimate success or failure of the project.

Reviewer 68:
This research is novel and is just what the Geothermal Technologies Program should be funding. Many other projects are like drug manufacturing - trying everything under the sun. This project utilizes the reactions actually taking place within the reservoir to infer critical parameters such as fracture area.

Reviewer 76:
The huge uncertainty in surface area, not just reaction rates, make the application of this research questionable.

Reviewer 53:
This project attempts to address a major problem. The results may add new capabilities but it is not clear. The use of isotopes may be the most innovative component.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
No Response Entered

Reviewer 89:
1. We have focused attention on tracer compounds; the present project proposes to use in-situ chemical reactions to estimate area. This is an interesting approach 2. Problems understanding relationship between BET and geologic areas, and whether one can be estimated from the other exist and need further consideration. 3. Significant dependence on numerical modeling dangerous – many uncertainties in (e.g.) mineral distribution preclude constrained solutions. 4. Good to be evaluating from interwell volumes, so the true surface area for an EGS system is estimated.

Reviewer 68:
Just the right balance is made between laboratory testing and using real reservoir rocks and data.

Reviewer 76:
Many hydrologists, petroleum geoscientists, and engineers have used geochemistry is a tracer, but this is a good idea that is deserving of the attention these investigators give it. Use of simple mineralogy models does, however, raise some questions.

Reviewer 53:
Approach although very basic seems appropriate for project objectives. Natural tracer selection must be very reservoir dependent. The use of natural isotopes is interesting and has potential.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
No Response Entered

Reviewer 89:
1. Sr ratio experiments show how isotopic analysis improves the understanding of chemical equilibria, which [Sr] failed to see. 2. Numerical modeling shows interesting multiple time periods of dis-equilibia, but it is not yet clear those conditions will yield estimates of surface area.

Reviewer 68:
Excellent demonstrations of soundness of hypothesis.

Reviewer 76:
Significant modeling and experimental results are reported.

Reviewer 53:
Difficult to determine project progress relative to the project schedule. The speaker had the problem of feedback or some kind of noise from the AV system. Regardless of this, the presentation was unclear and this may be related to being in the early stage of the research.

Comments Regarding Project Management/Coordination

Reviewer 99:
No Response Entered

Reviewer 89:
There is only one primary Go/No-Go decision. Others should be added (e.g., if modeling cannot obtain area estimates, if BET surface area and geologic surface area cannot be resolved).

Reviewer 68:
The PI offered real decision points, especially their "PRIMARY GO/NO-GO: Success of the reactivity and surface area experiments," and they have demonstrated a positive result on schedule.

Reviewer 76:
No Response Entered

Reviewer 53:
Project management is adequate. The project is about 44% complete. Collaboration with industry is minimal.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
Excellent project.

Reviewer 76:
No Response Entered

Reviewer 53:
This project seems a bit disjointed and I have concerns about the widespread applicability of the work. However, the data will be useful for the advancement of the science in this area.

Comments Regarding Strengths

Reviewer 99:
No Response Entered

Reviewer 89:
See comments above.

Reviewer 68:
No Response Entered

Reviewer 76:
An interesting approach and appropriate mix of expertise.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
No Response Entered

Reviewer 89:

No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
More discussion explicitly addressing effects such as Damkohler and Peclet numbers would be valuable in evaluating this work. Of course, this will reveal significant uncertainties in monitoring efficacy because of uncertainties in specific areas (BET order 1000 times higher than geometric expectations).

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
Project should collaborate with a petrologist/mineralogist

Reviewer 53:
No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1203
Presentation Title: Tracer Methods for Characterizing Fracture Stimulation in Engineered
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 2.56

Comments Regarding Relevance/Impact of Research

Reviewer 99:
Modeling only; purely theoretical research.

Reviewer 89:
There is potential for successfully estimating fracture surface areas from sorbing tracers. The method will hinge on defining suitable sorbing tracers. Existing results indicate more work is needed on this step. The use of a downhole tool to measure tracer concentrations is useful, although detection limits, etc. were not presented for the tool being developed.

Reviewer 68:
Using temperature as a tracer is obviously directly related to geothermal technology. A little bit of expert Lawrence Berkeley National Laboratory modeling can go a long ways to interpreting the most basic, easy-to-conduct push-pull test – single-well injection-withdrawal test).

Reviewer 76:
There are few fundamentally new ideas proposed in this research.

Reviewer 53:
The project may add to the overall capabilities available for industry to perform diagnostics of geothermal systems.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
Modeling apparently only considers a regularly-spaced, rectilinear grid work of fractures. This is unlikely to simlulate real fractures in an EGS, which are more likely to conform to fractal distributions of fracture spacing. The modeling could be improved by considering more realistic fracture networks.

Reviewer 89:
1. Tool development seems on schedule, etc. 2. Tracer modeling work is ongoing. It is unclear why the Geothermal Technologies Program is partially funding development of another geothermal simulation code. 3. It is unclear if matrix diffusion is relevant in crystalline EGS environments. 4. It appears that Safranin T does not sorb sufficiently to separate from conservative tracers. 5. The PI noted ―several of these tracers are conservative" when a) they don't exhibit identical (w/in experimental error) behavior, and b) no calculations have been shown that any actually are conservative.

Reviewer 68:
Excellent use of modeling to gain insight to sensitivity of push-pull testing to fracture interpretation.

Reviewer 76:
Injection-backflow is of questionable use in fracture-dominated systems, as this is so different from the flow and

composition paths to be experienced in an EGS development. The screening of tracers is useful.

Reviewer 53:
The approach seems to be appropriate for meeting the project's objectives. The project includes a good mix of lab experiments, modeling of chemical processes and field tests.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
Results were presented for modeling temperature variations only. While temperature is a robust tracer itself, the modeling to date has little linkage to informing the goals of the larger tracer application study (c.f. work by Peter Rose). Soprtion/desorption needs to be considered in future modeling efforts.

Reviewer 89:
1. A large portion of the PI's first ―Acomplishment" was done under another existing Geothermal Technologies project (Pruess, PI), as presented in a Stanford Geothermal Workshop paper in 2010. Is the present project taking responsibility for that work? If so, those projects should be combined. 2. Existing sorption results presented indicate the selected tracers do not exhibit sufficient retardation compared to conservative tracers (R should be around 1.2, according to one reviewer). 3. The tool development sounds interesting, but there was no mention of detection limits which makes its need uncertain.

Reviewer 68:
Results are completed and interpreted.

Reviewer 76:
The prospects for the timely development of the downhole device are poor.

Reviewer 53:
About 51% completed on the project. This is good involvement and use of a field test in this project. The talk was difficult to follow with respect to the accomplishments, results and progress. It appears that the project is progressing toward achieving project objectives. Hoowever, it wasn't clear what is new and unique about this effort.

Comments Regarding Project Management/Coordination

Reviewer 99:
Given what is provided in the write-up only, I am unable to judge project management performance.

Reviewer 89:
There are no Go/No Go decision gates.

Reviewer 68:
This is a subproject to another PI's much larger project.

Reviewer 76:
See above

Reviewer 53:
The project management seems to be appropriate for this level of effort.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
No presentation was given at the review of this project. This review is thus based solely on the summary write-up provided.

Reviewer 89:
See comments above.

Reviewer 68:
Extremely high value for the cost.

Reviewer 76:
No Response Entered

Reviewer 53:
Why not use fractures or surrogate fractures in the laboratory experiments? The use of sand is questionable with respect to application to modeling. It seems like the project is doing a bunch of stuff, but it is unclear as to how well the component pieces are tied together.

Comments Regarding Strengths

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
Strong team.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
The technical focus still too narrow, perhaps need more expertise in mineralogy and interwell-scale heterogeneity is needed to improve program.

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
No Response Entered

Reviewer 53:
No Response Entered

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1204
Presentation Title: Using Thermally-Degrading, Partitioning, and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs
Investigator: Watson, Thomas (BNL, PNNL, LANL)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 1.66

Comments Regarding Relevance/Impact of Research

Reviewer 99:
The attempted tracer technology proved unsuccessful. The design of new technology as a "fix" is unlikely to prove fruitful.

Reviewer 89:
Project focused on perfluorated carbons (PFCs) as hydrothermal tracers because of their detect limits (but offset by their solubility limits). Project proposes to coat perfluorated tracers (PFT's) to make them more attractive, but doesn't report if the resulting particle is neutrally buoyant, etc. There were one to two good ideas on temperature profiles that others are also working on, and PI indicates he does not expect to solve that before funding expires. All in all, this looked like a PFT solution in desperate need for a problem. It is not a good match. The project should be terminated now.

Reviewer 68:
This is tough to give a grade to because the researchers took a high-risk hypothesis, namely, using low solubility but low detection limit perfluorated tracer compounds (PFTs) as tracers and found a negative result, that is, they won't work. I guess in an ideal 'go-no go' management scheme, they would stop their work now.

Reviewer 76:
No clear incentive for using this technology in geothermal reservoirs. Poor prospects for formulating a field test.

Reviewer 53:
Objectives of the project seem to depend on the unique properties of perfluorated tracers (PFT). However, it is not clear that PFT properties are sufficiently unique to warrant research, especially with the discovered solubility issues. PFTs have been widely used elsewhere. The use in geothermal systems is new and this work indicates that direct use in aqueous solutions is not reasonable. Encapsulated microcapsules are interesting but it is not clear how PFT's are an advantage.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
Basic background research on suitability of PFTs, the chosen tracers, for geothermal reservoir characterization was lacking. The tracer was shown to not be water-soluble, which was likely known before project implementation.

Reviewer 89:
1. Focused exclusively on well-known gas phase tracers and tried to make them look like hot water tracers (very unlikely). Recognized that, but moved forward with coatings. 2. Failed to even know the number of potential hydrothermal tracers available. 3. Admitted he knows essentially any geology or reservoir engineering – probably shouldn't be working on a geothermal tracer program.

Reviewer 68:
The approach was sound. The result was negative and presented with candor.

Reviewer 76:
The approach seems valid in general, but mis-imagined for geothermal applications. Perfluorated tracers (PFT) solubility should have eliminated this prospect in PRE-application screening.

Reviewer 53:
The scientific approach was appropriate for meeting initial project objectives. The discovery of solubility issues was important and changed the scientific approach. It is not clear that the current approach is now valid. It seems like the project approach has been changed to a manufacturing and testing project for microspheres.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
No useful results have been obtained to date. The only result is that the tracer was shown not to be water soluble, a fact that was already known but "assumed" to be surmountable.

Reviewer 89:
1. Only accomplishment completed was not discussed (modeling complete). 2. All other accomplishments showed the flawed approach, and required modifications (e.g., incapsulate a poor hydrothermal tracer). 3. Aqueous phase tests on perfluorated tracers (PFTs) show no reproducibility in analysis.

Reviewer 68:
They did what they said they would do.

Reviewer 76:
Encapsulation is needlessly complex, and is a probably-doomed attempt to salvage this project from the mistake on low aqueous solubility.

Reviewer 53:
The direction of the project has taken a very sharp turn and it looks like progress from original scope is on hold for a while.

Comments Regarding Project Management/Coordination

Reviewer 99:
Rather than taking a new approach, management has chosen to doggedly pursue the same failed perfluorated tracers (PFT) tracers by encapsulation through an expensive process.

Reviewer 89:
No go no-go decision gates. Lab results showing the method is flawed only caused project team to continue in the same vein without sanity checks.

Reviewer 68:
So why don't they just stop the project, having found a negative result.

Reviewer 76:
Screening should have been done up front, reducing high-risk, relatively low benefit investment.

Reviewer 53:
Project management seems good, shows a lot of collaboration and communication been multiple laboratories.

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
This project has shown no useful results, and aims to continue along a costly path that is unlikely to succeed.

Reviewer 89:
No further work should be pursued

Reviewer 68:
Given that the project will continue, the shift to microencapsulation is ok, just not likely to be useful.

Reviewer 76:
No Response Entered

Reviewer 53:
This project has successfully looked at the direct application of perfluorated tracers (PFTs) as tracers in geothermal reservoirs. Future success depends on the results of encapsulation of PFTs and subsequent testing.

Comments Regarding Strengths

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
This is truly a case of a person with a hammer, so everything is a nail.

Reviewer 76:
Great *atmospheric* geophysics background.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
The PI admits he is not a geochemist, but it would have been useful to have a geothermal tracer expert on his team.

Reviewer 76:
Inadequate *aqueous* geochemistry expertise

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
No Response Entered

Reviewer 53:
No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1205
Presentation Title: Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2 and Water-based Geothermal Reservoirs
Investigator: Plummer, Mitchell (Idaho National Laboratory)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 2.63

Comments Regarding Relevance/Impact of Research

Reviewer 99:
This project has made more progress than others in conducting field tests with tracers, yet the results have been somewhat ambiguous. Further work may be promising.

Reviewer 89:
This project focuses on two issues of interest: 1) looking at thermally degrading tracers to estimate the temperature profile in a geothermal reservoir, and 2) combine the suite of existing interpretation tools for use by the industry. Goal oneis difficult (but maybe achievable); goal two is imminently achievable and of great use.

Reviewer 68:
The project used tracers for inverting for reservoir temperatures with the goal of providing an early warning system for reservoir cooling. The field tests were extremely valuable and there is a real attempt to provide industry with useful tools, in this case, Matlab tools.

Reviewer 76:
The main impact will be via collaboration with US Geothermal on a fluid test. No new methods are developed, and new (encapsulated) materials were not proved feasible.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
No Response Entered

Reviewer 89:
1. Field testing on Raft River is interesting, but the solutions are not well constrained. Additional test would be of great interest, but would require an extension of the project with associated budget. 2. Unclear what work was done on encapsulation that is completed. 3. Software distribution / web posting good idea, very useful in the geothermal industry.

Reviewer 68:
Very clear statement of using first-order reactions to develop tracers that can give temperature history of reservoir. Nice blend of modeling, lab, and field.

Reviewer 76:
No new analyses, methods, or materials.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
No Response Entered

Reviewer 89:
1. Software ready in FY 2011 for distribution 2. Raft River test analyzed, discussions regarding implications with operator.

Reviewer 68:
The results show the potential value of using reactive tracers for monitoring temperature drawdown.

Reviewer 76:
Field tests are useful.

Comments Regarding Project Management/Coordination

Reviewer 99:
No Response Entered

Reviewer 89:
No clear go no-go decision gates. Probably moot point, with current project terminated 9/2011.

Reviewer 68:
Good connection to U.S. Geothermal for field testing.

Reviewer 76:
No Response Entered

Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project‘s overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
This project has made more progress than others in conducting field tests with tracers, yet results have been somewhat ambiguous. Further work may be promising.

Reviewer 89:
Good project, interesting results, possible add-on funding should be considered.

Reviewer 68:
This project addresses the primary geothermal resource issue of temperature and obtained results that deliver on the promise.

Reviewer 76:
No Response Entered

Comments Regarding Strengths

Reviewer 99:

The data from the field tests in a real system are the most informative presented of all the projects. Results may have been ambiguous, but at least the data are real. These data provide information and hypotheses to be tested in further tracing tests. The focus should be on conducting as many tracing tests as possible under variable conditions in the same system, within the realm of feasibility.

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
Collaboration with US Geothermal for tests.

Comments Regarding Weaknesses

Reviewer 99:
A lot of emphasis on modeling, when the assumptions used in the models regarding fracture apertures and spacing may not be realistic. More focus should be on borehole fracture characterization in order to constrain model inputs.

Reviewer 89:
No Response Entered

Reviewer 68:
It would be nice to combine the reactive tracers with regular tracers to sort out the actual flow pathways when inverting the results for temperature.

Reviewer 76:
Porting existing solutions into MATLAB is not an impressive research product.

Suggestions for Improvement

Reviewer 99:
No Response Entered

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 1206
Presentation Title: Tracers and Tracer Interpretation: Verification of Geothermal Tracer Methods in Highly Constrained
Investigator: Becker, Matthew (California State University, Long Beach Foundation)
Panel: Tracers and Tracer Interpretation
Proposal Mean: 3.22

Comments Regarding Relevance/Impact of Research

Reviewer 99:
Field-based, experimental research into the movement of tracers within a single fracture in a sandstone. This research has direct relevance to the feasibility in general of using tracers to assess fracture surface areas in geothermal reservoirs.

Reviewer 89:
Multiple, good sets of data describing existing single fracture and subsequent heat transfer. Some issues of concern include what affect multiple fractures will have on methods developed. Further, it is unclear that the surface area can be determined from any of the datasets available, but will only be inferred via numerical modeling. Still, the data availability and diversity, accessibility (depth) of the fracture improve the success probability of the project.

Reviewer 68:
Reasonable test case, but jury is still out as much of the work is yet to be completed this summer and fall.

Reviewer 76:
Well-controlled, repeatable experiments are urgently needed in this area. While small-scale and limited in scope, these experiments could provide invaluable benchmarks if documented fully.

Reviewer 53:
Field testing of new tracers coupled with geophysics, pressure tests and thermal tests at a shallow easily accessible site are a great approaches. Field sites are very useful for demo of new methods. If an expensive, exotic method cannot work at this site, it probably won't work at a real geothermal site.

Comments Regarding Scientific/Technical Approach

Reviewer 99:
Project is well-focused and provides good controls on field-based tracer tests. Project employs advanced geophysical techniques, as well as, tracing applications to understand migration through bedrock fractures.

Reviewer 89:
1. Many multiple datasets, all of which offer one aspect of the fracture geometry, etc. 2. Performing a thermal stress test and directly measure heat transfer.

Reviewer 68:
Excellent plan to validate tracer testing in a field situation with one known GPR-mapped fracture. Still, how does one know the hydraulic properties of this fracture? And how do we know how to apply the results to geothermal fields?

Reviewer 76:
The hydrology, geophysics, and inverse methods are not cutting-edge but they are more than adequate to the task. They

are well conceived and integrated. The Monte Carlo inverse method was not explained well in materials, publications, or Q&A.

Reviewer 53:
Great test site and the project employs a wide integration of flow tests, geophysics, heat tests and tracer tests to build a comprehensive understanding of the flow behavior.

Comments Regarding Accomplishments, Results and Progress

Reviewer 99:
Only project of the entire review that has shown peer-reviewed results published in a leading journal outside of grey-literature or conference proceedings. Additional products related specifically to geothermal resources would be an improvement.

Reviewer 89:
Project seems on track, and well ordered. Many datasets have already been obtained and analyzed; progress on the rest seems good. The project needs a sorbing tracer if surface area is to be directly measured. The correct tracer will depend on mineral and fluid compositions on site.

Reviewer 68:
The objectives of obtaining hydrologic properties in a geophysically-validated, single fracture have essentially been met.

Reviewer 76:
No Response Entered

Reviewer 53:
The project appears to be progressing on or ahead of schedule. The data presented indicate promising results. Much work is planned for this field season, which will be critical for the successful completion of the project.

Comments Regarding Project Management/Coordination

Reviewer 99:
Project management has thus far met goals and shown promise for future results.

Reviewer 89:
No clear go no-go decision gates. Not clear if many gates are required for this project, given its organization (collect many datasets and calculate or infer properties)

Reviewer 68:
No Response Entered

Reviewer 76:
No Response Entered

Reviewer 53:
Project management is appropriate for the level of effort.

Overall

In addition to the above four criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Reviewer 99:
This project is on track to make a significant contribution to the understanding of tracer migration through fractured bedrock in general, and for utility in assessing fracture surface properties in geothermal reservoirs by extension.

Reviewer 89:
Good project, interesting results

Reviewer 68:
The PI makes the point that validating a tracer test in the simplest of field situations needs to be done to see if tracers have any value at all in geothermal systems. While this might be the way one would wish technological progress to proceed, and while this work is valuable in hydrologic science, it's relevance to the Geothermal Technologies Program is limited. While there might be concerns about tracers delineating fracture properties, there is enough empirical evidence in the geothermal industry to suggest that tracer development will continue, regardless of what problems are uncovered in this project.

Reviewer 76:
Fascinating experiment. I look forward to seeing reports and published results.

Reviewer 53:
This is an outstanding project that is developing a data set that will be useful for constraining numerical simulations and testing new and evolving tracer techniques. Several similar test sites are needed to enable collection of the basic data needed to advance the science of tracer tests.

Comments Regarding Strengths

Reviewer 99:
Well controlled, focused field study.

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
Excellent problem identification, site selection, and integration across specialties.

Reviewer 53:
No Response Entered

Comments Regarding Weaknesses

Reviewer 99:
Field site is not within a geothermal reservoir, nor is it geothermal at all. Transferability of results needs to be addressed.

Reviewer 89:

No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
No Response Entered

Reviewer 53:
No Response Entered

Suggestions for Improvement

Reviewer 99:
Focus on temperature as a tracer in addition to the artificial tracers used in the tests conducted.

Reviewer 89:
No Response Entered

Reviewer 68:
No Response Entered

Reviewer 76:
May want to consult petroleum reservoir engineering inverse methods (e.g., books by Oliver, Reynolds and Liu or by Evensen) for Monte Carlo inverse methods well-adapted to nonlinear flow problems with dense geophysical support.

Reviewer 53:
No Response Entered

Appendix B: Principal Investigator Rebuttals to Reviewer Comments

Data Systems

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10109
Presentation Title: State Geological Survey Contributions to National Geothermal Data System Data Development, Collection and Maintenance
Investigator: Allison, Lee (Arizona State Geological Survey) (AZGS)
Panel: Rebuttal - Data Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Data Systems:

Response to Reviewer 8: We agree. We have a multi-faceted plan to address this that involves collaboration and integration with the other National Geothermal Data System (NGDS) projects. The NGDS offers a perplexing issue in that the development, population, and deployment of the system is simultaneous. For example, while this project focuses on populating the system with geothermal relevant data, a companion project through Boise State University is building the desktop application in order to easily find and retrieve that data. In addition, data are being submitted by NGDS partner institutions such as Oregon Institute of Technology‘s GeoHeat Center and Stanford University. Thus, the system as a whole requires use cases, i.e., the NGDS requires use cases that span not only the State Geological Survey‘s contributions, but also the contributions of partner projects, contributors to the BSU project, Southern Methodist University, and the USGS. As such, the NGDS project steering committee has established the goal of providing use cases on a system-wide basis.

One of the first use cases has already been identified from DOE‘s Geothermal Technologies Program. The request consists of two maps of the United States, one reflecting undiscovered geothermal and one reflecting enhanced geothermal systems. Each map would provide heat flow to a specified depth, land ownership, and transmission capabilities. To enhance this map, additional layers such as ecological and environmental constraints or transportation corridors could be added. This will include data sets and digital maps from USGS, BLM, Western Regional Partnership, SMU, and others.

We intend to roll out an operational prototype of the data system with test data sets from all or almost all states by October 2011 and demonstrate it at exhibit booths at two national meetings. First, we provide demonstrations at the Geological Society of America Annual Meeting in Minneapolis, October 9-12, where most of the State Geological Survey project participants will attend. This provides an opportunity to work with our team of data providers to demonstrate best practices among our team, get comments, and provide guidance to others. Exhibit booths are also scheduled at the Geothermal Energy Association Summit (August 2011) and Geothermal Resources Council Annual Meeting and GEA Expo (October 2011). AZGS will be demonstrating the system and displaying the systems potential on a one-on-one user basis at these events. Feedback will be recorded. In addition, AZGS is taking part in the National Groundwater Association‘s Ground Water Expo and Annual Meeting, where we will be speaking to direct use drillers and gathering feedback on necessary components relative to direct use applications.

The first year of the project focused on getting all the subcontractors signed in, work plans developed and approved, and participants trained. We are now ramping up to a full production mode of data and services coming forward from all the participants. Thus, we have content to share with the user community so that they can see and assess real data in a working environment. Prior to this, we could only offer conceptualizations of what was forthcoming.

Response to Reviewer 17: We agree that geothermal energy varies in its nature and potential across the country. The AASG project looks at the full range of geothermal potential: EGS, hydrothermal, geopressured, co-produced, sedimentary basin, direct use, and ground source heat pumps. Each state is gathering the data that they determined was of greatest interest and value in their geographic regions, based on their long-term interactions and knowledge of their stakeholders and communities. While much of the Midwest and Eastern U.S. traditionally is viewed as not having much potential for electricity production, the recent Google study in West Virginia has been a game changer (e.g., http://www.reuters.com/article/2011/03/14/idUS316118491920110314). Other states in the region are similarly pursuing this unrealized opportunity.

Rebuttal Comments for Scientific/Technical Approach - Data Systems:

Response to Reviewer 27: Our whole team is delighted with the positive feedback from all the reviewers and will continue to strive to meet or exceed expectations.

Rebuttal Comments for Accomplishments, Results and Progress - Data Systems:

Response to Reviewer 2: We provided all of the data requested for the Peer Review but agree that there are additional metrics that would be valuable. Since the Peer Review meeting, we have developed an online tracking and reporting system for the data and service providers in the project. Below is a static picture of an interactive display which will be live on the www.stategeothermaldata.org site in August, showing what states have delivered data in what categories. The current enhancement to this will allow users to click on any data set or state and see the data and services being provided.

Rebuttal Comments for Project Management/Coordination - Data Systems:

Response to Reviewer 2**:** At the start, we were unsure how the role of DOE (as a cooperator on the project) would be manifested. We‘ve found however, that they provide invaluable guidance and insights to getting things done effectively and efficiently. They bring flexibility and a problem-solving approach to the project management.

In addition, the project‘s Management and Science advisory boards have carried out their duties as envisioned in the project proposal, which helps tremendously with project management but also serves to more solidly engage all the project participants in its success.

Rebuttal Comments for "Overall" - Data Systems:

Response to Reviewer 27: All the reviewers had similar comments that indicate they recognize and share our vision in how to use the DOE investment to leverage a sustainable, scalable, and transportable data integration and management system.

Rebuttal Comments for "Strengths" - Data Systems:

Response to Reviewer 27: We are pleased that the reviewers recognize the difficulties in creating an effective national collaboration of this magnitude. One of the reasons for our success is the camaraderie and trust among state geological surveys and state geologists, developed through decades of cooperation on national issues.

Rebuttal Comments for "Weaknesses" - Data Systems:

Response to Reviewer 2: If we understand this point correctly, it refers to the costs of how geothermal data users currently operate. Estimates are that researchers spend 80-90% of their time finding, retrieving, and validating information before they can make effective use of it (personal communications, William Michener, Univ. of New Mexico, PI of the DataONE project). It was recognized early-on that the tasks of scanning, digitizing, and entering data would be labor-intensive but that doing it once and serving it online was infinitely better than making every used re-do *ad infinitum*.

The issue of validation of data (QA/QC - quality assurance/quality control) is a huge, complex topic that extends well beyond the scope of this project and is being dealt with by communities in the data management and library science fields as well as by the domain science fields. We are currently negotiating to join the NSF-funded DataONE system as a member node, which will partner us with a leading national team that is investing significant resources into data quality issues.

Meanwhile, the State Geological Survey contributions to our project are undergoing extensive QA/QC prior to submission to the system. As long as AZGS is project manager and is providing funding for the project to sub recipients, all sub recipients are required to submit data in predefined and peer reviewed data templates; some templates are already industry standards, others could become industry standards as more and more data are captured within the template. Some data validation is electronic, particularly data associated with the metadata catalog, the mechanisms of which are discussed below. However, some data resists automation and requires manual review. Currently, data templates submitted to AZGS for review are processed by skilled geoscientists to identify extraneous or misplaced data. If such data are found, the data set is returned to the author for correction or validation. Upon completion of the funded portion of the project, AZGS intends to implement a peer review process, such as crowd-sourced quality ratings, on the contributed data, which will allow users to evaluate and rate data, provide feedback to data providers, and create pressure for data providers to meet higher standards. This is more in keeping with the nature of the scientific process as it exists.

Current Metadata Validation Procedures:

In order for the U.S. Geosciences Information Network (USGIN) metadata catalog, which is being implemented for NGDS, to be successful, verification that the metadata records are of good quality is important. There are many levels on which a record may be determined to be good or bad, and there are currently thousands of records that require this kind of validation procedure. In order to do this, we have developed a simple, Python-based tool for metadata validation. The tool is already a standard part of some of our cataloging workflows, and in the near future will be implemented more systematically.

After determining whether or not any XML document (including metadata records) is syntactically correct, the first step at determining the document‘s quality is schema validation: are all elements and attributes that should be there present, and are they in the right places within the document? ISO 19139 provides a well-defined schema to accomplish this.

In addition, we have defined our own USGIN-profile for ISO 19139 which adds some additional rules on how we want metadata to be structured in order to work in the system. Some of these rules are difficult to test using simple XML-schema validation. Examples of these rules include situations where at least one element from some set should be present, where we want to insure that the content of a particular element is valid, or where our profile requires an element‘s presence that the default ISO 19139 schema does not require. For example:

- Contact information must contain at least one of: email address, phone number, or mailing address
- Metadata standard must be identified as ISO-NAP-USGIN
- If distribution information is provided, a distribution format must be presented

These are the types of rules that our Python-based validation approach allows us to check for. At present, the tool allows us to define a number of different types of rules:

1. Exists Rules: Check if a particular XPath exists.

2. Valid URL Rules: Check if a URL provided in the document is valid (i.e. works as it should)

3. Value in List Rules: Checks if the value at a given XPath is contained in some predefined list. For example these rules can check if the language code given for a document is valid.

4. One of a Set Rules: Checks that at least one of a set of XPaths exists in the document.

5. Content Matches Regular Expression Rules: Checks that the value at a given XPath matches some regular expression. This allows us to do things like check if dates are formatted correctly, or that a field which should contain a phone number does not contain any letters.

6. Conditional Rules: Allows ―chaining" of the above defined rules. If one rule is satisfied, then another has to be satisfied.

Based on these six classes of rules, we can begin to define a set of rules that goes further than schema validation can towards checking a metadata document‘s quality. However, some things are still difficult to assess in an automated fashion. For example, Content Matches Regular Expression rule may be able to check that a metadata record‘s abstract has at least 50 characters in it, but it cannot verify that the text is grammatically correct. Similarly a Valid URL Rule may be able to check that a given URL resolves to an actual internet resource, but it cannot insure that the linked resource has any relevance to the metadata record itself.

For these types of issues, it is difficult to replace manual inspection, and as a result it is still an integral part of our cataloging process. As we continue to expand our Python-based rule set and integrate it into our various metadata collection processes, we hope to accomplish a significant amount of quality-control without the need for record-by-record visual inspection.

Rebuttal Comments for "Suggestions for Improvement" - Data Systems:

Response to Reviewer 8: It is our goal to provide such use cases and user views at the Geothermal Resources Council Annual Meeting and the Geological Society of America‘s Annual Meeting and Conference, both in October. By this time, we intend to have NGDS-wide use cases, as well as specific use cases within the State Geological Survey contributed data. As discussed in the previous section, certain data validation procedures are currently in place. AZGS will attempt to better advertise our QA/QC procedures to invite feedback as well as provide a basic level of data quality.

Following the public roll-out of project demos and use cases at the national conferences, we will be posting examples and tutorials on the project web site (www.stategeothermaldata.org) for users to test drive and comment on. We anticipate soliciting further feedback from the participants in the other NGDS projects and from individual state geological surveys which all have far ranging ties to the broad geothermal energy communities.

Response to Reviewer 27: The NGDS is a distributed network with various nodes contributing data. As part of the sustainability of the network, a back-up system between the nodes and the hubs is being arranged. This should help ensure recovery of the network from cyber-attacks. A workshop scheduled for August 2011 will begin the process of producing a system maintenance plan, which includes system reliability and redundancy, between State Geological

Survey hubs. The issue will be presented to the BSU NGDS project Steering Committee for further discussion amongst system participants and to the NGDS Technical Working Group and NGDS Coordination Group.

We addressed the reliability of the data (i.e., QA/QC) to some extent (in previous responses) also noting that as long as we are funding organizations we can require them to meet certain standards. But as the NGDS starts linking additional, volunteered data and services, new mechanisms are required to provide users effective tools and procedures to identify data reliability and measures to promote improvements. As we also noted, numerous other groups and network developers are struggling with these issues. We are developing formal and informal relations with these others to: 1) Learn from them, and 2) Promulgate more cross-disciplinary standards and protocols on data reliability.

Response to Reviewer 2**:** See the above section on data quality and validation assurances.

For much of the content we are dealing with, there is insufficient documentation to evaluate quality from the point of view of accuracy or precision. We can evaluate completeness, and schema validity and some rule-based validation. The next level—human review of text-based information is only possible for a few resources with the funding available. Evaluation of quantitative accuracy/precision for measured numeric data is generally impossible without conducting field studies to spot check data. Our best hope is that we can gather the measurements that have been done, and consistency between datasets is the best indicator of good quality data from the point of view of accuracy/precision.

In addition, we caution that NGDS has the potential to bring in vast amounts of additional data beyond that in the current projects, without the kinds of oversight and resources we can dedicate to data quality. Scientists and managers have to make decisions on how much credibility and weight to give to data they currently use. Delivering data digitally online does not mandate that the data messengers take over that responsibility from them. There are times when you are willing to use unverified or lower quality data because there may be nothing else available. You should have the option to do so if you choose, rather than be prevented because the system operators cannot vouch for it. So, it is critical that the system be designed to provide users with tools to readily understand the provenance and evaluate the quality of any data in the system and let users made informed decisions about how much risk they are willing to take.

Response to Reviewer 2: The projects Data Development Cycle calls for submission of test data as early as possible from each data provider to ensure that the templates are being followed correctly, proper metadata entered, and QA/QC standards are being met. Following review and approval of the test data and services, the providers are given approval to go to full production. However, there is a final QA check on final data sets and services before they are officially approved to be exposed through the NGDS.

Longer term, though, reviews of new data sets or updates to existing data, will not be carried out from a centralized authority. As described above, it is our intent to create evaluation and rating functions in the system to allow users to rate and comment on data sets and providers QA/QC standards and applications of them. To try to maintain centralized QA on data itself will require unreasonable resources. Instead, we foresee NGDS focusing on QA/QC of *network services* and *data evaluation tools and procedures*.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10111
Presentation Title: Heat Flow Database Expansion for National Geothermal Data System Data Development, Collection and Maintenance (SMU)
Investigator: Blackwell, David (Southern Methodist University)
Panel: Rebuttal - Data Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Data Systems:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Data Systems:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Data Systems:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Data Systems:

No Response Entered

Rebuttal Comments for "Overall" - Data Systems:

The primary comments that need discussion are the comments on the possible duplication of effort between this project and the Arizona and Boise projects (somewhat the focus of reviewer 2) and the question of data quality (emphasized by reviewer 8).

The duplication question is addressed by the close and ongoing communication between the three groups. Personnel from SMU and Siemans participate in the overall and the Technical working groups. In addition we have monthly telephone meetings among our group and also between SMU/Siemans personnel and DOE/NRL to coordinate and monitor the activities.

Each group has different foci in the overall consortium. The Boise group deals with the overall system, Arizona is in charge of an updated ―State Coupled" program, while SMU/Siemans deals with some of the largest legacy geothermal data collections and with specific data collection efforts not covered in the State (Arizona) efforts. This work focuses on the state geological surveys who may, in some states, not have the expertise nor the access to some relevant geothermal data sets that are covered in the SMU/Seimans consortia (the Geothermal Resources Council being one of these).

The duplication question is a good one and there has been great effort to deal with possible overlap. The SMU/Siemans group is a purely geothermal combine whereas the other 2 groups have limited geothermal experience. We have been the lead group in the development of data types and characteristic to be collected by the many groups involved in the data gathering. We have also been a lead in developing metadata standards for thermal data to be used in the data system and in specific geothermal components such as development of geothermal key words for the search engines to be implemented . Siemens has used existing software to generate nonduplicative document scanning lists for the all of the different groups in the data system. This avoids redundant efforts and allows coordination of the compilation of documents for the data base. The starting point was the already scanned documents in the extensive NTIS collection. Siemans is also working on automated systems to process some of the large legacy data sets, such as well headers, scout tickets, and field heat flow notes.

Furthermore, the National Geothermal Data System is a distributed system so there is no central ―official' repository. The data will be able to be referenced through one portal (Boise), although it may reside in many distributed places. There will be regional centers and SMU will be one of these, but this structure does not imply duplicative efforts.

The question about data quality is also a good one. Our group feels that the assessment of the quality of the data to be put into the data base is a major component of the activity. Wherever possible a quality value of some sort will be associated with all information input to the system. The details will vary with every piece of data of course, but quality will always be a field in the data forms.

Reviewer 27 mentioned the preparation of the systems to combat cyber-attacks. One reason to involve a professional group like Siemans is to make sure that we have the most up to date protection from this sort of problem. It is worth noting that the Siemans group working on the project is Corporate Research and they are approaching this project as an opportunity to develop tools for projects like this, not to perform a simple contract service.

Rebuttal Comments for "Strengths" - Data Systems:

No Response Entered

Rebuttal Comments for "Weaknesses" - Data Systems:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Data Systems:

No Response Entered

Enhanced Geothermal Systems (EGS)

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10401
Presentation Title: Enhanced Geothermal Systems – Concept Testing and Development at the Raft River Geothermal Field
Investigator: Moore, Joesph (University of Utah)
Panel: Rebuttal - Enhanced Geothermal System Demonstrations
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Overall" - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Strengths" - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Weaknesses" - Enhanced Geothermal:

Response to Reviewer 33 -We agree that additional modeling of the stress state and fracture performance will be useful. In-situ data will be obtained from mini-frac tests of the target zone and well logs once the bridge plug is removed. Logs will be run before the well is cased; the mini-frac tests after the casing is installed. These data will provide the basis for the numerical models.

Rebuttal Comments for "Suggestions for Improvement" - Enhanced Geothermal:

Response to Reviewer 33 - Modeling has been initiated to evaluate the effects of thermal cracking during the injection of cold water.

Response to Reviewer 26 - The population in the Raft River Valley is sparse. We have spoken with most of the ranchers individually.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10406
Presentation Title: Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field
Investigator: Walters, Mark (Calpine - Geysers Power Company LLC)
Panel: Rebuttal - Enhanced Geothermal System Demonstrations
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Enhanced Geothermal:

Response to Reviewer 33 - The Calpine demonstration is a hot dry rock (HDR) system that is, albeit, atypically hot. Fluid flow in the high temperature zone in Calpine's EGS appears to be advective which is expected in an HDR. In contrast, the overlying normal temperature reservoir is typical of a hydrothermal system in which fluid flow is circulating, often by convection.

Rebuttal Comments for Scientific/Technical Approach - Enhanced Geothermal:

Response to Reviewer 16 - The growth of microseismicity over time at the EGS demonstration will be better understood by this project as there are two permanent and two temporary seismic arrays for this project. One of the temporary arrays includes a 17 station focused MEQ array installed by Dr. Lawrence Hutchings of LBNL. All MEQ data and other results from the EGS demonstration will be publicly available as they are received. No information from the EGS demonstration will remain confidential.

Rebuttal Comments for Accomplishments, Results and Progress - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Overall" - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Strengths" - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Weaknesses" - Enhanced Geothermal:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Enhanced Geothermal:

Response to Reviewer 6 - There is every intent to study the implications of ductile vs. stick-slip stress relief and MEQ behavior using the geomechanical model constructed by Dr. Jonny Rutqvist at LBNL.

High Temperature Tools, Sensors, Systems, Drilling Systems

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10701
Presentation Title: Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems
Investigator: Oglesby, Kenneth (Impact Technologies, LLC)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 13- Microbores are the first step in looking at large bore drilling using the FLASH abrasive cutting system. It is important to note that if microbore arrays improve heat transfer efficiency, then fewer wells are needed.

Response to Reviewer 78- Agreed. However, if microbores do improve heat transfer, then by their very nature they will balance out the flow between each microbore and thus through the collecting fracture system. No need to measure, but if you do, you can measure the flow in/out of the one (microbore) source main bore.

Response to Reviewer 39- My fault for not making the work, effort and objectives clear.

Response to Reviewer 75 - Agreed.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 13- Good questions. Waterjetting is ineffective in hard rocks and cannot be done in an oilfield or geothermal drilling environment. Tremendous volumes of high pressure fluid are required for any cutting to occur- thus hydraulics becomes a problem at these high rates. Abrasive rebound will destroy many times a particle‘s volume while at the same time reducing the size of such particles to allow for easier flowback. Foams will be used to aid in solids removal. I did state that solids removal, if to the surface, will be the limiting factor affecting the drill rate. That‘s why I proposed allowing the cuttings and abrasive solids to drop into the rat hole (much slower velocities) after leaving the microbore. Note that we are using VERY LOW pump rates (2-5 gpm) and not the higher normal rates utilized by other drilling means. Nozzle wear will occur, but for the limited number of microholes in an array, they should last for that time required. We also have replaceable nozzle concepts and designs. In reality, the LBNL simulation effort actually should be done first to see if microbore arrays will even improve EGS efficiency, and if it does, what configuration makes the most sense. This simulation will allow for a better understanding of the number, diameter and length of needed microbores.Response to Reviewer 39- Many laboratory tests were performed during prior projects. We have done/will do high temperature but unconfined pressure tests on the rocks. We cannot afford (budget) to set up a true confining set of tests. We think that rock stress will help the drilling process since the rock is relatively brittle. We did perform hydraulic simulations of the drilling conveyance and hole cleaning system in a variety of configurations; however, this was glossed over due to lack of presentation time. We are still working on the surface system to improve efficiency for field operations.

Response to Reviewer 75- Good.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 13- I think I am aware, but there may be efforts that I do not know about. I think that the technology is sufficiently different from that which has gone before to be worth testing further. I do understand that we have a very long way to go.

Response to Reviewer 39 Agreed, we have much further to go. There have been equipment problems.

Response to Reviewer 75- This is like dog paddling- looks smooth and steady but slow on the surface, but working like mad just to keep afloat and make forward progress! We have worked on a number of array configurations, some of which we ended or hit simulation dead ends. We now have a new set of configurations that appear more promising, but we have no simulations to show off yet. We did modify TOUGH2 to include a better rock-bore heat transfer method. This has been formally presented to industry. The FLASH system and test bench needed upgrading for high temperature testing. We feel that most of the setup work is complete and more progress should be seen in the future.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 13- We did have some miscommunication during project startup outlining the possible configurations. This included finding new and potentially better configurations as well as finding mechanical problems with prior set configurations (once simulation models were already set up). Moving forward we will improve LBNL-Impact coordination. Nozzle wear and cutting efficiency are REAL concerns and we are/will conduct testing to better determine those abs/cuttings ratios at high temperatures but unconfined pressures/stresses. There was little/ nothing to report at the time of this presentation. Our simulations indicate that lateral hole cleaning is not a problem or can be addressed with additives. Also rat hole solids dumping still appears possible if we do not want to lift the solids to the surface (more of a dual string and high velocity concern).

Response to Reviewer 39 - Disagree. We simulated the drilling process with microbores to find the hydraulic limitations and the acceptable FLASH fluids required. We simulated some (more needed) microbore configurations to see if this will help EGS- if it does not help then we will stop further work in this area (saving money). If it does help, then the optimum configuration must be known so that we have a target to design the drilling system to, and to see if it is even possible. Considerations for system integration and implementation are the next Phase of the project (after bench testing).

Response to Reviewer 75- Agreed.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 13- I know most of the prior efforts with waterjetting. We do know that nozzle wear will occur and steps are needed to be taken to replace nozzles in-situ. Right now we are expecting a 40 hour life, sufficient for an array to be installed (of configurations now expected- see simulation efforts). We are not directionally guiding the nozzle as much as pointing and shooting at a large fracture wall and expecting physics to work (gravity and pipe bending, flowing early time 1960-1970s directional drilling methods). Abrasive plugging prior drilled microholes is more of a concern than plugging fractures, but both will need to be considered. We still believe that reservoir simulation will guide the later system designs.

Response to Reviewer 39- Both needed and we will do these.

Response to Reviewer 75- Will do.

Rebuttal Comments for "Strengths" - High Temp:

Response to Reviewer 13- this was already done in prior projects.

Response to Reviewer 39- That is not possible under the current budget. Maybe later.

Response to Reviewer 75- This will be done during ongoing testing and modeling.

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 13- Noted. Certain well conditions for optimal FLASH drilling are known and may be more of a show stopper than those listed. Hole cleaning is always a concern, but we have studied that as much as possible for now.

Response to Reviewer 39- Pictures of the equipment were given in the talk. Hydraulic modeling was fully performed for the drilling process, but only one slide was devoted to that. Field deployment issues are constantly being evaluated. Reporting on field deployment issues occurs in the next Phase.

Response to Reviewer 75- Will do.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 13- Already performed during a prior project. Our FLASH system is different. Nozzle wear is an issue to overcome.

Response to Reviewer 39- It is not in the Budget. Maybe we‘ll be able to do it during the next proposal.

Response to Reviewer 75- Agreed

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10703
Presentation Title: Development of a Hydrothermal Spallation Drilling System for EGS
Investigator: Potter, Jared (Potter Drilling, Inc.)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp

Response to Reviewer 78 – Reviewer comments are more directed at the Geothermal Technology Programs decision to fund novel drilling technology development vs. the actual impact and potential of the ongoing work by Potter Drilling (PD). In rebuttal to other arguments by Reviewer 78, the drilling approach using hydrothermal spallation deals with a number of issues affecting the overall cost of drilling (both conventional and EGS) not just ROP. These issues include tripping time and factors related to trouble (non drilling time) such as borehole stability and damage to the drill string during tripping. Improved approaches, such as those being conducted at PD, could lead to considerably longer continuous sections of borehole reducing, the number of casing segments needed.

Response to Reviewer 39 – Reviewer mentions the specific technical objectives that may not have been mentioned in the oral presentation or the written summary but they are outlined in the proposal. The projects goals are to drill three holes to 1000 ft total, show means to reach rate of penetration of 30 ft/hr, show a pathway to reach a tool life of 120 hours, and show that predicted drilling costs provide an advantage over conventional drilling technologies.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 13- Reviewer discusses the somewhat limited application of spallation to different rock types, especially limestone. To date, all true EGS projects have operated in crystalline basement rocks (granite, granodiorite, diorite) which have been shown to be very spallable. Many conventional geothermal fields are also in spallable rocks. By our estimates nearly 80% of all hydrothermal reservoirs are in spallable rocks (sediments, intermediate and silicic volcanics, crystalline silicate rocks). We believe that the evolution of relatively shallow thermal drilling will be towards a hybrid drilling system that uses thermal techniques to soften or cut kerfs into rock prior to being cut by more conventional pdc or tricone bits. Very deep drilling in crystalline rocks most likely will be based on pure thermal drilling technology.

Response to Reviewer 78- This reviewer appears to have issues with the choices made by the GTP and not the work being conducted at PD

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 13- Reviewer brings up some good points on the issues of dealing with water influxes and lost circulation zones. At shallow depths and competent rock we are doing this initial testing. To date these have not been issues but we expect they will be more problematic as we go into deeper wells and hotter environments found in true geothermal reservoir rocks. We have potential solutions to some of these issues such as operating with mixed air-water coolant cuttings transport similar to that used in air hammer drilling. Managed pressure drilling will allow us to operate at near balance conditions to limit loss and ingress of fluids. Operating in a drilling mud environment was not in the scope of this project but will be evaluated in future studies.

Rebuttal Comments for Project Management/Coordination - High Temp:

No Response Entered

Rebuttal Comments for "Overall" - High Temp:

No Response Entered

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 13- Reviewer mentions the inability to drill through all types of rocks. This was discussed in an earlier section. Hybrid Thermo-mechanical approaches offer the promise of working in all environments but will need extensive testing and development. Work on this project could lead to good understanding of the critical requirements to either weaken rock thermally of cut Kerfs in rock.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 13 - Reviewer mentions testing in a water filled hole which we are already doing. All of these tests are done in holes that are fluid filled and circulated to the surface to remove spalls.

Response to Reviewer 75- Continuous operation of the drilling process has proven to be one of the more difficult challenges of the project. We continue to make progress on this through testing and re-engineering and hope to reach the project goals by the end of the summer or early fall of 2011.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10704
Presentation Title: Technology Development and Field Trials of EGS Drilling Systems
Investigator: Raymond, David (Sandia National Laboratories)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

For the reasons cited in the Technical Barriers and Targets of the Project Summary Document, this project addresses a necessary step in the introduction and adoption of new technologies within the geothermal drilling industry. As the reviewer (13) notes, this process should have been undertaken by commercially-interested parties. However, the lack of geothermal drilling activity has suppressed this role from being addressed by industry. The difficulty Sandia has encountered in identifying a well of opportunity with an industry partner confirms the risk-aversion of the geothermal industry. Sandia's historical involvement in drilling technology development provides ideal experience for continued involvement in the process of technology demonstration and maturation. As confirmed by the reviewers (78, 39, 75), this continued involvement has the potential to result in significant economic benefit for reducing the cost of geothermal well construction.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

The research component of this project is to address the limitations of laboratory testing by conducting field testing to address the full range of failure scenarios that may be encountered and not adequately addressed or simulated within the laboratory. As noted by the reviewers (39, 75), the value of field experience cannot be understated. Directly involving the service companies in these experiences will ensure their appreciation for the unique problems encountered in geothermal drilling. The work plan in year two, to develop enabling technologies to ensure field drilling success, hinges upon identification of the problem areas to be addressed in the year one field trials. The year two work plan will be developed commensurate with these issues. The year three testing is a confirmation of the technology improvements realized within year two.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Although the project did incur a late start due to other commitments of the project team, as commented upon by the peer reviewers (13, 75) - the progress realized to date is steady and on track. The project team has been focused upon administrative coordination associated with the year one test plan. However, the project team has additionally been focused upon many of the technical issues surrounding the actual application of these new technologies for geothermal well construction. As noted by the reviewers (39), the location of the drill project and the accompanying well construction plan are in good agreement with stated project objectives.

Rebuttal Comments for Project Management/Coordination - High Temp:

Project Management is on track with commitment of resources in accordance with the original proposal. As observed by the reviewers (13, 39 75), the collaborations of the multi-organizational team have progressed smoothly.

Rebuttal Comments for "Overall" - High Temp:

Contrary to the viewpoint of one reviewer (13), the project definitively falls within the acceptability range of the EGS geothermal research program as there are no competing near-term technologies that can realize EGS development within a near term development timeframe and reasonable cost outlay. Superior technologies are available for transition from other drilling sectors with a small investment by the DOE Geothermal Technology Program.

Rebuttal Comments for "Strengths" - High Temp:

As noted by one of the reviewers (39), application of the targeted technologies has the potential to significantly improve geothermal drilling performance.

Rebuttal Comments for "Weaknesses" - High Temp:

In response to one of the reviewers (39), project funding allowances do not afford the benefit of multiple bit designs for the field trials. This is acceptable since this project is not focused upon bit optimization but field trials of mature technologies that are available from other drilling sectors. In response to one of the reviewers (75), additional details on technology development plans will be developed after the year one field trials. Naturally, performance data has not been realized yet since no testing has taken place yet.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

In response to one of the reviewers (39), the project budget and objectives do not support the objective of comparing multiple bit designs in a field trial.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10706
Presentation Title: Pressure Sensor and Telemetry Methods for Measurement while Drilling in Geothermal Wells
Investigator: Vert, Alexey (GE Global Research)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - High Temp:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

No Response Entered

Rebuttal Comments for Project Management/Coordination - High Temp:

No Response Entered

Rebuttal Comments for "Overall" - High Temp:

The improvement of the fabrication yield is an important aspect of this project. Device design rules are being constantly updated to implement best practices for the improvement of fabrication processes.

Rebuttal Comments for "Strengths" - High Temp:

It is expected that very active participation of GE Oil and Gas will occur at a later stage of the project (during technology transfer) when a significant effort will be made to encapsulate developed electronics in the existing 300°C-rated casing of GE HADES tool.

Rebuttal Comments for "Weaknesses" - High Temp:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

The improvement of the yield of fabrication processes (which is one of the major goals of the project) will enable lower-cost solutions for a novel technology. As a result of their superior lifetime, developed circuits could be re-used many times.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10707
Presentation Title: Resistant NanoComposite Stainless Steel Coatings and Bits for Geothermal Drilling
Investigator: Peter, William (Oak Ridge National Laboratory)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 23- Data is being generated for this new stainless steel nanocomposite coating and bulk consolidated components to be compared to a wide range of materials also tested in geothermal applications (e.g., steels, WC-Co, etc.).

The team was able to show a very good balance of fracture toughness for a stainless steel, with compression strength values 2 to 3 times greater than conventional stainless steels.

The wear results shared at this review were the preliminary "abrasive" wear loop tests which is only one mode of failure. When comparing the material to steels, the coatings are 5 times more wear resistant than the tool steels to which they are applied. However, the material fell short of out-performing the WC-Co. The intention of the researchers was to use this data in a preliminary fashion to gauge future modifications to chemistry and process optimization; not to use the data cautiously in predicting lifetime in geothermal conditions. This message was not well communicated during the presentation. Remaining tasks in this project are looking at the ability to enhance abrasive wear performance by modifying chemistry and/or compositing. In addition, ORNL recently finished the fabrication of a new test apparatus to evaluate impact, abrasive and environment conditions. This test will be much more in line with down-hole conditions.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 13 -The main objective of this project is to develop a new class of drilling materials that can outperform current materials, based on increasing hardness versus toughness, in order to improve drilling rates. Therefore, materials were compared to both steel and WC-Co.

Final microstructures and properties are very dependent on the initial feedstock chemistry and processing methodology. The glassy nature of these materials allow for higher concentrations (than conventional means) of carbon and boron to go into solution. Due to the Intellectual Property filing currently in process, the chemistries of this alloy could not be shared in the public meeting which would show how much carbon and boron can be put into solution. A significant amount of work has gone into the study of Fe based amorphous alloys, including work by C.T. Liu, J. Poon, A. Inoue, and the researchers involved in this project. The amorphous powders are then laser fused to the substrate at very high cooling rates or are vacuum hot pressed just above the glass transition temperature. Either way, materials are held at temperature for very short time periods; grain coarsening and diffusion are minimized. This approach is well documented in most books on nanocrystalline materials, and the divitrificaiton of glass alloys (e.g., J.C.M. Li, Editor, Microstructure and Properties of Materials. Volume 2, Chapter 6, "Nanocrystalline Materials" by C.C. Koch and C. Suryanarayana). The result expected for this project is the precipitation of nano sized carbides and borides in a refined metal matrix. ORNL was recently awarded a patent for this processing approach, and has observed coatings that are anything from a glass (no long range atomic ordering) to micron grains based on process parameters. ORNL has compared the properties of the nanocomposite stainless steel manufactured via conventional casting versus powder metallurgy and laser processing of glassy powders. As an example, a stainless steel composition has been cast with maximum Vicker hardness values of 400 to 500, compared to the 900 to 1100 values found in hot pressing and laser fusing of the glassy alloys. In addition, laser fusing parameters and powder metallurgy parameters greatly change the resulting hardness, strength, toughness, etc.

Please read the above comments under relevance. ORNL is still developing the optimum process and chemistry to achieve maximum abrasive wear values. However, high abrasive wear resistance is only one parameter of several that help to predict how well a material will perform in down hole. Mixed mode testing, simulated down hole evaluation, and field evaluations, as proposed for future work, will offer more insight as to the performance of these new materials. ORNL will continue to update results as optimization continues.

Many of the geothermal drilling companies that ORNL has spoken with have expressed interest in a lower cost, high performing material for geothermal drilling. Collaborations and partnerships with these companies has been discussed for future field evaluations when the technology matures.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 13 -In the last two years during which these materials have been developed, significant progress has been made. The materials are largely competitive with WC-Co in most attributes, and outperform tool steels. Abrasive wear factors, as those seen in the presentation, are usually evaluated on a log scale for the purposes of evaluating many different materials. As numbers become smaller, the significance becomes less (e.g., the difference between the wear of a 1 um^3 and 0.1 um^3 of wear). The data was not presented in this manner, and this communication was not made during the presentation. In the future, ORNL will present the data in the units of volume of wear per time for a given load.

With that being said, ORNL is still modifying the parameters to optimize the process and properties and decrease "abrasive" wear. ORNL hopes to find abrasive wear factor values that are on par with WC-Co by the end of the program. All other parameters are very good. See above for a more complete discussion.

Rebuttal Comments for Project Management/Coordination - High Temp:

No response entered

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 13: Please see response in technical approach. The advantage of the Fe-based coatings is that they have a very nice metallurgical bond with their substrate material. This project was not only to compare our product with WC-Co, but with steels and other materials.

The scope of the project did not include the testing of other deposited coatings. However, ORNL will perform a literature search for abrasive wear and toughness data to compare with the stainless steel coatings developed in this project. Further proposed work could include abrasive loop wear tests for other coatings and technologies.

Rebuttal Comments for "Strengths" - High Temp:

No response entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 13: Comments on slide material/content are understood. In the future, the presenter will streamline the slides to allow more time to cover figures shown.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

No response entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10709
Presentation Title: High-Temperature High-Volume Lifting for Enhanced Geothermal Systems
Investigator: Turnquist, Norman (GE Global Research)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 34 – Thank you for the comment. The modularity of the design will be stated more clearly in subsequent reviews.

Response to Reviewer 79 – It is true that the 300°C temperature requirement increases the level of technical difficulty (and cost) of the ESP, and that a lower temperature requirement would likely be sufficient for the majority of EGS applications. However, the team is trying to work within the 300°C temperature guideline set forth in the original DOE specifications. The team's current approach is to design the system to handle the 300°C environment, and evaluate system performance at lower temperatures to understand how the system might be "de-tuned" for optimal performance in lower temperature EGS wells. This will be made clear in subsequent reviews.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 34 – As the reviewer states, GE's recent purchase of Wood Group is being fully leveraged in the design of the EGS ESP system. ESP experts from Wood Group are involved in all project meetings and are being consulted on a daily basis to help guide the effort.

Response to Reviewer 53 – The estimated total power requirement is indeed relatively high, over 5 MW. Also, the borehole size of 10.625" puts additional constraints on the space available for active portion of the electric motor as real estate is claimed by the "meandering" of the borehole, areas for water flow and cabling to the motors, motor casing as a pressure vessel, shaft diameter sized for maximum torque, etc. The present thinking is to provide the total power in a modular fashion that respects all the constraints to make the system feasible. Once the motor electromagnetic two-dimensional cross section is finalized for maximum torque per unit axial length, the active length of the motor, along with the bearing span, will be firmed up as will the rotor dynamics and mechanical losses. This will define the power that can be delivered per motor and hence will determine the number of motors (equal to the number of 3-phase cables) that need to be connected in tandem. The motor rating will help size the cable for the 4160 volt operation as the current level gets finalized. As far as the stator winding ground wall is concerned, it is based on proprietary insulation work GE-GRC has conducted internally for a GE business, as well as developing high temperature insulation. Additionally, the motor windings will be immersed in dielectric oil, providing additional protection from oxidation. In addition to the component-level tests being conducted on the motor wire in an autoclave, during Phase 3 of the program, a prototype motor will be fabricated and tested as a system in a high-temperature, high-pressure flow loop at GE Global Research.

Response to Reviewer 79 – We thank the reviewer for recognizing our effort to improve reliability while increasing power density of the motor by using permanent magnet technology. The plan is to use SmCo permanent magnets that can operate at 300+ °C with very little performance degradation. The motor is rated to operate at 4160 volts (line-to-line, RMS). The present design is for 4 poles, resulting in the fundamental electrical frequency of 7000(RPM) * 4 (# Poles)/120 = 233.3 Hz. GE has vast experience in designing and testing motors at higher speeds and higher frequencies and thus does not see the speed or the frequency as constraints. Again, the modular approach of connecting many motors in tandem will allow us to develop the torque required by the pump to meet the overall system needs.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 34 – Overall ESP system efficiency is continually being evaluated as the design evolves. This is an area where the ESP design experience of Wood Group is especially valuable, and while standard ESP design practices are being used to guide the effort, novel ideas such as alternate placement of pump and motor modules are being considered.

Response to Reviewer 53 – In addition to the component-level tests being conducted on the motor wire in an autoclave, during Phase 3 of the program a prototype motor will be fabricated and tested under representative high-temperature, high-pressure conditions in a subscale flow loop at GE Global Research. As correctly stated, component tests of bearings will be done in a simulated environment by matching the expected fluid viscosity. Ultimately, during Phase 3 of the program, the bearings will be tested at the system level in the subscale flow loop.

Response to Reviewer 79 – Indeed, 5.8 MW is a significantly powerful motor and the approach is for the motor to be built in a modular fashion, with the number of modules dictated by the power requirement for each specific EGS site. Likewise, the number of pump stages will be selected based on the pressure boost and volume flow requirements of the site. It is expected that, by following this design philosophy, a very flexible system can be developed that can be tailored for a wide range of applications.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 34 – Personnel from Wood Group are now fully engaged with the program and their expertise in the design, fabrication, and service of ESP's is being leveraged.

Response to Reviewer 79 – Yes, there is a mistake on the Future Directions chart; the Go/No Go decision should indeed be in 2012, as indicated in the time line. Input to system requirements was in fact obtained from geothermal site operators and industry experts, but requirements for temperature, pressure, and flow rate specified in the original DOE goals were given priority. With the recent acquisition of Wood Group, these specifications will be revisited to be more in-line with expected EGS requirements.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 34 – While the primary emphasis at the moment is on meeting the technical requirements of the ESP system, cost is being considered in the evaluation of design configurations. Additionally, the experience of Wood Group is now being leveraged in the consideration of operations, maintenance, and overall pump design, including the consideration of thermal transients, clearances, and sand fraction.

Response to Reviewer 79 – While being able to operate at temperatures above 225°C may not enhance marketability at this time; the team's approach is to target the DOE-specified 300°C operating limit, and to evaluate system performance for less severe temperature applications. Overall market penetration of ESP's is important, and discussions are underway with ESP experts at Wood Group to ensure that technologies are developed to fulfill market-wide needs. Furthermore, the current EGS ESP design is being re-evaluated for application to smaller-bore wells.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 13 – In service, the motor wire will be exposed to the dielectric fluid within the motor, not the actual geothermal process water. Hence, high-temperature, high-pressure insulation tests are being conducted in air, which is more severe due to the potential for oxidation.

Response to Reviewer 53 – Additional high-temperature, high-pressure motor winding tests are ongoing to demonstrate the applicability and power capacity of the ESP permanent magnet motor design.

Response to Reviewer 79 – While not explicitly stated, input was provided by geothermal ESP operators and industry experts regarding the technical requirements, but these were under-emphasized in consideration of the DOE-imposed temperature specification. Overly constraining technical limits will be re-evaluated in light of the reviewer‘s comment, to ensure that a marketable ESP design is established.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 13 – While the cost and configuration of the power cable has been considered, it has not been given the same level of priority as the design of the motor and pump. This is due to the fact that other DOE-sponsored programs have been tailored specifically to cable development. The team will consider ways to leverage Wood Group experience to establish a cable design for the EGS application. With regard to erosion, geothermal industry experts have indicated that this is unlikely to be a primary factor affecting pump life, as the reviewer states. GE will leverage work on erosion-resistant coatings to address any potential erosion issues. Regarding the information-dense presentation, the early deadline for submittal was a contributing factor; the presenter wished to be prepared to discuss all subtopics when in fact there was only sufficient time to cover a few. As this was the presenter‘s first time presenting in this forum, the lessons learned will be taken into account for the next review.

Response to Reviewer 53 – Pump performance and power requirements will be re-evaluated for the existing, and a smaller diameter, design.

Response to Reviewer 79 – The project team is now fully engaged with their new partners at Wood Group. They have confirmed that reliability is the number one concern for this ESP application and are working with GE Global Research to address these issues.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10710
Presentation Title: Gas generator development and testing for controlled rapid pressurization using liquid propellants for EGS well stimulation
Investigator: Grubelich, Mark (Sandia National Laboratories)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewers 13, 75, 77: I agree with the reviewers. We will be using liquid rocket propellants for controlled stimulation.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 77 -In the second phase of funding we have included the use of computational tools to investigate optimal pressurization techniques.

Response to Reviewer 13- We will conduct computational modeling in phase 2 to better understand the coupling between borehole pressurization (rate) and fracturing. Actual borehole tests will be conducted in a borehole with no large pre-existing fractures and permeability will be subsequently measured.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response- We will be adding a computational effort in phase 2.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response -We will continue on this path for phase 2

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewers 13, 77 - We will be adding computational modeling effort to investigate pressurization effects.

Rebuttal Comments for "Strengths" - High Temp:

Response to Reviewers 13, 75, 77- Thanks

Rebuttal Comments for "Weaknesses" - High Temp:

Response - We will be adding a computational effort.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 77- OK

Response to Reviewer 13 - OK

Response to Reviewer 75- We will coordinate with Purdue University's Zucrow Laboratories for hardware testing and New Mexico Tech's Energetic Materials Research and Testing Center.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10711
Presentation Title: Feasibility and Design Studies for a High Temperature Downhole Tool
Investigator: Akkurt, Hatice (Oak Ridge National Laboratory)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response - We agree with the reviewers' assessment that tools based on nuclear methods are extremely important for reservoir characterization. Currently, nuclear-based tools are used in oil and gas industry for characterization purposes. We believe that the current project will have an impact not only for high temperature operations but overall improve the performance.

We also agree with Reviewers 53 and 48, for a complete tool analysis, one needs to investigate the other components including photomultiplier tube and power supply, both individually at the component level and all integrated together to determine performance. As stated during the presentation, the original proposal and research plan was prepared for a 3 year plan and included the investigation for photomultiplier tube as well; however, when the 3rd year funding was eliminated and the project became a 2 year project, we mainly focused on sensor components, and thus eliminated photomultiplier tube testing as well as a few other components in the proposal.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response -It seems like one comment during the presentation caused some misunderstanding. In the proposal, we proposed to investigate the high temperature response for 10 scintillators. Once the project started, we investigated the response of several others. Therefore, although originally we proposed to perform tests for 10 scintillators, to date tests have been performed on 16 crystals with 4 more planned, bringing the total number of scintillators investigated/to be investigated to 20. The measurements are complete for the following scintillators: BaF, BGO, $CdWO_4$, CsI (Na), CsI (Tl), GSO, GYSO, LSO, LYSO, LuAG, LuAP, NaI (Tl), YAG, YAP, $ZnWO_4$.; and in-progress for the following scintillators: $CeBr_3$, $CeCl_3$, $LaBr_3$, $LaCl_3$, SrI_2.

Out of the 20 scintillators, only 3-4 were received at no charge. However, it should be remembered that material cost is only a small fraction of the total cost, compared to staff time needed to perform the tests and analysis.

As stated by the reviewer, in addition to the temperature tests, we also have been working on environmental tests to gain a better understanding of environmental impacts on high temperature logging environments.

We do not understand the comment by Reviewer 23, ―full assessment of all possible materials and re-evaluation of screening approach". As stated, we have investigated everything commercially available and a few that are not commercially available. In addition, we also grew some of the crystals, which are not commercially available, in-house at ORNL. As a result, for this project, the number of evaluated detectors increased to 20, as opposed to the originally proposed 10. Due to time constraints, it was not possible to include the results from all the scintillators during the presentation, but the summary slide for gamma measurements provided the list of the all the evaluated scintillators. The results for all the scintillators will be documented as a report and included in Geothermal Data Repository

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response -As stated by the reviewers, all the tasks in this project are on track and work is in progress to accomplish all the goals of the project.

We do not understand what reviewer 23 meant by ―more screening work is needed" and hence it is difficult for us to respond. A more elaborative comment by the reviewer with concrete examples could have been useful and constructive for the team.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response - As stated by the reviewers, the project management is on target and all the tasks are in progress and producing results. As discussed during the presentation, prior to review, some efforts toward establishing collaboration with entities working in the area of HT tools have started. After the review, joint proposals with Sandia National Laboratories, working in the area of high temperature electronics, have been prepared and submitted to DOE.

Again for Reviewer 23, the comment is not clear and therefore providing a meaningful response is not possible. The remaining work has been presented and some preliminary efforts toward establishing collaborations have been mentioned during the presentation.

Rebuttal Comments for "Overall" - High Temp:

Response - As mentioned by the reviewer, high temperature detectors are needed for geothermal applications. Also, if successful, this work can have a significant impact, not only for high temperature geothermal but for the overall data logging industry (oil, gas, geothermal) for lower temperatures as well since the identified crystals show superior performance (in terms of efficiency, spectral quality) compared to the ones currently used in these industries.

Response to Reviewer 23 - Although again the comments are not very clear, perhaps the reviewer would have liked to see the results from all the tests that were done. Only highlights were presented due to time limitation of presentation. All the results will be included in the report, which will become available through geothermal data repository.

Rebuttal Comments for "Strengths" - High Temp:

Response - As stated by the reviewers, we focused on characterization of detectors for high temperature, shock and vibration and this comprehensive assessment should be very beneficial to developers of high temperature nuclear logging tools.

Rebuttal Comments for "Weaknesses" - High Temp:

Response - We agree with Reviewers 53 and 67 that photosensors and electronics need to be evaluated. However, as discussed during the presentation, these were outside the scope of the present project since the project time and funding was reduced from 3 years to 2 years. With regard to follow-on funding, first there appears to be a difference of interpretation of the mandatory ―Future Directions" slide. Based on the instructions regarding FY2011 activities and milestones, we interpreted GTP to be asking for a discussion of remaining work in FY2011, rather than plans for FY2012 and beyond. Second, some efforts toward initiating collaborations with other entities working in these areas were established prior to program review. As mentioned before, after the review, collaboration with Sandia has been established and joint proposals have been submitted to DOE in response to a call.
Regardless, we have addressed this criticism by responding to the AOP and FOA with a project covering precisely the work missing from the present project

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 53 - Addressed by our response to the AOP/FOA which teams with SNL.

Response to Reviewer 67 - Correct in that this gain instability needs to be run to ground. Some further investigations are planned to address this issue.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10712
Presentation Title: 300°C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems
Investigator: Vert, Alexey (GE Global Research)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - High Temp:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

No Response Entered

Rebuttal Comments for Project Management/Coordination - High Temp:

No Response Entered

Rebuttal Comments for "Overall" - High Temp:

Response - Our team is pleased with the comments related to the project and recognition of the importance of the development of SiC-based electronics for geothermal applications.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response - The evaluation of the thermo cycling tolerance of assembled boards is not included directly in the plan, but is already scheduled and will be performed by GE Oil and Gas as the first step of the technology transfer process.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10714
Presentation Title: Development of a High Temperature Fiber Optic Transmission System
Investigator: Henfling, Joe (Sandia National Laboratories)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - High Temp:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewers 48 and 65 - Correctly stated that this project is in the early stages with modest results thus far. This project is moving forward and is likely to be successful based on the lab demonstration tests. The major hurdles have been identified and a path forward is established.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewers 48, 65 - This project is about 25% complete and, as such, no detailed results are available.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 23 – Reviewer mentions hydrogen darkening of the fiber as a concern. This is a concern with any fiber that is utilized in a downhole application. While the development of hydrogen-tolerant fiber is beyond the scope of this project, we realize this is a concern. In fact, Sandia identified this issue many years ago and the report is still being referenced today. Sandia is working with a couple of manufacturers that are developing hydrogen-tolerant fiber, and our plan is to utilize the state-of-the-art fiber when field demonstrating the developed data link. This approach enables a complete system to be demonstrated (high speed data link using HT hydrogen-tolerant fiber) and quickens the path to commercialization.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 48 – Reviewer commented on his uncertainty regarding the fiber optic cable that will be used with the developed data transmission system. Suitable fiber is presently being developed by a few manufacturers. Sandia is working with a couple of them, and will demonstrate a complete solution by using state-of-the-art fiber optic cable with our communication system.

Response to Reviewer 65 - Reviewer commented on our approach of using the laser at the surface instead of downhole as a minor weakness. We looked at both approaches prior to the submission of this proposal. Currently, no laser or LED is adequate for this application, and developing a high temperature laser is beyond the scope of this project based on the available funding. After considerable deliberation, it was determined the approach with the best chance of success (considering the current technology) was one that did not require the laser/LED source to be downhole. If at a later date an adequate high temperature laser or LED is developed, our system can be adapted accordingly. Many of the same components would be required in the surface electronics design. The polarization issue (discussed in the presentation and paper) is presently being compensated at the surface where standard electronics can be utilized. If the illumination source was downhole, the compensation would be downhole. This would complicate the downhole electronics design and could be difficult to implement.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

No Response Entered

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10717
Presentation Title: Base Technologies and Tools for Supercritical Reservoirs
Investigator: Henfling, Joe (Sandia National Laboratories)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - High Temp:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 48 - We agree that fielding is an important step during the development of any downhole tool and as such, fielding will be carried out throughout this project. The first field test went smoothly and we learned information regarding the gain of our collar locator. This feedback will be used in the implementation of the MCM and is a good example of the necessity of fielding tools during the development.

Response to Reviewer 23 - Our program tasks are approximately 50% complete and our funding is about 50% spent. Due to the limited time for the presentation, the details could not be presented. The tasks and subtasks were given in the paper and outline the many areas addressed in this project. We agree that this project does have many workstreams and it can be confusing based on the limitations imposed on the length of the paper and presentation. Developing HT tools requires advancements in many areas and we have outlined tasks to accomplish this goal.

Response Reviewer 47 - While every attempt is made to meet the dates associated with milestones, many factors affect the milestones and at times, not all are as successful as initially anticipated. This can lead to delays.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 23 -The milestones and deliverables are being managed effectively. Our program tasks are approximately 50% complete and our funding is about 50% spent. The deliverables and tasks are clearly defined in the paper. The presentation was time-limited and may have been difficult to follow. Many topics had to be covered and the outline was predefined by DOE. This is an involved project and one must reference both the paper and the presentation to obtain a better understanding of the scope of the project.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 23- We agree that subject matter and deliverables are critical to the success of geothermal sensing. Since the focus of this project is to advance the HT technology required to successfully develop HT tools, our deliverables are a set of ―demonstration” tools to enable the geothermal community to observe the advancements and provide a path forward to develop future tools utilizing these advancements. While difficult to ascertain in the short presentation, the workstreams are managed through the use of a detailed work plan and a Gantt chart.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 47- Long-term 300°C tools are not practical using present technology. We have demonstrated a simple analog pressure/temperature tool rated for operation at 300°C. Due to limitations in printed circuit (PC) boards this analog tool used a ceramic board with wires physically attached to each electrical connection (wirewrap technique). These connections replaced the copper traces on a typical PC board. After each wired connection, the joint was laser spot-welded to eliminate solder. While this technique worked in a simple analog tool, it would be too cumbersome in a digital-based tool. In addition, the hundreds of wired connections would result in a reduction in overall reliability of the tool. Sandia is pursuing other board fabrication techniques to enable the development of higher temperature boards and thereby increasing the upper limit of the electronics for downhole tools. In the future, practical 280°C tools may be developed and demonstrated, but it is beyond the scope of this project.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 47 - Sandia is constantly pursuing higher temperature tools and is working with industry to test components as they become available. Sandia has been involved in life-time testing of components and sensors for many years and through testing programs we are able to determine the temperature limits of the ―system”. While many components and sensors continue to operate at temperatures of 300°C (or higher), oftentimes the overall system has a reduced operating temperature (or life-time) due to a critical component. Our funding is not adequate to develop components and as such, we provide recommendations to the manufacturer. DOE funded projects, such as FOA and SBIRs can help to advance the components necessary for a complete system.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10718
Presentation Title: Waveguide-Based Ultrasonic and Far-Field Electromagnetic Sensors for Downhole Reservoir Characterization
Investigator: Sheen, Shuh-Haw (Argonne National Laboratory)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 39 -Current acoustic sensing technology applied to geothermal systems is mainly the acoustic/ultrasonic imaging system such as the borehole imager by Schlumberger, either direct surface imaging or near surface measurement based on Stoneley wave. However the imaging system does not produce reliable and useful information regarding reservoir fracture and permeability. Furthermore, the current imaging system works only in low-temperature environment.

The scope of this project is to examine the feasibility of applying acoustic/ultrasonic techniques to measurements of other reservoir parameters such as temperature (and temperature profile), pressure, and mixed-phase properties including mass flow rate. Also, we propose to examine if the acoustic noise induced by water flow in reservoir can be used to predict the permeability and rock fracture. If all the feasibilities are demonstrated, at least three new acoustic tools will be developed: (1) ultrasonic enthalpy meter, (2) ultrasonic temperature profile probe, and (3) acoustic noise sensor for reservoir characterization. None of the above sensors are currently available; they do require efforts to advance the state-of-the-art acoustic technology.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 48 -We totally agree with the reviewer's comment on how this work, mainly acoustic noise measurement, can be related to determination of rock fractures, porosity and permeability. This part of the work (use flow-induced acoustics to predict permeability) is very preliminary; the concept has been illustrated in fluid mechanics text books but application to a real environment remain as a big challenge.

Response to Reviewer 39 -The ultrasonic temperature probe which uses a magnetostrive alloy probe along with a magnetic coil transducer can be applied to a high-temperature environment without further modification. The passive acoustic sensor for reservoir noise measurement is an Argonne National Lab patented high-temperature transducer that has been used in liquid sodium up to a temperature of 1200° F. For the ultrasonic flow instrument (or the enthalpy meter), we will use either a waveguide approach or high-temperature transducer using high-temperature piezoelectric materials which are currently available. We have recently developed an effective waveguide design for ultrasonic transmission; this part of the work was described in a FY2010 review meeting.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 48 -The reviewer is 100% correct on the value and meaning of measuring the speed of sound. The reasons we are looking into the speed-of-sound (SoS) measurement are: (1) we need the real-time SoS to resolve the fluid density measurement from the acoustic impedance measurement and (2) we hope the SoS can provide us with a fluid temperature prediction. Of cause, the result showed that the SoS cannot be used for temperature measurement. However, the SoS may be able to provide the fluid pressure measurement (a recent finding) if the fluid temperature can be measured by another sensor, such as our temperature probe.

Response to Reviewer 39 -The reviewer comment is totally accepted. The project is a feasibility study by which we want to demonstrate, in principle, the proposed concept. To operate a high-temperature and high-pressure test facility at Argonne National Lab requires a lot of effort to complete the safety review.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 39 -We accept the comment. Yes, the proposed work is too broad. At the time we proposed the work, we were relatively new in the geothermal business; we simply proposed to evaluate all the acoustic techniques we had developed over the years for other applications. We hope to see if our techniques can provide any new tools to the EGS.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 39 -If the comments were given in the FY2010 review meeting, we would not argue, however the overall achievement up to now, we believe, has accomplished and introduced several novel approaches that may provide in-situ and real-time measurements of reservoir parameters such as temperature, pressure (a new concept just developed), and flow enthalpy. Are any of the techniques close to commercialization? Yes, the temperature probe is ready. We have found the oil/gas industry expressing interest; the geothermal industry, no, because the market is limited.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10719
Presentation Title: Acoustic Sensor for Downhole Fluid
Investigator: Pantea, Christian (Los Alamos National Laboratory)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 39 -We agree with reviewer 39 that —the project does not advance the state of the art for high temperature tool construction". This project deals with the development of a novel sensor, and not a tool development. We do not mention the term —tool development" in any part of this project.

With that in mind, we agree that service companies and other labs have developed tools to much greater degrees, but those, most likely, proposed the development of a tool in their proposal.

Response to Reviewer 49 -No comment. We agree with reviewer 49.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 39 -To the best of our knowledge, this cavity based resonance technique is not currently used by other sensing technologies.

Response to Reviewer 49 -We agree with reviewer 49 that —it is not clear how the proposed techniques lead to measurements of the proposed parameters". We addressed this in great detail in the proposal and presented it in detail at the last review. We didn't think it necessary to describe it again as the theory is now well established.

Any acoustic transducer (e.g., piezoelectric disc) has several characteristic resonances, which are determined by the geometry and the transducer material (in this case $LiNbO_3$). We take advantage of the fact that there is a strong dependence of these resonances with temperature. In terms of pressure and fluid composition, these have no noticeable effects on the center position of the characteristic resonances of the transducer. The only effect of pressure and fluid composition is in mass loading the transducer which leads to attenuated characteristic resonances. In other words, there is no need for pressure and fluid composition to remain constant while making other measurements, such as temperature.

We do not agree with the statement of reviewer 49 —The SFAI technique may give measurements of sound velocity and attenuation but again both will not directly lead to any meaningful parameter measurements." Yes, it is correct that sound attenuation can be affected by many things, such as the container, etc. However, sound absorption can be related to liquid viscosity through Stoke's law. Sound speed can be directly related to composition in a binary mixture. The SFAI technique also allows the determination of liquid density. Both sound speed and density can be related to liquid/liquid composition through well-known relationships.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 39 -No comment for reviewer 39.

Response to Reviewer 49 -Temperature measurements and sound speed measurements in salt solutions are an important part of the project, and we demonstrated these successfully. Additionally, we performed modeling of sound propagation in different brines, taking into account the —many things” that can affect sound speed in fluid. Also, a great amount of work went into developing the algorithms for sound absorption and sound speed determination. The progress is in line with the schedule proposed for this project, and some of the data presented are ahead of schedule.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 49 -We strongly disagree with reviewer 49. According to our Gantt chart and the timeline provided in the presentation, this project is aligned EXACTLY to the schedule on technology development.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 23 -According to our Gantt chart, and the timeline provided in the presentation, this project is exactly aligned to the schedule. Preliminary data on sensor performance are given for temperature measurements and salinity measurements. Additional data taken at high temperature and high pressure were collected after the May deadline for the review slides and, as such, were not included in the slides.

Response to Reviewer 39 -We agree with reviewer 39 that —the use of acoustic tools is fairly mature in the Oil & Gas industry”. However, those tools cannot be readily applied to Enhanced Geothermal Systems (EGS). The main impediment is the high temperature present in EGS. Our work addresses the issues related to high temperature and also the conceptual development of a novel sensor based on frequency-dependent measurements. All available acoustic tools relate to time-of-flight measurements and provide much less information than the proposed sensor. As we mentioned previously, we did not propose the development of a tool, but that of a novel sensor.

Response to Reviewer 49 -The fluid flow can help characterize the man-made reservoir by: determining the nature and location of the fractures, determining the location and the amount of fluid that leaves and enters the borehole, and determining the relative contribution of each fracture to the total reservoir.

Reviewer 49 states that —only temperature measurement using an acoustic resonator has been demonstrated”. Ppossibly the examiner did not have a chance to read the full report. The following tasks were performed and presented: (i) temperature measurements, (ii) sound speed measurements in salt solutions , (iii) performed modeling of sound propagation in different brines, (iv) algorithm development for sound absorption and (v) algorithm development for sound speed determination.

We re-iterate some facts: the resonator (LiNbO3 transducer) cannot measure both temperature and pressure or viscosity. The resonator is used only for temperature determination. The resonance cavity that encloses the working fluid can determine the following: sound speed, absorption and density. A secondary cavity with a 4 transducer arrangement can determine the fluid flow. For pressure, we are working on a novel concept also related to frequency-dependent measurements.

Rebuttal Comments for "Strengths" - High Temp:

Response to Reviewer 49 -Although this potentially contradicts the reviewer‘s previous statements, we agree with this statement.

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 39 -We agree, but this proposal does not deal with the development of a tool. In terms of measurement technique understanding, frequency-dependent measurements are well established in the scientific community. The novelty of this proposal consists in using, for the first time, a frequency-dependent approach in acoustical sensors. The service companies deal only with time-of-flight measurements, and cannot determine all the quantities presented in our proposal.

Response to Reviewer 49- We disagree with reviewer 49. We already addressed these issues in the answers to his other comments.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 49 -We agree with reviewer 49's statement, and this is reflected in our initial plan, task 7: Demonstration of proof of concept in laboratory. As shown in the presentation, we do have a high-pressure high-temperature system that can reproduce the exact conditions present in an Enhanced Geothermal System.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10720
Presentation Title: Geothermal Ultrasonic Fracture Imager
Investigator: Patterson, Doug (Baker Hughes Oilfield Operations Incorporated)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 39 – The new system is designed to have a logging speed 2 to 3 times that of the current system (goal of 15 ft/min). Therefore with the 3-4 hours an interval of roughly 2000 ft could be logged. If there is a need to log longer intervals this could be extended by adding additional heat sinks in the electronics section.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewer 49 – The ultrasonic imager does map out the surface features at the borehole wall. While the borehole environment is not ideal, the experience in the Oil & Gas Industry over many years have shown that the evaluation of the pulse echo reflection information, amplitude and transit time, does provide critical information in evaluating fractures in the subsurface. While the scattered waves do create ―noise" we have experience in dealing with it (especially in the Oil & Gas industry) where the borehole fluid, drilling mud, has much higher attenuation properties than the fluids typical for the Geothermal industry. As for permeability evaluation, a different borehole acoustic system is employed which uses a monopole source to create the borehole guided Stoneley wave.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 49 – The project focus has been to address the highest risk item, which is the sensor exposed to the 300°C environment. The testing has shown the sensor is functional and works at 300°C. The ability to image features has been achieved in the lab, with an upcoming test later this quarter to demonstrate it at temperature and pressure.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 39 – There have been some delays in the project due to some critical resourcing issues. The original plan had a delivery date of July 31, 2011, but with the delays the updated schedule is now March 31, 2012.

Response to Reviewer 49 – The array operation at 300° C has been demonstrated and will have a temperature and pressure test with an image later this quarter.

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 49 – The ultrasonic system to image the borehole surface for fractures was the requirement of the of the request proposal. The use of Stoneley waves and porosity measurements is also of value in reservoir description but is accomplished by the use of a monopole borehole acoustic device, a different device, operating at much lower frequencies. The typical compressional measurement is made at 10 kHz and is a standard method of porosity evaluation. The Stoneley is a borehole guided mode that is lower in frequency (typically 2.5 kHz and lower) that responds to hydraulic leakage from the borehole into the formation. It should also be noted that the Stoneley responds to the direct leakage path so it requires a conductive path from the borehole out into the formation, if a fracture does not intersect, it will not respond. It has been used in the Oil & Gas Industry with good success but is an omni-directional measurement. The use of multipole borehole acoustic systems, i.e. cross dipole is also of extreme value evaluating the presence of azimuthal shear-wave birefringence to detect both the presence and direction of high angle fractures. This method does look some 2-4 feet out into the formation and can detect fractures that do not intersect the borehole and can work in cased hole.

Our recent research developments in the borehole acoustic arena has also demonstrated the ability to use horizontal shear body waves generated by a dipole source to look away from the borehole and map fractures up to 60 feet outside the borehole region.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 49 – There is value to the imaging and interpretation of fractures at the borehole surface. This has been demonstrated over several decades in the Oil & Gas Industry. Stoneley analysis can be added with a borehole acoustic tool and does provide additional information, but does not provide any directional information.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 49 – Currently we are imaging at room temperature with a featured target and plan to have a test at temperature and pressure by the end of this quarter.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10721
Presentation Title: Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells
Investigator: Lowell, Mark (Draka Cableteq USA, Inc.)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response to Reviewer 63 -A 400° C solution has been found for the insulated conductors, but a solution for 400° C fiber is not likely for this project. Current fiber solutions appear very good for 300° C and possibly as high as 350° C.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response to Reviewers -Agree that field testing is essential to prove results of lab testing.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response to Reviewer 50 -Agree that existing data is only an early indication of the hydrogen resistance and high-temperature polyimide coatings performance. Completing the lab work in these two areas is currently the primary focus of the project and should be completed in 2011.

Rebuttal Comments for Project Management/Coordination - High Temp:

Agree with Reviewers' comments.

Rebuttal Comments for "Overall" - High Temp:

Agree with Reviewers' comments.

Rebuttal Comments for "Strengths" - High Temp:

Agree with Reviewers' comments.

Draka's experience with downhole fiber optic cables in the oil and gas reservoir management market is also a great strength.

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 50 - In general, this is more of a development than a research project, but some of the more pure research elements were not covered or disclosed at the peer review meeting because of pending IP issues.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response to Reviewer 63 -We agree with this suggestion, but the additional work involved is not currently in the project scope or budget.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10722
Presentation Title: Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems
Investigator: Challener, William (General Electric Company)
Panel: Rebuttal - High Temp Tools, Sensors, Systems, Drilling Systems
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - High Temp:

Response - We agree with the reviewer comments. Identification of fibers that resist hydrogen darkening and maintain tensile strength at high temperatures will enable a variety of sensing applications. Laboratory testing of commercially available fibers has identified a few that are suitable for downhole testing.

Rebuttal Comments for Scientific/Technical Approach - High Temp:

Response - As Reviewer 50 notes, this project spans a wide range of TR levels. Testing a variety of fibers at high temperatures in the presence of hydrogen is not a big engineering challenge, but is an essential step for the remainder of the project. In response to the MEMS sensor issues from Reviewers 50 and 63, it should be noted that while the general optical readout technique has been previously demonstrated in the lab and in some industrial applications, robustness has been an issue and there are no sensors currently available for the high temperatures (384° C) targeted in this project. The comment about splicing from Reviewer 63 is a point well taken.

Rebuttal Comments for Accomplishments, Results and Progress - High Temp:

Response - In the project proposal, we were specifically only going to develop a *plan* for downhole testing. The two actual downhole tests that are scheduled for the second year of the project are ―above and beyond" the actual proposal, although we agree that downhole testing is essential to fully characterize our system.

Rebuttal Comments for Project Management/Coordination - High Temp:

Response to Reviewer 50 - In response to Reviewer 50, although project management is a very important aspect of this project, there are also several key inventions / engineering challenges that must be overcome such as MEMS sensor design for an optimum optical signal, sensor packaging for maintaining optical alignment over the wide temperature range, FBG development with metallized fiber, FBG package design that is not susceptible to spurious strain, and fiber cable design for high temperatures (without the use of gel).

Rebuttal Comments for "Overall" - High Temp:

Response to Reviewer 53 - In response to Reviewer 53, the project team does include Qorex with very substantial oil & gas experience, as well as Sandia National Laboratory with very substantial geothermal well experience. In response to Reviewer 23, the primary delays in year 1 were in development of the MEMS sensor and in testing all the optical fiber. Suitable fiber has been identified for the downhole test and the fiber cable is undergoing manufacture. It should be completed with plenty of time to enable both downhole tests. The MEMs sensor requires a second iteration and the schedule is very tight, but still doable. In response to Reviewer 50, I agree fully – during this year everything needs to come together.

Rebuttal Comments for "Strengths" - High Temp:

No Response Entered

Rebuttal Comments for "Weaknesses" - High Temp:

Response to Reviewer 63 - The comment from Reviewer 63 regarding fiber splices and welds is one we will consider in future implementation. It may indeed be possible to eliminate the splices in a practical commercial sensor.

Response to Reviewer 50 - It is true that there is no research to develop a suitable optical fiber but rather we are primarily trying to select from existing commercially available fibers (though as mentioned in the Q2, 2011 quarterly report, we have also worked with one fiber vendor to help them develop a new, superior high temperature metallized fiber). On the other hand, there has been a substantial amount of research to develop the MEMS and FBG sensor technology.

Rebuttal Comments for "Suggestions for Improvement" - High Temp:

Response - If our experience, if the first downhole test does not go smoothly, we will consider the reviewer‘s suggestion to seek additional help and advice from a fiber deployment company.

Innovative Exploration Technology

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11101
Presentation Title: Caldwell Ranch Exploration and Confirmation Project
Investigator: Walters, Mark (Calpine - Geysers Power Company LLC)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response to Reviewer 28 - To the best of my knowledge, no geothermal operator has ever used whole-rock oxygen-18 isotopic analyses and downhole, high-temperature noble gas isotope analyses in combination with the lithologic section and static temperature profile to assess the production zones in a geothermal reservoir.

Rebuttal Comments for Scientific/Technical Approach - IET:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - IET:

No Response Entered

Rebuttal Comments for Project Management/Coordination - IET:

No Response Entered

Rebuttal Comments for "Overall" - IET:

No Response Entered

Rebuttal Comments for "Strengths" - IET:

No Response Entered

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 28 - To the best of my knowledge, no geothermal operator has ever used whole-rock oxygen-18 isotopic analyses and downhole, high-temperature noble gas isotope analyses in combination with the lithologic section and static temperature profile to assess the production zones in a geothermal reservoir. Use of this combination of methods is very likely to be transferable to other hydrothermal systems in the United States such as Dixie Valley, Medicine Lake, and those in Indonesia and the Philippines.

Rebuttal Comments for "Suggestions for Improvement" - IET:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11104
Presentation Title: Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada
Investigator: Zehner, Rick (Geothermal Technical Partners, Inc.)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response to Reviewer 28- It is true that shallow temperature sampling has been around a very long time, but the method outlined by Coolbaugh et al. is more quantifiable and is rapid. The point of the study is to try and conclude: once a shallow anomaly has been detected, what does it mean? Is there boiling water at 30m depth or a magma chamber at 500m? What sorts of things inhibit a shallow anomaly when a true anomaly exists at depth?

Rebuttal Comments for Scientific/Technical Approach - IET:

Response to Reviewer 28 -You have some good points here, but allow me some clarification. First, I was trying to say that the accuracy of the equipment was about 0.5°C: if a number of rods were planted at the same site, I would expect them all to be within about 0.5°C of each other. Perhaps that did not come out right during the presentation. Regarding the Coolbaugh et al. article citing factors contributing to temperature variation, I have several points. First, we've found seasonal variation to be closer to 10°C, so I agree with your argument there. I'd add that planting permanent rods and using them to normalize for the seasonal variation appears to work very well. Regarding slope, albedo, etc., I agree that these factors are definitely significant and that I did not mention this topic at all during my presentation. I also agree that these factors can change the measured 2m temperature by about 4-6 °C. At a study site like McGee Mountain, these variables could be accounted for using methods similar to Coolbaugh et al, but in actual practice 2 points should be kept in mind: 1) the kind of adjustments suggested by Coolbaugh et al. would be too time consuming and expensive in a reconnaissance setting, and 2) the magnitude of the true temperature anomalies we are finding are well above this 4-6 °C range. Regarding the hydroprobe (a.k.a. geoprobe) data at different depths, we would all prefer that drills of any kind would always go to TD and we could compare ―apples with apples". Since this is seldom the case, and didn't happen here (which I specifically mentioned), I think I would have attracted even more criticism by trying to normalize the data to some depth. Reviewer 28 also states that ―the resolution of the method is poor enough that a substantial outflow zone could exist and not be seen". I agree, and would point out that the kinds of questions I'm trying to answer are: "how can you interpret the subsurface temperature regime with a shallow survey?" or "under what conditions can you get a false negative?" In retrospect the study might better have been devised to include several sites with shallow temperature anomalies but different geology, a point I have made to my DOE 'handlers' and might even be addressed in an amended SOPO. All this said, I thank Reviewer 28 for his/her comments, which are on or close to the mark, and duly noted.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response to Reviewer 28 - As I mentioned in the presentation, I feel the project is behind schedule, more for financial reasons than for permitting reasons. I hope to accelerate progress but with the decline in investor appetite for financing geothermal companies and projects, I cannot guarantee this. I am working on a fallback where I would review 3 areas where shallow temperature measurements were taken by both 2m and geoprobe equipment.

Rebuttal Comments for Project Management/Coordination - IET:

No Response Entered

Rebuttal Comments for "Overall" - IET:

No Response Entered

Rebuttal Comments for "Strengths" - IET:

To Reviewer 28: I approached Dave Blackwell months ago and asked for his help on this project, which he informally granted. I am waiting for further funding and some TG data before I approach him again for his suggestions and methodology.

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 28 -See comments in Scientific/Technical section above.

Response to Reviewer 12 - Good points.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 28 -

1. I believe I am aware of many of the limitations of the technique. A lot of this project is to detect and address some of those limitations.
2. I was limited to a 15 minute progress report. I felt my presentation was more valuable than presenting plotted geoprobe temperatures and their depths as an image to show progress to date.
3. Regarding the lack of shallow thermal anomaly at McGee when we expect one to be there, at this stage I strongly disagree with the suggestion that I say something like "...if it is 100°C it has to be deeper than..." rather than "didn't see one". The former is guesswork and conjecture while the latter is observation, which is the exact reason why we want to drill the TG holes and get an observable answer.
4. Blackwell: As stated above, a good idea that I'm already working on.

Response to Reviewer 12 - Good points. I think things are tracking in the direction you suggest.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11111
Presentation Title: Validation of Innovative Exploration Techniques Pilgrim Hot Springs, Alaska
Investigator: Holdmann, Gwen (University of Alaska Fairbanks)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response - We appreciate the compliments on the airborne remote sensing work. Reviewer 40 comments that ―chances of the resource to be exploited seems low". While the nearest community, Nome, is over 30 air miles and 50 road miles distant from the resource, the energy costs in Nome are quite high. The community spent almost $8M in diesel fuel alone in 2010, and has an average load of approximately 5MW. We selected this site because it is generally considered one of the more promising sites for development in Alaska, and our matching funds, provided through the State of Alaska Renewable Energy Fund, were awarded based on the economic feasibility of developing the resource.

In addition, the revised flux values that we have estimated after improved remote sensing based thermal imaging and modeling are almost twice as high as the flux values originally measured by the researchers in the 80s. The general consensus among team members and project partners is that there is a greater likelihood of identifying a developable resource than existed prior to this current exploration effort.

Rebuttal Comments for Scientific/Technical Approach - IET:

Response - We appreciate the compliments from reviewers on our approach. Reviewer 40 asks ―What is the overall geologic model?". This will take place through subsequent phases of the project. We expect the work completed this summer will be combined with existing data sets to develop a conceptual model of the system, including identification of the upflow zone. Phase 3 includes reservoir modeling to define how the system could be developed, based on the outcome of the confirmation drilling program.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response - We concur with Reviewers 60 and 40 that our project is ―on schedule with solid results for the funding spent to date", and ―Results so far appear encouraging in terms of usefulness of infrared remote sensing". Reviewer 12 comments that there is slow progress, but we do not think this is accurate based on the established timeline and/or budget.

Rebuttal Comments for Project Management/Coordination - IET:

Response -We appreciate the recognition of our efforts to maintain good communication with our local partners, and within the various project participants. We feel we have a strong and effective team and have worked hard to foster good relationships.

Rebuttal Comments for "Overall" - IET:

Response to Reviewer 60 – Reviewer asked if we had performed geochemical sampling and geothermometry that could help identify whether an electricity-grade resource exists at some depth. This has been done, and we have good agreement among geothermometers that a resource of ~150°C exists at depths, a fluid which could be developed using a binary system. In addition, as suggested by DOE in a prior review, we have purchased chloride sampling kits and will carry out sampling of several targets of interest identified by FLIR with these new kits later in August and in early September.

Response to Reviewer 40 – Reviewer comments that the primary result of drilling would be validation of our methods rather than improving prospects for large-scale development due to the distance from potential market. We agree that the required transmission distance for a project that would serve the nearest major population center in Nome is a major challenge to resource development, but as mentioned previously the economics are different in Alaska due to the extremely high energy costs. While it is unknown whether development will move forward, it should not be discounted at this point. The purpose of this project is primarily to validate the airborne remote sensing work; however the site was selected due to local interest in developing the site.

Rebuttal Comments for "Strengths" - IET:

Response to Reviewer 40 – Reviewer comments on our team‘s “good communication with community and stakeholders”, as well as “solid understanding of technique”. We appreciate this positive feedback.

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 40 – Reviewer comments that it would be useful to “add more about conceptual model and other data sets”, and Reviewer 12 comments that “integration w/ previous geophysics and temperature gradient drilling lagging”.

While we did not provide a slide showing this interpretation because our goal was to keep the presentation focused on our new project and new achievements, there has been substantial effort in this regard. We have thoroughly researched the known body of knowledge on the resource and have used all the existing data to aid in the current interpretation. For example, we georeferenced the existing geological maps, digital elevation data, 1980s shallow temperature contour map along with more current data sets, such as the recently conducted shallow temperature survey data collected by our team, and the ground-based gravity data collected by the USGS within a GIS framework. We have also extensively referred to earlier published and unpublished papers and reports as we build this work. For example, we have used the predicted flow rates from the earlier (1980s) geothermal heat flow model to compare and contrast our geothermal heat flux model.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 12 - Our only suggestion for improvement came from Reviewer 12, who suggested we need to better integrate with existing data. As previously mentioned, we did not provide a slide showing this interpretation because our goal was to keep the presentation focused on our new project and new achievements, however there has been substantial effort in this regard. See the section ‗Comments Regarding Weaknesses‘ for more information.

We prepared an illustration showing a GIS integrating different datasets, including geological faults, recent shallow temperature data, the spring FLIR survey data, and high resolution satellite imagery for this rebuttal but were not able to attach it to our comments.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11116
Presentation Title: A 3D-3C Reflection Seismic Survey and Data Integration to Identify the Seismic Response of Fractures and Permeable Zones over a Known Geothermal Resource: Soda Lake, Churchill County, Nevada
Investigator: Benoit, Dick (Magma Energy Corporation)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response - I think the bottom line of the 3D 3C survey at Soda Lake is that without a very large amount of pre-existing deep drillhole information it would have been impossible to develop a nearly unique seismic interpretation. Instead of seismic being a preliminary exploration technique it may be a better later stage development tool. It is also going to be limited to restricted geological environments and a very limited subset of geothermal fields.

Rebuttal Comments for Scientific/Technical Approach - IET:

Response - I think that this exercise tended to confirm that integration of various geothermal data sets provides the best road map for developing drilling targets. There is no single magic bullet, such as 3D seismic that will completely dominate future geothermal exploration. Also, I think it is important to note the amount of time and effort that have to go into working with even routine or normal exploration data to develop a detailed understanding of a geothermal field amounts to man years of work. It can not be credibly performed in weeks or months by even the most knowledgeable consultants.

Response to Reviewer 51- Reviewer suggested that statistical analysis be applied. This was not part of the SOPO and Magma Energy Corp. simply does not have this expertise in house.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

No Response Entered

Rebuttal Comments for Project Management/Coordination - IET:

Response to Reviewer 51 -Regarding Reviewer 51 comments on the converted wave processing, the converted wave effort consisted of 3 processers working part time over a 6 month period. It was intermittently passed back and forth between them and was not their highest priority and amounts to less than 6 man months of work.

Rebuttal Comments for "Overall" - IET:

Response - I agree with Reviewer 51 about 3D seismic being expensive. It is debatable as to how much value it provides per dollar spent. I also agree with Reviewer 4 in that it will be difficult for this particular survey to have a large impact on the geothermal industry outside of areas such as the Imperial Valley.

Rebuttal Comments for "Strengths" - IET:

No Response Entered

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 51 - Regarding Reviewer 51, statistical analysis is a skill set not available within Magma Energy and statistical analysis was not included within the SOPO.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response - I hope that both the positive and negative results from the Soda lake 3D seismic survey are incorporated into discussions throughout the industry regarding the applicability of various exploration techniques in various geological environments. Magma is already sharing these data with researchers interested in improving the interpretation.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11117
Presentation Title: Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System (An Alternative to Grid-Drilling for Geothermal Exploration): McCoy, Churchill County, Nevada
Investigator: Benoit, Dick (Magma Energy Corporation)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response - Reviewers question the amount of innovation. It is true that nothing truly "new" has been proposed in terms of exploration techniques. However, McCoy is at a quite preliminary stage of exploration with basically an existing temperature data set. Once a significant mass of existing data are available in a geothermal prospect then it becomes exponentially easier to propose or justify new work with these data, develop hypotheses about the area, and rationally develop a more sophisticated approach that can include innovative techniques.

Rebuttal Comments for Scientific/Technical Approach - IET:

Response -A lack of innovation was noted by 3 of the 4 the reviewers (see the above rebuttal comments on that topic). One reviewer expressed concern that the expected temperature of the resource may not be high enough. This is always going to be a fundamental challenge in exploration for blind resources where water tables are far below the surface.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response - The reviewers note that drilling targets have not yet been identified. This in part resulted from slow permitting, allowing a diversion of staff time to work on the Soda Lake 3D seismic project. The project does not have a go/no-go decision point prior to the drilling of the angled slimholes. Permitting has been slower than desired but we now appear poised to apply for drilling permits in August, 2011 and are reasonably confident that two angled slimholes can be drilled before winter arrives in late Nov. or Dec. 2011.

Rebuttal Comments for Project Management/Coordination - IET:

Response - No question that permitting has taken longer than planned or desired due to the preparation of an EA. However, this hurdle is now almost behind us.

Rebuttal Comments for "Overall" - IET:

Response - McCoy is presumably representative of what future blind geothermal systems will be like. Without surface indications such as active thermal features, silica terraces, etc. it will be impossible to predict subsurface temperatures. Experience at McCoy may someday be seen as pioneering in learning how to assess blind geothermal systems lacking geothermometry. There has been a relatively long permitting effort to get things moving on the ground but by the end of 2011 there should be data from 2 slim holes.

Rebuttal Comments for "Strengths" - IET:

No Response Entered

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 24 – Reviewer would like to have seen small 3D seismic profiles but the steep topography at McCoy and absence of roads running across the topography effectively prohibit use of seismic lines. A 3D seismic survey at McCoy would be a major project onto itself. The topography at McCoy limits permitable drill pads to a small percentage of the lease area. Angled slim holes will be less costly than directional holes in accessing much of the leased area. However, it is not yet clear if the first slim holes will need to be angled or can be more effective as vertical holes.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 51 – Reviewer would like to see some statistical analyses of correlations between datasets. This was not in the SOPO and the Magma staff does not have expertise in this discipline.

Response to Reviewer 41- Reviewer requested more detailed data. Unfortunately, there are no more detailed data to present at this time, other than the temperature data.

Response to Reviewer 24 – Reviewer would prefer to see small seismic studies. This was not in the SOPO and the topography and permitting at McCoy do not allow this in any reasonable time frame.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11118
Presentation Title: Advanced Seismic Data Analysis Program ('Hot Pot Project') - Analytical Techniques of Coherency First Arrival Data Processing and Full Waveform Inversion Velocity Model and Validation by Drilling Wells
Investigator: Moore, Shuman (OSKI Energy LLC)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response to Reviewer 24 - Agreed.

Response to Reviewer 4 - Although not discussed in the Peer presentation, one shown slide (and thoroughly discussed in the completed Stage Gate Report) demonstrated that the applied technique did in fact offer useful structural imagery to very extensive depths without well control information. The presentation did discuss that the received imagery was further improved through the integration of well control information and the corresponding reprocessing of the data. The process works without geologic input - but is improved through integration of geologic information.

Response to Reviewer 51 - If exploration leads to the successful development of projects, permanent jobs will be created.

The presentation made at the Peer review did not discuss or promote the large amount of geologic, geophysical and geochemical data collected and analyzed in preparation and design of the applied seismic program. Although seismic is an expensive exploration tool - this project has clearly demonstrated several cost-saving measures in its successful application:

A. The numerical technique allowed the imagery of structure to several thousand feet deeper than that would have been obtained utilizing traditional processing techniques, capturing imagery at depths common to higher-temperature geothermal systems that might be masked in other regions with unremarkable lithology at shallower depths.

B. The numerical technique allowed the imagery of structure several thousand feet greater horizontally than that would have been obtained utilizing traditional processing techniques, allowing a less-dense line spacing to be applied, resulting in reduced line length to be run.

C. The project demonstrated that the utilized numerical analysis techniques could be improved through the integration of well control data to obtain more refined imagery. This has not been previously discussed in the literature when applied to geothermal systems, and the Hot Pot project demonstrates its successful application.

D. Applying these analytical techniques to data sets obtained on other projects utilizing traditional techniques may yield beneficial results - lowering exploration and development costs.

E. Reprocessing of existing data sets that have utilized Optim‘s analytical techniques with well control data as it becomes available may yield beneficial results - lowering exploration and development costs.

Rebuttal Comments for Scientific/Technical Approach - IET:

Response to Reviewer 24 **-** The innovative nature of the numerical analytical technique applied by Optim were not heavily discussed in the Peer review presentation. However, reprocessing of the obtained seismic data set to incorporate known well control data was discussed. This technique may be common-sense and utilized in other industries with traditional processing techniques, but the presented method and results were innovative when applied to the numerical methods utilized by Optim, and innovative when applied to imagery of complex geothermal systems.

The presentation made at the Peer review did not discuss or promote the large amount of geologic, geophysical and geochemical data collected and analyzed in preparation and design of the applied seismic program. Dense-grid gravity data was collected, and utilized in the layout, orientation, and area of coverage of the seismic program.

Response to Reviewer 4 **-** Thank you.

Response to Reviewer 51 **-** Agreed that the numerical method utilized by Optim and applied to the seismic data set collected in this project has been successfully applied in a few studies over the last decade (DOE/ID/13465-T). However, this method has not also been successfully applied on many projects - mostly referenced in unpublished, private reports other development and operational projects (2009 OIT direct use well drilling- design and results report). This does not mean that the technique is not valid, but inconsistent results obtained over the years by multiple operators led to disparate opinion of the usefulness of this technique. The methods utilized in the Hot Pot project clearly demonstrated that there was room for improvement to the analytical method, which could be overcome through integration of geologic information and iterative re-processing of the seismic data.

The perception of knowledge gaps may be a function of the limited information presented under the Peer review format. The completed Stage Gate report - which was thoroughly discussed with the project‘s DOE Technical Review Committee - addressed all acquired and analyzed geologic, geophysical and geochemical data utilized in conjunction with the seismic program on the Hot Pot project.

We agree that application of a 25 line mile seismic program is not applicable to all projects. In fact it would be an obvious waste of money to apply to inferred single-range-front fault systems, when a more focused, lesser extent program would be sufficient. However, the extensive line-length was required for the Hot Pot project for several reasons:

A. The hidden nature of the potential geothermal system,

B. The large areal extent of the measured elevated thermal gradient,

C. The 3-D analysis and imaging of the proposed project, requiring a grid layout of data collection. If 3-D imagery was not part of the project scope of work, then selected seismic profiles would have been run, instead of cross-cutting and over-lapping line runs.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response to Reviewer 24 **-** Agreed, but an extension of the project end date was requested in the Peer Presentation. Locations for the 2 Phase 2 slim holes have been completed based on the information obtained in Phase I, are near completion of permit requirements, and are anticipated to be completed only a few months beyond the original proposed schedule.

Response to Reviewer 4 **-** Agreed, and a more thorough discussion of methods and interpretation were made in the completed Stage Gate report.

Response to Reviewer 51 - Thank you for acknowledging that the accomplishments and results to date are in good relation to the project targets and goals. We agree that Optim is a quality, professional company - that is why we chose them as the seismic data collection and analysis contractor. Results from this project have improved Optim's methodology and ability in program design and subsequent reprocessing value. They now have the experience to know what additional data to ask for and integrate available well control information into their analysis product.

We agree Optim, as a seismic contractor, would typically collect seismic data along lines and routes as prescribed by their client. Despite the known elevated cost of a 25 mile line-length seismic effort, this program was designed by Oski to address the proposed exploration project needs:

A. The hidden nature of the potential geothermal system,

B. The large areal extent of the measured elevated thermal gradient,

C. The 3-D analysis and imaging of the proposed project, requiring a grid layout of data collection. If 3-D imagery was not part of the project scope of work, then selected seismic profiles would have been run, instead of cross-cutting and over-lapping line runs.

Rebuttal Comments for Project Management/Coordination - IET:

Response to Reviewer 24 - Discussion of the Go/No-Go decision process was not utilized in the Peer Review presentation format.

A. Results obtained from the Phase I seismic data collection and analysis would determine if drilling of Phase 2 slim holes was warranted.

B. Results of the Slim Hole drilling would determine if drilling of the Phase 2 resource confirmation well was warranted.

Response to Reviewer 4 - Agreed.

Respnse to Reviewer 51 - Geologic, geophysical and geochemical information was used to design the layout, orientation, extent and overlap of the seismic program.

Rebuttal Comments for "Overall" - IET:

Response to Reviewer 24 - The presentation made at the Peer review did not discuss in detail the analytical methods utilized by Optim in processing the obtained seismic reflection data. However, results from the project to date have demonstrated:

A. The numerical technique allowed the imagery of structure to several thousand feet deeper than that would have been obtained utilizing traditional processing techniques, capturing imagery at depths common to higher-temperature geothermal systems that might be masked in other regions with unremarkable lithology at shallower depths.

B. The numerical technique allowed the imagery of structure several thousand feet greater horizontally than that would have been obtained utilizing traditional processing techniques, allowing a less-dense line spacing to be applied, resulting in reduced line length to be run.

C. The project demonstrated that the utilized numerical analysis techniques could be improved through the integration of well control data to obtain more refined imagery. This has not been previously discussed in the literature when applied to geothermal systems, and the Hot Pot project demonstrates its successful application.

D. Applying these analytical techniques to data sets obtained on other projects utilizing traditional techniques may yield beneficial results - lowering exploration and development costs.

E. Reprocessing of existing data sets that have utilized Optim's analytical techniques with well control data as it becomes available may yield beneficial results - lowering exploration and development costs.

Response to Reviewer 4 - Although not discussed in the Peer presentation, one shown slide (and thoroughly discussed in the completed Stage Gate Report) demonstrated that the applied technique did in fact offer useful structural imagery to very extensive depths without well control information. The presentation did discuss that the received imagery was further improved through the integration of well control information and the corresponding reprocessing of the data. The process works without geologic input - but is improved through integration of geologic information. As a geothermal project is developed, wells will have to be drilled, and this information can be utilized as it is acquired to re-process and improve the collected project seismic data sets. The Hot Pot project has shown that shallow wells typically used to obtain temperature-gradient data could now be used to provide geologic information to refine the project area seismic imagery, improving the design of subsequent deeper wells and reducing drilling risk.

Response to Reviewer 51 - Agreed, given the project scope and objectives, and the hidden nature of the potential geothermal system. We proposed to accomplish a lot through seismic analysis, which required the collection of an extensive seismic data set.

Rebuttal Comments for "Strengths" - IET:

Response to Reviewer 24 - Agreed.

Response to Reviewer 4 - No comment made by reviewer.

Response to Reviewer 51 - Agreed.

Rebuttal Comments for "Weaknesses" - IET:

Response toReviewer 24 - No comment made by reviewer.

Response to Reviewer 4 - No comment made by reviewer.

Response to Reviewer 51 - Agreed that the numerical method utilized by Optim and applied to the seismic data set collected in this project has been successfully applied in a few studies over the last decade. However, this method has not been successfully applied on many projects. The methods utilized in the Hot Pot project clearly demonstrated that there was room for improvement to the analytical method, which could be overcome through integration of geologic information and iterative re-processing of the seismic data.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 24 - Other geologic, geophysical and geochemical data sets were collected and used in the design of the seismic program. This integrated approach was thoroughly discussed in the completed State Gate report.

Response to Reviewer 4 **-** No comment made by reviewer.

Response to Reviewer 51 **-** The spent funds were a function of the program design necessary to address the project objectives and the hidden nature of the potential geothermal system.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11119
Presentation Title: Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation
Investigator: Noel, Donna (Pyramid Lake Paiute Tribe)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

Response to Reviewer 41 - We agree with this comment.

Response to Reviewer 24 - We agree with this comment.

Response to Reviewer 4 -As outlined in the peer-review presentation, each of the proposed techniques will be assessed during Phase III (not Phase I or II) to determine the relative information gained versus cost. Therefore, we generally agree with reviewer 4 that a take home message is needed, but this will be done during Phase III of the project.

Response to Reviewer 51 - The existing well APS-1 wasn't drilled or completed at the target depth and therefore couldn't be used as an appropriate monitoring well. A production well and monitoring well completed at similar depths are needed to obtain all of the parameters (i.e. storage parameters) required for the reservoir model. We inadvertently used an incorrect temperature log in slide 12 that only provided the upper 500 ft. The entire log will be provided in the Phase III report. During the presentation, Dr. Pohll did point out the fact that downhole temperatures were 95 degrees C.
Phase III is definitely required to assess the geothermal resource potential. A preliminary economic analysis of the Astor Pass resource has been done by Oski Energy which found that the Astor Pass Geothermal Site is a viable resource. Using a conservative production estimate of 500 gpm, the site would produce 539 kW with a simple pay back of 5.8 years. The economics are marginal at such a low production rate, but given the results of the well testing it is likely that fluid production could be much larger than 500 gpm. The project team and Oski Energy agree that a reservoir model is needed to ascertain sustainable production rates both in terms of fluid flow and temperature. Given the permeability at the site, we expect sustainable production rates near 2,000 gpm, which would provide nearly $700,000 in annual income for the tribe. Since the economic feasibility is dependent on the long term sustainability of the resource, modeling is needed to reduce the risk of commercial investment.

Rebuttal Comments for Scientific/Technical Approach - IET:

Response to Reviewer 41 - Since data and results from Phase I were presented during the 2010 peer-review session and a Phase I report has already been submitted to DOE, we didn't include Phase I results at the peer-review meeting. Additionally, the presentation template that we were given didn't allow for a large number of highly detailed results/data slides. The fracture analysis (borehole and regional) wasn't completed prior to the review as we had just finished drilling the wells and were performing well testing at that time. Data from previous exploration was provided in the Phase I report and these data will be uploaded to the data repository and presented in the Phase III report. Although detailed results could not be presented for all of the technologies presented on slide 6, some of these results were presented in the Phase I report, and the others will be presented in the Phase II or III reports. The geophysical data presented in slide 12 was meant to provide an example of the data, not the entire dataset. The borehole geophysical dataset is enormous and couldn't possibly be presented in one or two slides.
The rationale for drilling the two wells close together wasn't explicitly provided in the presentation, but an argument was given during the go/no-go process and that review team agreed with the well locations. (The existing well APS-1 wasn't

drilled or completed at the target depth and therefore couldn't be used as an appropriate monitoring well. A production well and monitoring well completed at similar depths are needed to obtain all of the parameters (i.e., storage parameters) required for the reservoir model). Note that the MT survey was funded from another source and was presented as an example simply because it was helpful in targeting the well locations.

Response to Reviewer 24 - We agree with this comment.

Response to Reviewer 4 -We agree with this comment and Phase III will ultimately determine the efficacy of individual exploration technologies.

Response to Reviewer 51 - All of the geophysical /geological data and the associated conceptual model developed from these data were used to site the two new wells. We do not know what the reviewer means by ―supplementary surveys" as the only additional data collection activity that followed the well drilling was the well testing that was underway during the peer-review meeting. Maximum temperatures obtained from the static temperature logs were 92 degrees C yet during well testing we observed temperatures as high as 95 degrees C. Therefore, we observed temperatures very close to the expected 100 degree target.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response to Reviewer 41 -We strongly disagree with this comment. First, the project team is not disjointed. Each component of the study feeds into the next and we meet regularly to discuss preliminary results and plan for future tasks. For example, as outlined in slide 9 of the peer-review presentation, field data is collected and analyzed, a conceptual geologic model is made, and then the reservoir model is constructed according to these results. We also planned for an iteration step using input from all project team members to iterate if necessary. We understand that in the past low temperature systems, such as Astor Pass, were not economically feasible, but recent advances in technology allow these sites to be developed. The project team is working directly with Oski Energy, one of the world leaders in low temperature geothermal development using the Kalex ammonia water system. As noted above, a preliminary economic analysis of the Astor Pass resource has been done by Oski Energy which found that the Astor Pass Geothermal Site is a viable resource given the results of the well testing. Oski Energy agrees that a reservoir model needs to be developed to optimize the pumping strategy, which will improve the likelihood of success at Astor Pass.

Response to Reviewer 24 - We agree with this comment.

Response to Reviewer 4 -Temperatures are actually 5 degrees C less than expected, and through a combination of reservoir modeling and economic analysis we will determine the viability of the resource.

Response to Reviewer 51 - We disagree that the project is not successful. Recall that there are two overarching project goals. The first is to ascertain the viability of the site and the second is to determine which exploration activities provide cost-beneficial information for site development. Given the preliminary economic analysis performed by Oski Energy, the Astor Pass site is economically feasible, but a reservoir model is needed to optimize the operational strategy. The comprehensive geophysical-exploration approach, including advanced seismic imaging, is new and provides crucial constraints for the reservoir model. Likewise, the reservoir model will be used in combination with statistically derived sensitivity analysis to evaluate the information content of data. To our knowledge, we are the first to apply data assessment techniques to identify which data collection activities dominate prediction accuracy within a geothermal reservoir model. These techniques also provide an estimate of model uncertainty which will be critical to make important economic decisions regarding the reservoirs long term sustainability.

Rebuttal Comments for Project Management/Coordination - IET:

Response to Reviewer 24 - We agree with this comment.

Response to Reviewer 51 - We strongly disagree with this comment, and it appears that this reviewer was not given the project proposal and associated management plan. A management plan was provided to and agreed upon by DOE which included a series of go/no-go decision points. At the first decision point the project results were reviewed by a technical review team and DOE following the first round of data collection which included the shallow temperature survey and seismic analysis. All parties felt that the project was successful and should continue to Phase II – Drilling. The second decision point occurred after the first well was drilled and the review team agreed that the site was a low temperature system, but could be viable given recent advances in geothermal energy systems (e.g. Kalex ammonia water system). Given the preliminary economic analysis performed by Oski Energy, the Astor Pass site is economically feasible, but a 3D geological model and reservoir model are needed to optimize the operational strategy, which will likely increase the annual profits for PLPT. The project team has a clear plan to complete the remainder of the project, and justification thereof.

Rebuttal Comments for "Overall" - IET:

Response to Reviewer 41 - We strongly disagree with this comment. The existing well APS-1 wasn‘t drilled or completed at the target depth and therefore couldn‘t be used as an appropriate monitoring well. A production well and monitoring well were completed at similar depths to obtain all of the parameters (i.e. storage parameters) required for the reservoir model.
We inadvertently used an incorrect temperature log in slide 12 that only provided the upper 500 ft. The entire log will be provided in the Phase III report. During the presentation, Dr. Pohll did point out the fact that downhole temperatures were 95 degrees C.
Phase III is definitely required to assess the geothermal resource potential. As noted above a preliminary economic analysis of the Astor Pass resource has been done by Oski Energy which found that the Astor Pass Geothermal Site is a viable resource given the results of the well testing. Oski Energy agrees that a reservoir model needs to be developed to optimize the pumping strategy, which will improve the likelihood of success at Astor Pass. Since the economic feasibility is dependent on the long term sustainability of the resource modeling is needed reduce the risk of commercial investment..

Response to Reviewer 24 -Numerous innovative technologies were presented in slide 6 of the peer-review presentation and we feel that four in particular are highly innovative and new. First, the high-quality structural results could only be developed through advanced seismic imaging, acquisition and processing, conducted by Optim in collaboration with PI J. Louie. The P-wave arrival time data was inverted for subsurface velocity within the geothermal field using innovative and proprietary SeisOpt® simulated-annealing algorithm. The PIs know of only two other seismic surveys in the Great Basin showing direct fault-plane reflection images that have been drilled, at Blue Mountain and Brady‘s. Comparison of the quantitative, statistically supported reflection seismic attributes across such datasets will provide better and more quantitative assessment of geothermal exploration approaches, adding much national and GTP Program value to the Astor Pass data sets. Second, the 3D structural modeling and slip-dilation tendency analysis are innovative approaches to targeting fault segments that are most susceptible to channeling fluid, which will aid in planning of any future well paths. Third, the use of a stochastically-based continuum method to map the fracture network is the first application known to us for a geothermal reservoir model. Fourth, the proposed iterative modeling framework is novel and used in combination with statistically derived sensitivity analysis will allow us to evaluate the information content of data. To our knowledge, we are the first to apply data assessment techniques to identify which data collection activities dominate prediction accuracy within a geothermal reservoir model. These techniques also provide an estimate of model uncertainty which will be critical to make important economic decisions regarding the reservoirs long term sustainability.

Response to Reviewer 4 - We agree with this comment and feel that the modeling framework can be applied at other geothermal sites.

Response to Reviewer 51 -Again, given the limited amount of time during the project presentation, only a portion of the project results were presented at the peer-review meeting. All results are being presented in the individual Phase reports.

Rebuttal Comments for "Strengths" - IET:

Response to Reviewer 41 -We agree with this comment.

Response to Reviewer 24 -We agree with this comment.

Response to Reviewer 51 - We agree with this comment.

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 41 - During the presentation, Dr. Pohll did point out the fact that downhole temperatures were 95 degrees C.

Response to Reviewer 24 - Depth to water at this site is greater than 30 m so saturated flow at 2 m is not an issue. Given the arid environment, recharge below the root zone is minimal, and therefore should not impact the 2 m temperature data.

Response to Reviewer 51 - All available data was used to target the well sites including geophysical (seismic and MT), geologic (structural), shallow temperature data, and geothermometry. The geophysical and shallow temperature data showed a high permeability and high temperature zone located just west of the tufa spire. The quartz and Mg-corrected Na-KCa geothermometers suggest 132 °C and Na-K geothermometer indicates slightly higher temperatures of 155 degrees C. The project team went over this in detail with the review team during the go/no-go process and unfortunately the current review team wasn‘t briefed. Well testing is complete and was extremely valuable in determining the reservoir characteristics and viability.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 41 - The well testing task has been completed and pumping during well testing lasted 30 days, followed by a few weeks of continued monitoring after pumping ceased.

Response to Reviewer 24 - We agree, and we are leveraging a seismic network already installed in the area by the UNR Seismological Laboratory.

Response to Reviewer 51 - Well testing is already completed.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11122
Presentation Title: We propose to explore and commercially develop ―blind" (no surface evidence) convective hydrothermal systems associated with a young silicic pluton on the flanks of Newberry Volcano, Oregon.
Investigator: Waibel, Albert (Newberry Geothermal Holdings, LLC)
Panel: Rebuttal - Innovative Exploration Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - IET:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - IET:

Response to Reviewer 9 -This is an important point, particularly in that the JGR ―Newberry" volume, 1988, provided a synthesis of a lot of work done on the volcano. We will certainly clearly show how the current project has been constructed on the foundation laid by our predecessors.

Response to Reviewer 4 - The toolbox includes substantial geophysical methods. Of these techniques, only temperature gradient drilling identifies variations in temperature with depth. Others, such as MT, seismic, and gravity are unable to distinguish hot from cool areas. To better quantify the results of the methods, non-geophysical methods such as LIDAR (remote sensing for structures) and geochemistry and geology have been added to the toolbox. At this early stage we have chosen a group of techniques that should complement each other. As the project proceeds we will better understand the strengths and weaknesses of each of the methods, as applied here. The final report will discuss the strengths and weaknesses of each method. More importantly the final report will discuss the interpretive contribution gained through using various sets of data to quantify the interpretations of other sets of data.

Response to Reviewer 51 - The project has three components, the design, the funding, and the execution. Internally the latter, execution, is dependent on many contracted companies, each with their own peculiarities. A stall with any one of the three components has the potential to have ripple effects on other components, particularly when seasonal weather (significant snow fall on Newberry Volcano in Central Oregon) determines when fieldwork is conducted. The most sensitive of these to start-up delays is the drilling, with the majority of the first season lost due to permitting / approval delays. Since Davenport entered into a fixed price contract with the lowest cost drilling bidder, we have limited influence of the speed of drilling.

Rebuttal Comments for Accomplishments, Results and Progress - IET:

Response to Reviewer 24 - The gravity and MT components are now completed and the modeling will begin soon.

Rebuttal Comments for Project Management/Coordination - IET:

Response to Reviewer 51 - The first delay after being granted the DOE award was uncontrollable by Management. DOE would not let the project proceed until they conducted their own EA review even though the EA was previously approved by the BLM and Forest Service. Management may have been able to recover some of the lost time from this delay by throwing substantial additional money at trying to drill through the December-April winter months using a truck mount rig, but decided it was not a prudent use of our money and DOE's money.

Rebuttal Comments for "Overall" - IET:

No Response Entered

Rebuttal Comments for "Strengths" - IET:

No Response Entered

Rebuttal Comments for "Weaknesses" - IET:

Response to Reviewer 24 - The design and geometry of the seismic monitoring array was guided by the seismic company, Apex HighPoint. Outside seismic experts have reviewed this program for Davenport and have been in communication with Apex HighPoint. Davenport is trusting that they, with their substantial experience in applying this technique in the oil fields, are best suited to guide Davenport in the application. The microseismic test will involve multiple monitoring points. Ten geophones will be installed to a depth of 700 feet to collect data.

Rebuttal Comments for "Suggestions for Improvement" - IET:

Response to Reviewer 24 - The final report will address the value of each technique separately, and the value of each technique for its value in contributing to the quantification of the interpretations of data from other techniques.

Low Temperature, Co-Production, Geopressured Demonstration

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10800
Presentation Title: Beowawe Bottoming Binary Project
Investigator: McDonald, Dale (Beowawe Power, LLC)
Panel: Rebuttal - Low - Temperature, Co-Production, Geopressured Demonstration
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - LOW TEMP:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - LOW TEMP:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - LOW TEMP:

No Response Entered

Rebuttal Comments for Project Management/Coordination - LOW TEMP:

No Response Entered

Rebuttal Comments for "Overall" - LOW TEMP:

Response - The Dixie Valley and Beowawe Binary Projects were criticized by the review panel for two main reasons. The first complaint claimed that the two projects are not unique given the prevalence of binary plants throughout the industry. However, Terra-Gen refutes this claim and asserts that the two projects are indeed unique. The Beowawe Binary project‘s working fluid is non-corrosive, non-toxic, and inflammable (uncommon for a project of this size), superheats from relatively cool brine, and is utilized by a specially designed axial flow turbine. This project has led to the development of a family of R-134 driven expanders that can be used in similar waste heat recovery units. The Dixie Valley project builds on Beowawe‘s innovative characteristics by heating the environmentally friendly working fluid to the supercritical state and by rejecting heat by air cooled condensers. The air cooled condensers are comprised of six large fans that are driven by VFDs rather than typical ACC system that requires upwards of fifty maintenance intensive fans.

The second common complaint is that Terra-Gen is not committed to providing operating and design data. However, Terra-Gen would like to remind members of the review panel that Terra-Gen is committed to providing the Department of Energy monthly reports that detail binary plant outages, revenue figures, operating costs, brine chemistry, and performance data. Additionally, design and efficiency data specific to the unit itself is TAS‘ intellectual property and has not been shared with Terra-Gen. With regard to condenser fouling; the binary unit does not have sufficient instrumentation to calculate the heat transfer coefficients of the individual heat exchangers. However, fouling will be apparent with less generator output and heat transferred to the working fluid, which is data that is provided on monthly reports.

In conclusion, the project had yielded several economic and technical benefits. The project showed that low temperature brine can be used to generate electricity profitably using refrigerant, contributed to job growth and increased tax and royalty payments, reduced greenhouse gas emissions, and is providing proprietary and non-proprietary data to the DOE.

Rebuttal Comments for "Strengths" - LOW TEMP:

No Response Entered

Rebuttal Comments for "Weaknesses" - LOW TEMP:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - LOW TEMP:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10801
Presentation Title: Dixie Valley Bottoming Binary Project
Investigator: McDonald, Dale (Terra-Gen Sierra Holdings, LLC)
Panel: Rebuttal - Low - Temperature, Co-Production, Geopressured Demonstration
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - LOW TEMP:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - LOW TEMP:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - LOW TEMP:

No Response Entered

Rebuttal Comments for Project Management/Coordination - LOW TEMP:

No Response Entered

Rebuttal Comments for "Overall" - LOW TEMP:

Response - The Dixie Valley and Beowawe Binary Projects were criticized by the review panel for two main reasons. The first complaint claimed that the two projects are not unique given the prevalence of binary plants throughout the industry. However, Terra-Gen refutes this claim and asserts that the two projects are indeed unique. The Beowawe Binary project‘s working fluid is non-corrosive, non-toxic, and inflammable (uncommon for a project of this size), superheats from relatively cool brine, and is utilized by a specially designed axial flow turbine. This project has led to the development of a family of R-134 driven expanders that can be used in similar waste heat recovery units. The Dixie Valley project builds on Beowawe‘s innovative characteristics by heating the environmentally friendly working fluid to the supercritical state and by rejecting heat by air cooled condensers. The air cooled condensers are comprised of six large fans that are driven by VFDs rather than typical ACC system that requires upwards of fifty maintenance intensive fans.

The second common complaint is that Terra-Gen is not committed to providing operating and design data. However, Terra-Gen would like to remind members of the review panel that Terra-Gen is committed to providing the Department of Energy monthly reports that detail binary plant outages, revenue figures, operating costs, brine chemistry, and performance data. Additionally, design and efficiency data specific to the unit itself is TAS‘ intellectual property and has not been shared with Terra-Gen. With regard to condenser fouling; the binary unit does not have sufficient instrumentation to calculate the heat transfer coefficients of the individual heat exchangers. However, fouling will be apparent with less generator output and heat transferred to the working fluid, which is data that is provided on monthly reports.

In conclusion, the project had yielded several economic and technical benefits. The project showed that low temperature brine can be used to generate electricity profitably using refrigerant, contributed to job growth and increased tax and royalty payments, reduced greenhouse gas emissions, and is providing proprietary and non-proprietary data to the DOE.

Rebuttal Comments for "Strengths" - LOW TEMP:

No Response Entered

Rebuttal Comments for "Weaknesses" - LOW TEMP:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - LOW TEMP:

No Response Entered

Power Conversion Technology

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10200
Presentation Title: High Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants
Investigator: Klockow, Helge (GE Global Research)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to Reviewer 34 -The process of choosing a fluid is not new to the industry, the novelty in this work is rather the range of fluids investigated (starting from an initial list of 17,000 possible fluids) in addition to Phase-II of the project that involves cost optimization of both the reservoir/well site and the power plant in collaboration with our EGS partner, AltaRock Inc. There is no precedent for this kind of ‗holistic' optimization approach. The number of working fluids found in industry today is small: the ‗R-xxx' refrigerants, isobutane, butane, n-pentane etc. Our work, on the other hand pushes the envelope out to include many fluids that have not been investigated in ORC's – either in industry or academia.

Evidence to this effect is provided in table-3.2 on page 9 of the Milestone report #1 submitted to the DOE. This table is a list of the down-selected 38 fluids that formed part of the technical modeling/optimization study performed under this work. Furthermore, a comprehensive table of past ORC studies that have investigated different working fluids in order to optimize performance is available in reference-1. It is clear from a comparison of the two tables that no study in the past has included the range of fluids considered in this study, moreover, no study in the past seeks to couple power conversion performance with reservoir performance and optimize LCOE like this study.

The results showed a higher resource temperature results in a higher optimal working fluid critical temperature and saturation temperature. This was presented as a confirmation of well-known trends in industry and not as a novelty. The novelty, in essence is the sheer range of fluids considered in phase I of this project and the strong coupling with EGS reservoir optimization with our partner AltaRock Inc to optimize overall LCOE.

Reference-1: *S. Quoilin, Sebastien Declaye, B.F.Tchanche, V. Lemort, "Thermo-Economic optimization of waste heat recovery Organic Rankine Cycles", Applied Thermal Engineering, In Press – available online, May, 2011*

Response to Reviewer 7: The reviewer has misunderstood the aims of this project – neither the ―Milestone report no.1" nor the presentation made at the 2011 Peer Review suggest that the work ―seeks to determine whether investment in "drilling" or power plant improvements give the best return on investment". Rather, the aim of the work performed under Phase-1 is to:

1. Evaluate Cycle Performance for High Potential Working Fluids
2. Identify Key Fluid Parameters that impact Cycle Performance

Results from the above aims were presented at the peer review and reported in detail in Milestone Report no. 1.

Furthermore, the reviewer writes, ―The first part of the research compares working fluids and makes claims that seem unreasonable, such as 100% improvement in net output? This first portion of the research seems to be a repeat of research work already done. We know that higher temperatures (critical) will produce more efficient cycles at higher temperatures."

The cycle studies in this work were performed in HYSYS, an industry accepted software package with validated fluid properties taken from NIST databases such as REFPROP. The results of the simulations indeed showed performance improvements as high as 100% against standard ORC fluids under a limited set of conditions. The results of the subcritical cycle are used as an example as follows. Figure 13.1 of milestone report #1 shows the performance vs. resource temperature plot of the fluids investigated in the sub-critical cycle. Furthermore, Figure 13.6 is a re-configuration of figure 13.1, where the performance indicated by the best performing fluids is divided by the performance of n-butane.

It can be seen from the above figures that the performance improvement of 100% (vs. n-butane) is only seen at a resource temperature of 100°C. For intermediate temperatures of 125°C - 225°C, the improvement was typically < 10%. This is to be expected, since it is a known fact that the optimum working conditions for n-butane lie at an intermediate temperature range.

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 21 -Please refer to reference-1 that lists past investigations into optimization of ORC's by varying the working fluid. It can be seen that no single investigation in the past has investigated such a wide variety of working fluids for a wide range of resource temperatures as was done in this work – starting from an initial list of 17,000 to a final 38 that were modeled in HYSYS. Therefore, the novelty of the work performed under phase-1 of this program is the ability to ‗pick-and-choose' an optimum working fluid and cycle based on the resource temperature – this has not been done before in past literature.

Response to Reviewer 34:

Cost of fluids and cycles will be the major consideration in Phase-II of this program (in progress). The aims of Phase-I were:

1. Evaluate Cycle Performance for High Potential Working Fluids
2. Identify Key Fluid Parameters that impact Cycle Performance

Criteria used in the fluid selection process have been detailed in section 3.3 of the Milestone report #1. These selection criteria include factors like flammability and toxicity that were mentioned by the reviewer. Again, the reader is referred to a much more detailed treatment of the subject in the milestone report #1, section 3.3.

Response to Reviewer 7:

This is similar to the reviewer's comments on the ‗IMPACT/RELEVANCE OF RESEARCH'. The rebuttal is therefore the same:

The cycle studies in this work were performed in HYSYS, an industry accepted software package with validated fluid properties taken from NIST databases such as REFPROP. The results of the simulations indeed showed performance improvements as high as 100% against standard ORC fluids under a limited set of conditions. The results of the subcritical cycle are used as an example as follows. Figure 13.1 of milestone report #1 shows the performance vs. resource temperature plot of the fluids investigated in the sub-critical cycle. Furthermore, Figure 13.6 is a re-configuration of figure 13.1, where the performance indicated by the best performing fluids is divided by the performance of n-butane.

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Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 21 - The idea behind presenting the fluid performance in this manner was to compare the performance to a standard ORC fluid. In this case, the standard fluid chosen was n-Butane. The reviewer correctly points out that the performance of n-butane is poor at low and high resource temperatures and optimal only at intermediate resource temperatures. In section 13.2 of the milestone report #1, comparisons were made with other standard ORC fluids (these were not presented at the DOE review due to shortness of time). They are graphically represented in figure 13.7 of the milestone report #1.

It is clear that the study showed performance gains against the 4 standard ORC fluids – the performance improvement depended on the resource temperature and the type of cycle. In some cases, there was no performance improvement over the standard fluid for a particular resource temperature and cycle.

Response to Reviewer 34 -_The reviewer is correct in pointing out that standard ORC fluids have an optimal operating range in resource temperature. However this is not the only reason the relative performance plots showed gains as much as 100%. In many cases, the performance gains were made even in the optimum operating range of the standard working fluid (see figure 13.7 of milestone report #1). This is mainly due to the wider range of fluids considered in this study vs. industry knowledge.

The reviewer states, ‗*It was unbelievable that they could produce a cycle that had double the output as current cycles used.'* The topic of 100% performance improvement was discussed in detail in the rebuttal to comments from reviewer no. 7 in the ‗Comments Regarding Scientific/Technical Approach'.

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response to Reviewer 7 -

Phase-1 of this work had the following aims:

1. Evaluate Cycle Performance for High Potential Working Fluids
2. Identify Key Fluid Parameters that impact Cycle Performance

Determining drilling costs was not part of the goals of Phase-I. Rather the cost of the power plant and reservoir creation/management activities is being addressed in the ongoing Phase-II. The end goal is to obtain a parametric LCOE value.

Rebuttal Comments for "Overall" - Power Conversion:

Response to Reviewer 21- The comparison plots shown on page 109 of the Milestone report #1 in figure 13.7 indicate a step change (>30%) in efficiency when appropriate fluid/cycle combination is used for a given resource over the standard industrial ORC fluids. These numbers are derived from advanced cycle decks developed using highly reliable component performance data. Moreover, due to high parasitic loads from the down-hole and reinjection pumps in an EGS setting, it was seen that a small improvement in power plant performance can greatly enhance the overall electric output of the geothermal resource.

Response to Reviewer 34 -_The main focus of Phase-I of this study has been to develop ORC power plants with improved performance for EGS applications. The ORC cycle is a relatively small component of a geothermal power system but small improvements in power plant performance can greatly improve the overall economics and LCOE numbers, making such plants feasible. The uniqueness of this study lies in the setup of the economic analysis being currently done in phase II, wherein, the LCOE model incorporates detailed geothermal resource cost modeling in addition to power plant cost and performance.

Rebuttal Comments for "Strengths" - Power Conversion:

No Response Entered

Rebuttal Comments for "Weaknesses" - Power Conversion:

Response to Reviewer 21 -The comparison plots shown on page 109 of the Milestone report #1 in figure 13.7 indicate a step change (>30%) in efficiency when appropriate fluid/cycle combination is used for a given resource over the standard industrial ORC fluids. These numbers are derived from advanced cycle decks developed using highly reliable component performance data. Moreover, due to high parasitic loads from the down-hole and reinjection pumps in an EGS setting, it was seen that a small improvement in power plant performance can greatly enhance the overall electric output of the geothermal resource.

Response to Reviewer 34 -The main focus of Phase-I of this study has been to develop ORC power plants with improved performance for EGS applications. The ORC cycle is a relatively small component of a geothermal power system but small improvements in power plant performance can greatly improve the overall economics and LCOE numbers, making such plants feasible. The uniqueness of this study lies in the setup of the economic analysis being currently done in phase II, wherein, the LCOE model incorporates detailed geothermal resource cost modeling in addition to power plant cost and performance.

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

Response to Reviewer 34 - The comparison plots shown on page 109 of the Milestone report no.1 in figure 13.7 demonstrate how the best performing fluid at a particular source temperature compares with 4 common fluids currently being used in the industry. The aim of this exercise is to determine the performance benefit of using a specific fluid/cycle combination instead of a modular design. All the data points are optimized at the given conditions for a fluid/cycle combination. On the other hand, the plots on page 108 of Milestone report #1 (in figure 13.6) compare the best performing fluid for a given source temperature to the best performing fluid using the subcritical cycle. Per the reviewer‘s request, plots showing the cycle efficiencies, relative to Carnot efficiencies, of the best operating fluids found in this study versus the Carnot efficiency of a standard ORC fluid (iso-Butane) will be generated and Milestone report #1 will be updated.

Response to Reviewer 7 -_This project is currently investigating the design of ORC cycles for EGS systems with particular emphasis on geothermal resources within the US. The geothermal resource planning, cost structure and performance characteristics for this project are being developed under close collaboration with Altarock Inc. A small increase in output power from the ORC power plant in an EGS setting not only changes the specific cost of the power plant but also offsets the resource cost in a big way. These changes in $/kWe for the power plant and the overall EGS system will be analyzed together to study their impact on the LCOE (ongoing in Phase-II). Such a detailed analysis for LCOE has not been performed before in close collaboration with EGS developers and the geothermal community at large. In addition, this team has collected feedback from, and shared calculations with, the community at numerous conferences and meetings including International Geothermal Conference, Freiburg, 2011; RMOTC Geothermal in the Oil Field meeting in WY, 2010; Stanford Geothermal Workshop 2011; GEA showcase, 2010; EGS conference, Reno, NV, 2010; and numerous other meetings.

The team is open to suggestions for improvements in the overall deliverables of the project – these can be discussed and adopted with the approval of the DOE.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10201
Presentation Title: Tailored Working Fluids for Enhanced Binary Geothermal Power Plants
Investigator: Mahmoud, Ahmad (United Technologies Research Center)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to Reviewer 34 -

With respect to:

"Nothing New": The objective of this project, to identify a cycle design (including components) and working fluid concept that maximizes kW/gpm of resource, while maintaining $/kW and thermal efficiency of the system, may seem like nothing new. However, the comprehensive nature of this study, with its multi-faceted and iterative approach, has not been documented in the open literature. In addition, conclusions from earlier investigations about cycle design and fluid selection need to be revisited as there has been significant change in environmental regulations, fundamental knowledge gained regarding thermodynamic and thermophysical data, including EOS modeling and transport modeling (extended corresponding states) for enhanced fluids insufficient or no experimental data, and significant improvements in the scientific community with respect to materials, refrigerants, and heat exchanger designs.

No technical results were presented: No technical results were presented at this review because the session was public and the results available from the project thus far are proprietary. The results of the project thus far are model development, a robust screening methodology and refrigerant assessment. Data generated later in the program from the application of these proprietary methods will be presented at the next Peer Review and published in archival journals. We would recommend for future peer reviews that the DOE consider having closed sessions with the reviewers in addition to the public sessions so that proprietary data could be presented for evaluation. The closed session could be done at the request of the PI as some projects may have no proprietary data.

Costs: As was stated in the presentation, costs are being considered under this project as highlighted in the task structure slide. These results will be included in the written material for the next Peer Review.

Benefit UTC Only: The findings of this project will benefit both the geothermal and scientific communities. The results will be communicated at the next peer review and in archival journal publications. Publications are planned on the follow subjects: 1) Equations of State for next generation fluids (NIST), 2) Equations of State for multi-component fluid systems (NIST), 3) Assessment of correlations for the prediction of condensation heat transfer for enhanced working fluid systems (UTRC), 4) In-tube condensation heat transfer and pressure drop of alternative refrigerants (UTRC), and 5) In-tube condensation heat transfer and pressure drop of a binary refrigerant system (Georgia Tech).

Limited experience with trilateral cycle and lower expander efficiency: Regarding the trilateral cycle, UTC does have experience with bi-phase turbines and trilateral cycles. Carrier Corporation (a UTC division) first patented the bi-phase turbine for work recovery in vapor compression technology in the early 1990's. The technology was commercialized in the 19XRT centrifugal chiller in place of the throttling valve. The 19XRT has been installed in over 250 installations worldwide. With respect to Energent, they patented the use of the same bi-phase turbine concept for ORC technology since Lance Hays, who was involved with the development of the turbine technology with UTC, started that company. Due to IP restrictions, we evaluated an alternative lower-cost expansion concept. The major cost and innovation in the bi-phase expander is the nozzle. The expander efficiency used in our analysis of the trilateral cycle was based on a positive displacement type machine that Carrier manufactures. The characterization of the efficiency was determined through the use of existing analytical models that had been validated for vapor compression applications. The models were applied to the expander and yielded a total efficiency in the vicinity of 50% including mechanical and generator losses. A Go/No-Go decision was held to select the concept at the down-selection stage (i.e. which concept makes the most business and technical sense). Due to the following considerations: 1) IP restrictions, 2) poor efficiency of a cost-effective positive displacement expander, 3) scalability concerns and 4) challenges associated with lubrication, the trilateral ORC concept was given a No-Go decision. It should be noted that alternative enhanced working fluids were part of this decision.

Response to Reviewer 7 - The validated models that we have developed in Tasks 1 (Down-selection) and 2 (model development and validation) have indicated that a well-designed ORC cycle could increase net power output by at least 40%. The challenge is to do so in a cost-effective manner as the ultimate goal would be to decrease the LCOE. We have run models for thermal performance and cost of the system and components and believe this is possible.

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 21 -

Nothing new: The objective of this project, to identify a cycle design (including components) and working fluid concept that maximizes kW/gpm of resource, while maintaining $/kW and thermal efficiency of the system, may seem like nothing new. However, the comprehensive nature of this study, with its multi-faceted and iterative approach, has not been documented in the open literature. In addition, conclusions from earlier investigations about cycle design and fluid selection need to be revisited as there has been significant change in environmental regulations, fundamental knowledge gained regarding thermodynamic and thermophysical data, including EOS modeling and transport modeling (extended corresponding states) for enhanced fluids insufficient or no experimental data, and significant improvements in the scientific community with respect to materials, refrigerants, and heat exchanger designs.

Previous work on trilateral and supercritical cycles: Re-evaluation of the trilateral, supercritical and subcritical cycles for opportunities to improve on work done in the 80's and 90's was part of the first and second tasks of this project. This effort was motivated by the recognition that there may be room for improvement on work done 10 to 20 years ago due to 1) fundamental knowledge gained by the scientific community regarding thermodynamic and thermophysical data, including EOS modeling and transport modeling (extended corresponding states) for enhanced fluids with insufficient or no experimental data, and 2) significant improvements made in the scientific community with respect to materials, refrigerants, and heat exchanger designs. In addition, there has been a significant change in environmental regulations that could impact the usefulness of conclusions made in the 1980s and 1990s. A Go/No-Go was held to select the concept at the down-selection stage (i.e. which concept makes the most business and technical sense).

Response to Reviewer 34 -

No technical results were presented: No technical results were presented at this review because the session was public and the results available from the project thus far are proprietary. The results of the project thus far are model development, a robust screening methodology and refrigerant assessment. Data generated from application of these proprietary methods will be presented at the next Peer Review and published in archival journals. We would recommend for future peer reviews that the DOE consider having closed sessions with the reviewers in addition to the public sessions so that proprietary data could be presented for evaluation. The closed session could be done at the request of the PI as some projects may have no proprietary data.

Heat transfer: We are assessing the impact of working fluid choice on cost, effectiveness and type of heat exchanger required. UTC follows a stage-gate process that has identified the most promising concept so that we do not fall into the

―ll of the above approach" trap. This was mentioned during the presentation. Results will be shared in the next Peer Review.

Response to Reviewer 7 - Regarding focusing on individual issues related to the screening of the optimal working fluid, it was mentioned (and listed) in the task structure slide that the evaluation of working fluids was based on a specific and detailed analysis including ODP, GWP, toxicity, flammability, material compatibility, oil solubility and refrigerant availability and cost. With respect to heat transfer, we are assessing the impact of working fluid choice on cost, effectiveness and type of heat exchanger required. UTC follows a stage-gate process that has down selected the most promising concept so that we do not fall into the ―all of the above approach" trap. This was mentioned during the presentation. The results of the project thus far are model development, a robust screening methodology and refrigerant assessment. Data generated from application of these proprietary methods will be presented at the next Peer Review and published in archival journals.

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 34 -The objective is to identify a cycle design (including components) and working fluid concept that maximizes kW/gpm of resource while maintaining $/kW and thermal efficiency of the system. The combination of these three metrics impacts LCOE positively and directly since power equipment represents 20-30% of the project cost. With regards to screening of the optimal working fluid, it was mentioned (and listed) in the task structure slide that working fluids are evaluated based on ODP, GWP, toxicity, flammability, material compatibility, oil solubility and refrigerant availability and cost. Thermal breakdown of refrigerants is not expected for low to medium temperature geothermal applications and corrosive fluids are eliminated from the start.

Response to Reviewer 7 -We agree with your assessment. Due to the fact that the sessions were open to the public, details regarding methodology and modeling development carried out in the first 12 months of the project could not be discussed in the 2011 Peer Review. This will change for next year's Peer Review as UTRC, Georgia Institute of Technology and NIST will publish non-proprietary work from this project as follows: 1) Equations of State for next generation fluids, 2) Equations of State for multi-component fluid systems, 3) Assessment of correlations for the prediction of condensation heat transfer for enhanced working fluid systems, and 4) In-tube condensation heat transfer and pressure drop of alternative refrigerants. We would also recommend that the DOE consider having closed sessions with the reviewers, in addition to the public sessions, so that proprietary data could be presented and evaluated. The closed session could be done at the request of the PI as some projects may have no proprietary data.

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response to Reviewer 34 –

Benefit UTC Only: We believe this is not the case. The geothermal and scientific communities will benefit directly from this work as it deals directly with fundamental issues related to 1) mass and heat transfer (through work at UTRC and the Georgia Institute of Technology) and 2) fundamental thermodynamic and thermophysical data (NIST thermophysical properties division). The results will be communicated at the next peer review and in archival journal publications. Publications are planned on the follow subjects: 1) Equations of State for next generation fluids (NIST), 2) Equations of State for multi-component fluid systems (NIST), 3) Assessment of correlations for the prediction of condensation heat transfer for enhanced working fluid systems (UTRC), 4) In-tube condensation heat transfer and pressure drop of alternative refrigerants (UTRC), and 5) In-tube condensation heat transfer and pressure drop of a binary refrigerant system (Georgia Tech).

Response to Reviewer 7 - Managing of this project has required significant coordination between UTRC, NIST and Georgia Tech to ensure alignment, maintain schedule and maximize productivity. The team has generated significant results that have enabled model development, a robust screening methodology and refrigerant assessment. However, due to the fact that the sessions were open to the public, details regarding methodology and modeling development carried out in the first 12 months of the project could not be discussed. We would recommend that the DOE consider having closed sessions with the reviewers in addition to the public sessions. The closed session could be done at the request of the PI as some projects may have no proprietary data.

Rebuttal Comments for "Overall" - Power Conversion:

Response to Reviewer 21 - it should be noted that I mentioned a 40% improvement in resource utilization, not efficiency (net power output/ heat input). This metric considers that for each gpm of the resource, the net site power can be increased by 40% over baseline R245fa or R134a cycles. Details regarding working fluid selection, fluid characteristics and component designs that enable this realization will be disclosed in a closed forum only. The results of the project thus far are model development, a robust screening methodology and refrigerant assessment. Data generated from these proprietary methods will be presented at the next Peer Review and published in archival journals.

Respone to Reviewer 34 - The geothermal and scientific communities will benefit directly from this work as it deals directly with fundamental issues related to 1) mass and heat transfer and 2) fundamental thermodynamic and thermophysical data. The findings from these fundamental issues will lead to the design of next-generation power conversion technology. These results will be presented at the next Peer Review. Reviewer 34 makes a very good point of considering the LCOE. In our analysis however, we have found that by maximizing kW/gpm at the same $/kW and thermal efficiency levels will improve the LCOE by up to 30% when compared to the baseline. The detailed analysis of LCOE and presentation of results is planned for the CY12 Peer Review. Other comments in other sections detail other screening criteria that were discussed during the course of the presentation.

Response to Reviewer 7 - I would like to clarify the approach that was taken. As I stated in the presentation, only the first 3 months (Stage 1 - opportunity analysis) involved a broad evaluation of options including trilateral, supercritical and subcritical cycles with different working fluid concepts. In Stage 2, a sole concept was selected from this wide variety of options. The project is now focused at addressing and reducing the critical risks associated with that technology (Stage 3). The results of the project thus far are model development, a robust screening methodology and refrigerant assessment. Data generated from these proprietary methods will be presented at the next Peer Review and published in archival journals.

Rebuttal Comments for "Strengths" - Power Conversion:

Response to Reviewer 34 - The models that we have developed in Tasks 1 (Down-selection) and 2 (model development and validation) have indicated that a well-designed ORC cycle could increase net power output by at least 40%. The challenge is to do so in a cost-effective manner as the ultimate goal would be to decrease the LCOE. We have run models for thermal performance and cost of the system and components and believe this is possible. As detailed in responses to other sections of this document, we have incorporated several metrics and criteria for both the optimal working fluid choice and cycle concept. We are not just examining power levels as the objective of this program is to identify a cycle design (including components) and working fluid concept that maximizes kW/gpm of resource while maintaining $/kW and thermal efficiency of the system. The combination of these three metrics impacts LCOE positively and directly.

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

Response to Reviewer 34 - We are not just examining power levels - the objective of this program is to identify a cycle design (including components) and working fluid concept that maximizes kW/gpm of resource will maintaining $/kW and thermal efficiency of the system. The combination of these three metrics impacts LCOE positively and directly. We are accounting for 1) optimal working fluid characteristics and properties (including ODP, GWP, toxicity, flammability, material compatibility, oil solubility, refrigerant availability and cost), 2) validity of thermodynamic and transport property data, and 3) component designs that allow us to take advantage of the characteristics of alternative working fluids in a cost-effective manner.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10202
Presentation Title: Working Fluids and their Effect on Geothermal Turbines
Investigator: Sabau, Adrian (Oak Ridge National Laboratory)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

The questions and answers are labeled with Reviewer ID .# and are preceded by Q and A, respectively, where # is the question number raised by each reviewer.

Reviewer 177:

Response to Reviewer 34 -As the composition for each of the two types of mixtures is varied, the work includes much more than two working fluids. Due to the funding limitation, the effect of the composition on working fluid performance could not have been quantified.

Response to Reviewer 7 - As stated on page 3 of the presentation, the project aims to ―identify new working fluids for binary geothermal plants" through property measurement and assessment of performance (efficiency, cost, safety).

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 2 - There is an ongoing reevaluation of the ―global warming potential - GWP" of SF_6. An extremely high GWP equivalent has been assigned to SF_6 as it is a very stable molecule. However, recent research shows that its life in the atmosphere is probably several times shorter than previously estimated. The other side of the inert nature of SF_6 is its lack of interaction with atmospheric ozone. The GWP value of a new working fluid containing SF_6 can be only evaluated by estimating the reduction in the CO_2 emissions brought by the improvement in efficiency of geothermal energy conversion versus the estimated rate of emission of SF_6 due to leaks in the equipment.

Response to Reviewer 34 - The separation problem is common to all nonazeotropic mixtures. Since the vapor has a different composition than the liquid from which it evaporates, any leaks of the vapor phase may result in the enrichment of the remaining mixture in the less volatile components. However, nonazeotropic mixtures are currently accepted and recommended by EPA as the only alternatives and substitutes for single-component refrigerants, which will be phased out as ozone-destructive. The reason for introduction of dozens of new blended refrigerants is that neither single-component nor azeotropic working fluids with the physicochemical properties needed to simultaneously fulfill the high efficiency, safety, and environmental requirements have not been identified.

The remedy to both problems, i.e., composition changes and greenhouse gas potential, is reduction of leakage in new installations. From the testing at ORNL (lab scale testing) and Sandia (loop testing), it was found that the leakage of SF_6 was negligible and thus did not point to any systemic problem of the CO_2-SF_6 mixtures.

The following information related to cost was included on slide 10 of the presentation: ―The wheels required for compression/expansion are very small, reducing capital investment and plant footprint. Less work input is required during the compression stage of a supercritical cycle, increasing its efficiency.‖ In addition, the data on the size of the heat exchangers is presented as they are one of the most expensive components of the plant..

Response to Reviewer 7 - The reviewer may have overlooked that the first slide is a snapshot of the project showing pictures of testing equipment from ORNL and testing loop at Sandia. Moreover, on slide 5 of the presentation, the text (from which a small excerpt is pasted here) speaks for itself as well as the experimental data on page 7, page 10, and supplemental page 19: ―Scientific research method: Measurement of densities and liquid-vapor phase boundaries, will be conducted using a unique, high-pressure, vibrating tube flow apparatus and novel methods (ORNL)."

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 21 - Once the efficiencies of the investigated mixtures are made public (through several papers being written, DOE geothermal data repository, and REFPROP database), there is a strong possibility that CO_2-SF_6 and/or CO_2-isobutane mixtures will be used in geothermal binary power plants.

Response to Reviewer 34 - The reviewer raises valid concerns about the role of contaminants, which was addressed in the original three-year project. The reviewer needs to be aware that the project was scaled back to two years, and hence, the scope of work had to be revised. Investigation of the role of contaminants was the portion removed, but we have proposed to study this in an extension to the project. Interestingly, a literature exists on the properties of CO_2-rich fluids and the changes in phase diagram arising from contamination related to CO_2-pipeline transport and sequestration. Toxicity is not our expertise and is not part of the scope of work of the project.

There is no evidence of separation in the testing of the SF_6+CO_2 mixture in a ―real" loop at Sandia, in the measurements of fundamental properties, or in the literature for the CO_2 mixtures (in our experiments CO_2-SF_6 and CO_2-isobutane). We do envision that monitoring of fluid composition needs to be part of the instrumentation of a binary-cycle loop, so that components can be ―titrated" in to optimize performance (not only over long periods of operation, but also to adjust for seasonal variations).

Response to Reviewer 7 - A similar question was raised by the same reviewer at the ―Relevance/Impact of Research" section. The project aims to ―identify new working fluids for binary geothermal plants" – page 3 of the presentation, through property measurement and assessment of performance (efficiency, cost, safety). Thus all the effort presented is on property and performance indicators. In addition, on page 10, a short discussion on turbines is also presented where a picture of a turbine wheel is shown: ―The wheels required for compression/expansion are very small, reducing capital investment and plant footprint. Less work input is required during the compression stage of a supercritical cycle, increasing its efficiency. ―

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response to Reviewer 34 - The USF work on refrigerant mixtures was initiated in order to have a wider portfolio for investigating new working fluids, i.e., in order not to limit the project to the SF_6+CO_2 and C_4H_{10}+CO_2 mixtures. The integration of the USF cycles was implemented by simulating the same binary cycles that were considered at ORNL.

Experimental testing into an actual loop was conducted at Sandia for SF_6+CO_2 and C_4H_{10}+CO_2 mixtures (slide 10 and slide 19). If promising, in future work, other refrigerant mixtures will be tested.

Rebuttal Comments for "Overall" - Power Conversion:

Response to Reviewer 21 - We disagree with the reviewer. As a matter of fact, a paper documenting the proposed method was submitted by the authors to the ASME 2011 Congress, ―Energy Systems Analysis, Thermodynamics, and Sustainability" (track), ―Design and Analysis of Energy Conversion systems" (topic) which was accepted with the following comments "In conclusion I consider the paper acceptable with the above minor modifications, since it provides a complete approach in the study of ORCs systems, from thermodynamic property measurements to thermodynamic cycle analysis, and provides promising results for a new mixture to be used as working fluid in ORCs.”

Response to Reviewer 34 - The following information related to cost, which was rightly noted by the reviewer from the statement that —CO_2 cycles tending to be quite small, and offer a potential cost savings” was included on slide 10 of the presentation: —The wheels required for compression/expansion are very small, reducing capital investment and plant footprint. Less work input is required during the compression stage of a supercritical cycle, increasing its efficiency. —In addition, the data on the size of the heat exchangers is presented as they are one of the most expensive components of the plant. Pending availability from suppliers, actual cost information will be added.

Response to Reviewer 7 A similar concern was raised by the same reviewer at the —Relevance/Impact of Research and Accomplishments, Results and Progress” sections. The project aims to —identify new working fluids for binary geothermal plants” – page 3 of the presentation, through property measurement and assessment of performance (efficiency, cost, safety).

Rebuttal Comments for "Strengths" - Power Conversion:

No Response Entered

Rebuttal Comments for "Weaknesses" - Power Conversion:

Response to Reviewer 34 - The reviewer is correct in that experimental validation of transport properties has not been done in these tests. This testing can be accomplished using dynamic light scattering for a single-phase fluid, or from surface light scattering for a vapor-liquid interface. This is a separate project unto itself, well worthwhile, but outside our scope of work.

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10203
Presentation Title: Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems
Investigator: McGrail, Peter (Pacific Northwest National Laboratory)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to Reviewer 34 – Reviewer suggests that this novel concept may result in unanticipated problems. We concur, but that is why we hope to pursue a step-wise R&D strategy to investigate performance of these nanofluids in a variety of contexts from simple capillary tubes to eventually a complete ORC system, including mini-turbine. Pending successful outcome from these tests, we already have interest from ORC equipment providers (such as ORMAT) to test in a commercial system.

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 21 – Reviewer makes several assertions (without supporting evidence) regarding possible performance issues with nanoparticles. Our first experiments, presented at the review and a couple of published papers, counter these assertions. These papers include:

- Bi, S.-s., L. Shi, and L.-l. Zhang. (2008). "Application of Nanoparticles in Domestic Refrigerators." *Appl. Therm. Eng.* **28**(14-15):1834-1843.
- Canter, N. (2008). "Improving Refrigeration with Nanoparticles." *Tribol. Lubr. Technol.* **64**(11):14-15.

Bi in particular conducted extended performance tests through a full VLC cycle and reported the performance improvements. Our experiments and the results cited in these papers clearly demonstrate that plating, fouling, and nanoparticle losses are not intractable issues but do require further investigation in actual ORC systems.

Response to Reviewer 34 -We concur with Reviewer 34 that a cost/benefit analysis is needed. However, this was explicitly planned in the original project to occur in the 3rd year when sufficient information was available to perform a credible analysis. Discussions are underway with the GTP program on a funding mechanism to initiate this planned work. The 30% figure comes from an analysis of how much additional heat could be produced per kg of CO_2 for a geothermal project using CO_2 as a working fluid. It was provided only as an example of heat transfer impacts that are theoretically possible with the MOHC concept. We are not in a position to calculate LCOE impacts for this application of MOHC nanofluids - this research has been proposed as part of work with GreenFire Energy, but is not funded at this time.

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response - The PM made the decision, when the ARRA programmatic redirection was announced, to maintain R&D efforts directed at nanofluid development and performance testing, leaving cost/benefit analysis to hopefully be performed with follow-on funding. This decision resulted in accomplishing all the project technical goals planned for the first two years and significantly more. Based on the significance of the technical findings, this PM believes he made the right decision on resource allocation.

Rebuttal Comments for "Overall" - Power Conversion:

Response -As stated previously, the PM disagrees that limited resources should have been spent on cost/benefit analysis as there was insufficient technical information available concerning MOHC nanofluids to support such an analysis. However, the GTP program management and I concur on the need, now that critical data is available and have identified a funding path forward, to complete the analysis early in FY12.

Rebuttal Comments for "Strengths" - Power Conversion:

No Response Entered

Rebuttal Comments for "Weaknesses" - Power Conversion:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10204
Presentation Title: Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy
Investigator: Jody, Bassam (Argonne National Laboratory)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to Reviewer 34 - We agree with the comment from reviewer #34 that this project examines a high risk, high payback novel approach and an "important area of research".

Response to Reviewer 7 -We also agree with reviewer #7 that the use of an alternate energy carrier to bring the geothermal energy could "revolutionize the geothermal industry."

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 34 - We agree with # 34 that aspects beyond available energy should be used in evaluating the prospects of these fluids, and that other aspects such as costs, toxicity, corrosion, chemical stability, etc. should also be considered. We are presently addressing the cost and chemical stability issues. We also agree with the reviewer that ―injection of chemicals underground will not be a concept that the public will embrace." We stated in the presentation that we conceived designs which will recover the geothermal heat without the working fluid coming in contact with the ground. We could not describe some of these concepts in enough details because they are considered proprietary. Since the review, we have been developing the designs for closed systems where the fluids will not come in contact with the underground or above ground surfaces and started to evaluate their economics.

Response to Reviewer 7 - We agree with reviewer # 7 that other issues need to be addressed. We are considering routes to avoid them with engineering designs, or adding criteria that include impacts of carrier interactions.

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 34 - We agree with reviewer # 34 who suggested matters beyond the available energy should be used when evaluating working fluids. We agree, we used exergy rate gain as a criterion and not specific (per unit mass basis) thermodynamic properties. We also identified other criteria that should be used. Presently we are evaluating the economics of selected working fluids to determine their impacts on the LCOE. We also developed and are evaluating designs that will recover the geothermal energy without having the working fluid come in contact with the ground.

Response to Reviewer 7 -We agree with review #7 that potential carriers have been identified.

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response to Reviewer 34 - We agree with reviewer # 34 that the project is well coordinated and it is obtaining interesting result.

Response to Reviewer 7 -We agree with reviewer # 7 that satisfactory progress is being made.

Rebuttal Comments for "Overall" - Power Conversion:

Response to Reviewer 21 - We agree with reviewer # 21 that although the project is in a very eary stage "it presents a basic advantage of transferring heat at constant temperature with reduced flow", and it is "very important for EGS".

Response to Reviewer 34 - We agree with reviewer # 34 that "the concept may result in a better LCOE". We are presently evaluating the economics.

Response to Reviewer 7 -We agree with reviewer #7 that "this research could lead to radical changes in how a lot of things are done". We also agree with his recommendation that –the current research continues to identify and test potential carriers", and that the chemically reacting carriers will bring issues of their own that will require solution.

Rebuttal Comments for "Strengths" - Power Conversion:

Response to Reviewer 34 - We agree with reviewer # 34 that "this study essentially introduces another free parameter available to the system designer. If we can extract energy via thermal and chemical means, the design space becomes larger and the optimal point is likely outside the space with no chemical extraction. I liked the presentation very much where they indicated that the optimal solution is dependent upon the actual site. For example deeper wells will drive the design to different optimal points."

Response to Reviewer 7 - We agree with reviewer # 7 that –this is a new way of developing a resource".

Rebuttal Comments for "Weaknesses" - Power Conversion:

Response to Reviewer #34 – Reviewer stated that " The concept is in its initial phase, however, some discussion still should have been provided addressing the potential drawbacks to this program: 1. Cost of loss of working fluids, 2. Contamination of working fluids, 3. Corrosion problems, 4. Pollution, etc." We are presently addressing many of these issues by developing closed system designs that will allow for careful control of the working fluids and their reactions and interactions. This wasn't part of the work covered in the 2011 review period.

Response to Reviewer 7 -We agree with reviewer #7 "A success in the carrier will likely come with issues that must be resolved. The research underway will likely not identify all the issues." Experimental testing is necessary to allow identification of issues that may not be obvious from the theoretical analysis. It was in the plan for the third year to conduct the testing. We will pursue funding to address this need.

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

Response to Reviewer 34 -Reviewer # 34 stated that —the presentation could have been more balanced if potential problems were identified that make this concept less attractive". In the presentation, we stated the issues that need to be evaluated including cost and environmental impact. We are presently evaluating engineering design that could make these working fluids cost effective and address environmental impact issues. We identified many of the drawbacks and stated that we are addressing them through improved closed system designs. Addressing all of the issues was beyond the phase I work scope.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10206
Presentation Title: Optimization of hybrid-water/air-cooled condenser in an enhanced turbine geothermal ORC system
Investigator: Wu, Hailing (United Technologies Research Center)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to Reviewer 34 - We agree that the LCOE is the most important parameter in determination of the success of a geothermal project. However, geothermal cycle efficiency is a key parameter in optimizing LCOE - it determines the first cost of the system (higher efficiency requires smaller heat exchangers per kW produced) as well as the operational cost (higher cycle efficiency means less heat rejection per kW produced which leads to lower parasitic power requirements). The reviewer is correct in stating that this efficiency should not be gained at the expense of under-utilizing the geothermal resource; that is, sending it back into the ground at a higher temperature. Good system design accounts for this tradeoff.

Response to Reviewer 7 - We do not agree that ―this work has been done… the mission here has already been achieved." Prior research regarding the use of evaporative cooling to boost geothermal power plant summer performance (e.g. Kutscher and Costenaro, 2002) focused primarily on experimental assessments of different methods (including wetted-media systems, spray systems or deluge systems). The cooling approach in the current project is different than this prior work. Our approach uses fine mist for both evaporative precooling of the air and mist deluge cooling at the condenser surface (the latter means the condenser surface is wetted and cooled by the remainder of the fine mist in the incoming pre-cooled air). Based on a search of the literature, very little work has been done to understand the fundamental heat and mass transfer involved in this approach or to model an evaporative cooled wet condenser under various wetness situations so that the water consumption and heat transfer performance can be predicted.
Our modeling capability enables simulation of both the mist evaporative pre-cooling of the air and the evaporative cooling of a partially or fully wet condenser. This effort is new to the community and will contribute to the understanding of the physics and help design an efficient hybrid-cooled condenser. The knowledge could also be applied to evaporative cooled HVAC chiller systems.
C. Kutscher, D. Costenaro, (2002), Assessment of evaporative cooling enhancement methods for air-cooled geothermal power plants, Geothermal Resources Council Annual Meeting, Reno, Nevada.

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 34 - We agree with your summary – this project includes analytical models validated by experimental data.

Response to Reviewer 7 -We do not agree that ―this work has been done… the mission here has already been achieved." Prior research regarding the use of evaporative cooling to boost geothermal power plant summer performance (e.g. Kutscher and Costenaro, 2002) focused primarily on experimental assessments of different methods (including wetted-media systems, spray systems or deluge systems). The cooling approach in the current project is different than this prior work. Our approach uses fine mist for both evaporative precooling of the air and mist deluge cooling at the condenser surface (the latter means the condenser surface is wetted and cooled by the remainder of the fine mist in the incoming pre-cooled air). Based on a search of the literature, very little work has been done to understand the fundamental heat and mass transfer involved in this approach or to model an evaporative cooled wet condenser under various wetness situations so that the water consumption and heat transfer performance can be predicted.

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C. Kutscher, D. Costenaro, (2002), Assessment of evaporative cooling enhancement methods for air-cooled geothermal power plants, Geothermal Resources Council Annual Meeting, Reno, Nevada.

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewers 21, 34 - Our approach is to use a low-cost radial in-flow turbine with a baseline efficiency of about 83% rather than an expensive multi-stage axial turbine. The efficiency of the baseline turbine will be enhanced by optimizing the aerodynamics of the rotor and by adding a diffuser. Variable nozzles will also be added. However, the nozzles are not used to increase the turbine isentropic efficiency. The primary purpose of the nozzles is to enable the power output to be maintained at the gross power limit when conditions change, even if that means a drop in isentropic efficiency. As ambient temperature goes up, the nozzle area will be increased to allow more flow and hence increase the power output.

No technical results were presented at this review because the session was public and the results available from the project thus far are proprietary. We do plan to publish results from the turbine tests and application of the models. The deliverables from this project are: a validated hybrid-cooled condenser model; an enhanced turbine design and its performance demonstration; an optimum design of PureCycle® Power ORC system and a feasibility analysis of geothermal-driven membrane distillation-based pure water supply. These will provide value to the community in terms of improving the ORC system design/operation by predictive capability of wet condenser performance and water consumption, improvement of turbine design and operation optimization, as well as knowledge gained regarding feasibility of water supply based on membrane distillation in a geothermal ORC system.

We would recommend for future peer reviews that the DOE consider having closed sessions with the reviewers in addition to the public sessions so that proprietary data could be presented for evaluation. The closed session could be done at the request of the PI as some projects may have no proprietary data..

Response to Reviewer 7 - We agree with the comment.

Rebuttal Comments for Project Management/Coordination - Power Conversion:

Response to Reviewer 34, 7- We agree with the comments.

Rebuttal Comments for "Overall" - Power Conversion:.

Response to Reviewer 34 -No technical results were presented at this review because the session was public and the results available from the project thus far are proprietary. We do plan to publish results from the turbine tests and application of the models. The deliverables from this project are: a validated hybrid-cooled condenser model; an enhanced turbine design and its performance demonstration; an optimum design of PureCycle® Power ORC system and a feasibility analysis of geothermal-driven membrane distillation-based pure water supply. These will provide value to the community in terms of improving the ORC system design/operation by predictive capability of wet condenser performance and water consumption, higher efficiency turbine design and operation optimization, as well as knowledge regarding feasibility of water supply based on membrane distillation in a geothermal ORC system.

We would recommend for future peer reviews that the DOE consider having closed sessions with the reviewers in addition to the public sessions so that proprietary data could be presented for evaluation. The closed session could be done at the request of the PI as some projects may have no proprietary data.

Response to Reviewer 7 - We do not agree that ―this work has been done… the mission here has already been achieved.” Prior research regarding the use of evaporative cooling to boost geothermal power plant summer performance (e.g. Kutscher and Costenaro, 2002) focused primarily on experimental assessments of different methods (including wetted-media systems, spray systems or deluge systems). The cooling approach in the current project is different than this prior work. Our approach uses fine mist for both evaporative precooling of the air and mist deluge cooling at the condenser surface (the latter means the condenser surface is wetted and cooled by the remainder of the fine mist in the incoming pre-cooled air). Based on a search of the literature, very little work has been done to understand the fundamental heat and mass transfer involved in this approach or to model an evaporative cooled wet condenser under various wetness situations so that the water consumption and heat transfer performance can be predicted.

Our modeling capability enables simulation of both the mist evaporative pre-cooling of the air and the evaporative cooling of a partially or fully wet condenser. This effort is new to the community and will contribute to the understanding of the physics and help design an efficient hybrid-cooled condenser. The knowledge could also be applied to evaporative cooled HVAC chiller systems.

C. Kutscher, D. Costenaro, (2002), Assessment of evaporative cooling enhancement methods for air-cooled geothermal power plants, Geothermal Resources Council Annual Meeting, Reno, Nevada.

Rebuttal Comments for "Strengths" - Power Conversion:

Response to Reviewer 34 -We agree that water purification is important to address clogging, scaling, reduced heat transfer, corrosion and durability. However, the scope of this project task was limited to a technical feasibility assessment of a novel water purification technique. That feasibility assessment was completed and showed that the liquid-gap-membrane-distillation (LGMD) technology is directly applicable to the ORC system design for distilled water production. A recommended architecture was developed for the geothermal-driven LGMD-based pure water supply. Further development of the membrane-based water purification will be the subject of a future project.

Response to Reviewer 7 - We do not agree that the project should be redirected. The deliverables of this project will benefit the community, e.g. the modeling tools for evaporative cooled condensers is physics-based allowing better understanding of the heat and mass transfer process in a wet condenser. It will enable the prediction of the wet condenser performance at various wetness situations, which is important when water consumption is of concern.

Rebuttal Comments for "Weaknesses" - Power Conversion:

Response to Reviewer 34 -We agree that for geothermal systems the system design should optimize output power and not cycle efficiency. Maximizing output power is the goal of this project. This is what the variable nozzles are designed for – to widen the range of operation over which the maximum power output is available.

Cycle efficiency is an important parameter in optimizing LCOE. It determines the first cost of the system as well as the operational cost. Systems with higher efficiency require smaller heat exchangers per kW produced, or conversely may produce more kW per geothermal resource available. Higher turbine isentropic efficiency results in higher cycle efficiency which leads to less heat transfer per kW produced. The new turbine design consists of several features that increase efficiency (improved diffuser, improved nozzle efficiency and improved aero design for lower pressure ratios).

The variable inlet nozzle feature is used to optimize the net site power output, not to improve turbine isentropic efficiency. The figure (sent to the reviewer by e-mail because it is not yet available for public release) shows how the nozzles are adjusted to maintain the power output at various operating conditions. Turbine efficiency and power are plotted as a function of pressure ratio and nozzle vane angle. Assume the unit is designed to run at the circle on the right, with the nozzles positioned at an angle a_1 (red lines, which is most closed). As the pressure ratio decreases (this happens due to increasing ambient temperature), the power drops following the red line. To bring the power back, the nozzle will be adjusted to another angle a_2 (blue lines). The power and isentropic turbine efficiency remain roughly constant in this example. However, the cycle efficiency will decrease due to the lower pressure ratio.

—’ả is the angle of the vane position, which represents the open area of the nozzles

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

Response to Reviewer 34 -We agree that the LCOE is the most important parameter in determination of the success of a geothermal project. Unfortunately we have limited data regarding the cost associated with exploration and drilling, which are significant portions of the overall cost. However, geothermal cycle efficiency is a key parameter in optimizing LCOE - it determines the first cost of the system (higher efficiency requires smaller heat exchangers per kW produced) as well as the operational cost (higher cycle efficiency means less heat rejection per kW produced which leads to lower parasitic power requirements). The reviewer is correct in stating that this efficiency should not be gained at the expense of under-utilizing the geothermal resource; that is, sending it back into the ground at a higher temperature. Good system design accounts for this tradeoff.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10207
Presentation Title: Hybrid and Advanced Air Cooling
Investigator: Bharathan, Desikan (National Renewable Energy Laboratory)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

Response to reviewer 34: This is correct, but we do not see this as a critical issue. The technology is applicable anywhere there is limited water, which is surely the case in many areas where wet cooling isn‘t practical but some water can be obtained. As an extreme example, the use of brine to distill usable water is an approach that can be taken, though we have not evaluated the economics of such an approach.

Response to Reviewer 7 - We agree that many investigations have been done in the past in this area. We reference those investigations in the background section of our progress report submitted to DOE. Despite the various investigations, there are no operating geothermal power plants that use hybrid cooling on a permanent basis.

Two major conclusions can be drawn from these observations, namely,

1) Hybrid cooling captures the interest of the industry to find solutions to potentially improve the performance of the plants and their economics.

2) None of the prior work has addressed all potential concerns related to implementation of such a system on a permanent basis at any power plant.

Our study will change this predicament and arrive at ―best practices” for implementing hybrid cooling. The results of the effort will provide a more specific identification of the engineering issues related to hybrid cooling, identification of specific barriers, and best practices for use in both retrofit and new construction.

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

Response to Reviewer 34 - Designing cost-effective, low-maintenance modifications to the air cooled equipment is the subject of this work. We will be analyzing the air-flow patterns, using CFD, around the air-cooled equipment to assure pre-cooled air is used effectively.

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

Response to Reviewer 34 - Work is continuing to conduct Phase II tests (upon a go/no-go decision from DOE) and Phase III results.

Rebuttal Comments for Project Management/Coordination - Power Conversion:.

Response to Reviewer 34 - We plan to test installation at RMOTC. The power plant has a capacity of 250 kW and is suitable for the planned tests. The installation will be adequate for the purposes of testing most-effective water use at a small geothermal plant. The costs for acquiring, installing and testing have been taken into account in the financial plans.

There are adequate funds for the planned tests. Our plan to conduct tests this summer is ahead of schedule based on the original plan. Should we miss this window, we can still follow the original plans and conduct tests during the hottest periods of CY 2012.

Response to Reviewer 7 – Reviewer identifies the best use of an existing facility owned by DOE.

Rebuttal Comments for "Overall" - Power Conversion:

Response to Reviewer 21 – Reviewer identifies the effort as important for future work.

Response to Reviewer 34: We are working to see that selected options for hybrid cooling can be used as ―on-demand” basis. The work will certainly offer unique systems that have the potential to be less costly.

Response to Reviewer 7: We are pursuing practical solutions that can be implemented on a permanent basis for geothermal power plants. We believe that our design addresses many of the barriers that have kept hybrid cooling from being commercially applied in the geothermal industry.

Rebuttal Comments for "Strengths" - Power Conversion:

Response to Reviewer 34 -Yes, designs will be carefully chosen to fit within the allotted resources.

Rebuttal Comments for "Weaknesses" - Power Conversion:

Response to Reviewer 34 - The present study focuses on using limited amount of water for hybrid cooling. Other options such as absorption coolers are not within the scope of this work. Water quality is important. Measures to clean the water for use with cooling equipment are necessary. Costs are being looked at for both initial costs and operating costs.

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

Response to Reviewer 34 -Solutions to the problem are site specific. Each plant site must be evaluated on the local weather and wind patterns as well. Pre-cooling is not appropriate for humid conditions. Local wind patterns affect the air flow and will have to be investigated using CFD for the prevalent conditions. Further progress in these areas will provide industry more guidance in selecting suitable approaches to hybrid cooling.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10208
Presentation Title: Air-Cooled Condensers in Next-Generation Conversion Systems
Investigator: Mines, Greg (Idaho National Laboratory)
Panel: Rebuttal - Power Conversion Technology
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Power Conversion:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Power Conversion:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Power Conversion:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Power Conversion:

No Response Entered

Rebuttal Comments for "Overall" - Power Conversion:

Response:

- The 1st part of this project was performed in order to be compliant with the stated objectives of the FOA. We did not look at any new technologies, but we did (per the FOA) look at the effects of designing plants for different ambient conditions and trying to establish designs that would increase output during periods when it is hotter. With existing technologies only small improvements can be achieved, unless one is comparing performance to a cycle that is not optimized either for power production or minimal project capital cost. While the technologies that were examined are commercially available, I am aware of no published work that has looked at the effect of both varying ambient and geothermal fluid temperature for cycles with these commercial concepts incorporated. In addition, I am not aware of any published work that looked at the impact of designing a turbine for ambient conditions other than those for which the plant is designed. This work looked at all of these scenarios.
- The existing or near-term technology that can significantly improve the performance of air-cooled binary plants is the use of mixed fluids. Numerous prior studies have looked at the benefits of mixtures. One can obtain similar benefits whether one uses mixed hydrocarbons or mixtures of the engineered refrigerants – it is a matter of getting the right fluid combinations and composition. Vaporizing mixtures in subcritical (boiling) cycles will be a problem, which can be resolved by going to supercritical cycles. Once one goes to these cycles, the advantages

from mixtures for heat addition is negated – they provide no, or minimal performance advantage relative to pure fluids. Supercritical cycles have been widely study and investigated, and used in operating plants and experiments – they work. Unfortunately there is no similar concept or configuration that can allow pure fluids to provide the same performance advantage as is derived during the ideal heat rejection process of mixed working fluids. Again, there has been prior work that showed the ideal heat rejection process of mixed working fluids can be approached with water cooled condensers. For EGS resources, the issue is whether this can be achieved with air-cooled condensers. That is the focus of the current work. Based on prior testing with the water-cooled condenser, we believe that it will be possible to achieve the integral condensation that is critical to the performance benefit when using condensers with tubes that are nearly horizontal. The remaining issue is whether an air-cooled condenser can approach a counter-current flow path. We know that the designs typically used (1 or 2 passes) will not approach this flow path. However with multiple passes, the ideal flow configuration can be approached. This can be integrated into current condenser designs, but the issue is whether it is cost effective – multiple passes will increase cost, and more importantly the pressure drops on both the tube and air-side of the condenser, i.e., more fan power and a higher turbine exhaust pressure (less turbine output). The effect of the pressure drops can be mitigated by the design of the condenser, but this mitigation will involve increasing condenser cost. This cost tradeoff is further complicated by the effect of changing sizes on fluid velocities and heat transfer coefficients. This task is looking at all of these issues and is trying to identify whether it is economically feasible to use existing air-cooled condenser design configurations with these fluids. We are under no illusions that this is going to provide any significant cost benefit – it may or it may not.

- We are not aware of anyone who has examined the effect of mixtures in air-cooled condensers. This may be because of the issues that have been alluded to, however it is a question that must be resolved or it will arise again.

Rebuttal Comments for "Strengths" - Power Conversion:

No Response Entered

Rebuttal Comments for "Weaknesses" - Power Conversion:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Power Conversion:

No Response Entered

Reservoir Exploration, Characterization and Modeling

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10900
Presentation Title: Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling
Investigator: Newman, Gregory (Lawrence Berkeley National Laboratory)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response to Reviewer 40 - Our approach needs to be tested. We are now in the process of testing and validating it at the Raft River EGS site.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response to Reviewer 40 -We recognize that resolution could be a problem, especially if a lack of seismicity persists. Times lapse Controlled Source Electromagnetics (CSEM) and Magnetotellurics (MT) measurements can help out here and we are working hard on the data to get the maximum amount of information to address the resolution issue.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response - The lack of seismicity is a concern at Raft River, but it is expected to pick up once EGS stimulation commences.

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response -Original site to conduct the time lapse EGS experiment was at Desert Peak. All out survey design experiments were based upon this site. Because of a lack of seismicity, we were forced to identify another site to conduct our measurements. Raft River was the only viable site that could be identified and so the decision was made to move the experiment there.

Rebuttal Comments for "Overall" - Reservoir:

No Response Entered

Rebuttal Comments for "Strengths" - Reservoir:

No Response Entered

Rebuttal Comments for "Weaknesses" - Reservoir:

Response - Baseline datasets have already been acquired and analysis is proceeding as planned. A second set of measurements will be made after stimulation in FY12. It is realized that desired model resolution may be difficult to obtain at the desired level. However, we have to work the time lapse data and EGS registered microearthquake (MEQ) events to ascertain the ultimate model resolution we can obtain in the field. There is significant value in carry out time-lapse experiments as they will provide important technical insights into making these measurements at other fields and the expected data precision that can be achieved. We are not aware of any other time-lapse measurements in the Geothermal Technologies Program portfolio, so it is important to complete them as planned at Raft River to gain important technical knowledge for future survey layout and planning.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response - We plan to focus on other sites as well in the future, but it is important to complete the time-lapse measurements and processing at Raft River first for reasons mentioned above.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10901
Presentation Title: Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-Dimensional Electrical Resistivity Structure
Investigator: Wannamaker, Phillip (University of Utah)

Rebuttal Comments for Relevance/Impact - Reservoir:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response to Reviewer 25 - This is an algorithmic issue, not a geothermal field issue. Need to compare, for example, algorithm accuracy and versatility to 2-D simulations or limited 3-D in the literature.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response - Agreed, it is likely that a no-cost extension request will be submitted.

Rebuttal Comments for "Overall" - Reservoir:

Response - Indeed this is intended to be a specific technology development project. Given the ill-posed nature of the problem, it is paramount that the tools brought must be top-rate.

Rebuttal Comments for "Strengths" - Reservoir:

No Response Entered

Rebuttal Comments for "Weaknesses" - Reservoir:

Response to Reviewer 19 -The Coso example using algorithm capability to date exemplified our integrative capability, where resistivity, temperature and seismicity were strongly corroborative and showed the unique added value of resistivity. Low-temperature clay cap and non-geothermal graben sediments were clearly identified.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response to Reviewer 40- Stronger prioritization now that principle PhD student arrived. However, regarding the other projects, prioritization to a large degree must reflect when project arrived.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10902
Presentation Title: Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes
Investigator: Faulds, James (University of Nevada, Reno)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response - Comments by reviewers were all positive, noting important relevance of our project for 1) improving site selection for both EGS and other hydrothermal systems, 2) development of better conceptual models, and 3) geothermal education.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response - Comments were positive but did raise some constructive questions.

Response to Reviewer 3- Reviewer commented on how some of the structural settings described seem to be similar. Major structural settings discussed include step-overs (or relay ramps), fault terminations, fault intersections, accommodation zones, displacement transfer zones between normal and strike-slip faults, and major range-front faults. There is indeed some overlap between some of the settings. For example, a broad accommodation zone, consisting of overlapping oppositely dipping normal faults, will naturally contain some step-overs (or relay ramps) along an individual fault. Also, relay ramps will contain some fault intersections between minor faults and the two major fault strands on either side of the step over. This is generally a question of scale—we view these settings at the scale of a geothermal field, which is generally on the order of 1-10 square kilometers. We evaluate the dominant structural setting at this scale, but also note that some systems contain more than one type of setting.

Response to Reviewer 40 – Reviewer commented that the structural setting for geothermal fields was expressed as a general percentage but not compared to or normalized to the percentage of the fault that contains that setting. This is a good point that we have considered and are currently evaluating by compiling appropriate data. This reviewer also asked whether GPS/strain data could be used: We are indeed incorporating such data for estimating regional stress orientations (e.g., extension directions) and type of dominant regional strain in a particular area (e.g., extension vs. dextral shear).

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response - Reviewers noted good progress and good results of ~~–c~~clear utility to explorers”.

Response to Reviewer 3 – Reviewer commented that spending is not in line with time. This was expected, because Phase II and III (years two and three) of this project are much more expensive than Phase I. Phase II and III involve the detailed work at representative sites, including intensive field work and analyses and subcontracts, whereas Phase I was the broad structural inventory, involving primarily reconnaissance and literature reviews. Also, some of the lower spending resulted from industry support of one graduate student on this project.

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response - Reviewers noted generally good management, good collaboration with industry, good integration with other Geothermal Technologies Program projects, and that key activities for the remainder of the project are very well specified.

Response to Reviewers 3, 25 - However, Reviewer 3 thought that the participation of the co-PI's could have been better managed, and Reviewer 25 noted that the project was a little behind schedule, particularly with respect to spending. As other reviewers noted, however, problems with the loss or reduced efforts of some co-PI's was addressed by including new researchers. Although minor delays did result from the loss of some of the co-PI's, these problems were addressed promptly and discussed with Geothermal Technologies Program managers for approval. In regards to the spending level, this was expected, as noted above, due to the lower cost of Phase I versus the more expensive detailed studies in Phases II and III. Also, some of the lower spending resulted from industry support for one graduate student on this project.

Rebuttal Comments for "Overall" - Reservoir:

Response -All general comments were very positive, noting the scientific and practical applications of this project to understanding geothermal systems, as well as the important educational component in training the next generation of geothermal scientists in modern techniques.

Rebuttal Comments for "Strengths" - Reservoir:

Response - Noted strengths included the simplicity, focus, and relevance of the project.

Rebuttal Comments for "Weaknesses" - Reservoir:

Response to Reviewer 19 - Reviewer noted that only a limited number of fields are being investigated in a given area. It is true that only ~six sites can be studied in detail in this project, but these sites are spread broadly across the Great Basin. As for the structural inventory, it is not true that a limited number of sites are being reviewed, as we are attempting to review all known 463 geothermal sites in the Great Basin to determine their general structural setting. As noted in our summary, however, many of these sites reside in the middle of large basins or simply consist of one warm well in the central part of a basin. These sites are difficult to evaluate. In contrast to this reviewer's comment, however, the catalogue should be comprehensive and complete.

Response to Reviewer 40 – Reviewer questioned why a geothermal class is part of a funded grant and was concerned that federal funds were covering time for the teaching. The class was included in this grant, because many individuals in industry and federal agencies have noted the need for training of the next generation in geothermal techniques. Further, the class was one way of quickly disseminating the results of this project and other related projects. The class exceeded capacity (20 graduate students). Federal funds covered only a very small fraction (~5% or less) of the preparation time but did cover some field expenses for field trips.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response to Reviewer 3- Reviewer commented on inclusion of extensive work from the oil and gas industry on structural settings. This work has been incorporated, where applicable, but some of the settings for geothermal systems differ significantly from those that host hydrocarbon deposits.

Response to Reviewer 19 - Reviewer suggested looking at a developed field as a green field and seeing if the suggestions based on the new catalogue turn out to be correct. We have done that in a few cases, and the results have been positive. We will continue to employ this test for other areas.

Respons to Reviewer 40 - Reviewer suggested calculating the expected percentage of geothermal settings along faults. As noted above, this work is in progress. This reviewer also suggested including GPS data, and we are doing that where applicable (again as noted above).

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10903
Presentation Title: Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation.
Investigator: Iovenitti, Joe (AltaRock Energy, Inc.)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response to Reviewer 19 -Like any data product, the favorability map needs to be assessed in light of the assumptions and postulations used to make it.

Response to Reviewer 5 Using waveforms recorded at 50km aperture arrays of 5km spaced instruments is a new approach in ambient noise processing with the scope of shear-wave seismic-velocity model estimation. This approach, applied for the first time in Dixie Valley, is well-suited for such a region of low seismicity, because it does not need seismic events. The seismic-velocity models and parameters such as attenuation are being investigated to determine among other things, if seismic data can infer temperature and rock type at depth.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response to Reviewer 3: The modeled data is certainly of concern. We are aware of this limitation but at the same time it is all we have to work with. As such, we are treating the modeled data as a subcomponent of Subject Matter Expertise. We are also aware that some parameters correlate due to the underlying physics or because they both increase with depth (e.g., temperature and vertical stress). We are evaluating such data to ensure that we minimize or eliminate such correlations. The geostatistics are not driving the parameters that will be used for the favorability map. The major parameters for the favorability map were pre-identified as stress, rock type, and temperature along with a number of minor parameters such as existing faults, distance to a permeable structure, and resistivity. The statistics are being used to determine if we can infer parameter values that may be used in the favorability map. For example, can we use seismic data to infer temperature or rock type? If such a correlation can be defined statistically, then the infer parameter value may be used in the development of the favorability map.

We also agree that soil gas is a point data and out of place in a regional analysis. However, in this case, we are collecting soil gas to test a hypothesis related to the structural intersection of the N-trending structures with the NE-trending structures whose result may provide insight to the new Magnetotellurics (MT) data being collected in the area. Finally, with respect to the ―other data (e.g., seismic, MT) being collected along traverses, this is not so. It is true that the existing MT data has been collected along traverses. This is the existing (or baseline) dataset and such data was not in our control -- it is essentially our ―given" data set in this project. For the enhanced analysis, we are collecting data throughout the project area with a focus on the calibration area (i.e., the Dixie Valley geothermal well field). Our objective in the ―enhanced" data collection task is to generate a comprehensive, high-resolution, integrated 3-D subsurface model based on the primary data and its resulting modeled data, inferred data, and statistical-inferred data. Under this condition, we believe, the data will be useful for the enhanced favorability map if we can establish sufficient correlation with other data sets (e.g., well data, gravity and magnetics model).

The Dixie Valley geothermal system provides the best dataset for a Basin and Range geothermal system in the public domain. The public domain dataset plus some minor additional data we have obtained from the field developer is the basis for our baseline work. We are using the existing (baseline) data set for the development of a baseline conceptual model that will be used to establish the baseline favorability map. New data is being collected (e.g., MT, seismic, and gravity) for the development of a higher resolution enhanced conceptual model and an enhanced favorability map. Comparison of these two maps will expectedly allow (1) more critical evaluation and refinement of the baseline conceptual model, (2) better determination as a result of higher resolution data, and (3) a critical assessment of the usefulness of additional data in developing a more robust correlation for EGS exploration.

Response to Reviewer 25 - The 5km x 5km area was chosen as a representative project area target size for an EGS development project. Our goal is to determine if we can identify such a region, and then within said region identify specific drilling targets. We fully expect that the data sets being collected and analyzed will not only allow the target area to be identified as a potential EGS development area but also allow identification of the potential drilling targets at a finer scale within the area of interest.

At the time of the required presentation submittal, the process by which a favorability map was not developed. As described in the response to other comments, we fully expect to have a baseline favorability map generated for the Annual Geothermal Resource Council meeting in October 2011.

Response to Reviewer 5 - The reviewer has captured the essence of our direction with the statistical work at this stage in the project.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response to Reviewer 3 - In my presentation, I did not report that no statistical correlations have been made yet. I reported on the analyses conducted and indicated that we are working on the significance of the geostatistical analysis--the Classification and Regression tree analysis indicating that temperature can be predicted for seismic, Magnetotellurics (MT), and gravity/magnetic models. I also reported that ―deciphering the significance of geostatistical correlations in geoscience terms” is one of the challenges we face in this project.

The datasets chosen for analysis were based on the available datasets within the project (e.g., geology, MT, gravity, magnetics) and these are the types of data most available in an exploration project. On data gathering for the enhanced analysis (see discussion above) is focused on improving data resolution and reducing dataset uncertainty. We are currently in the processing of developing the baseline favorability map from a dataset of varied resolution. We are planning to present the complete baseline assessment including the baseline favorability map at the Annual Geothermal Resource Council meeting in October 2011.

I firmly disagree with the reviewer that the project is moving ―…towards a traditional exploration mindset in data gathering rather than remaining focused on the development of a favorability map at a scale of 5km x 5km.” The project plan from the onset was to review the baseline data and develop a baseline favorability map, collect higher resolution (enhanced) geophysical and geological data and develop the enhanced favorability map. There is no drift. The only adjustment in the original proposal plan has been the collection of soil gas data in select areas. This adjustment came about through the discovery of the structural intersections (described above and in the presentation) which may be localizing hydrothermal cells and be responsible for the development of the hydrothermal reservoir currently being developed.

Response to Reviewer 19 The presentation given discussed the ―then” status at the time of presentation submission on the project's baseline work. It provided the qualitative geoscience correlations made including but not limited to the correlation of the shallow thermal anomalies along the range front fault bounding both sides of the Stillwater Range with the structural intersection of N-trending and NE-trending Basin and Range faults; and the type of geostatisctical analyses conducted and issues encountered in interpreting the geostatistical data in geoscience terms, the siginficance of the correlation of temperature with seismic, Magnetotellurics (MT), and gravity models via a Classification and Regression Tree analysis. Additionally, not discussed in the presentation was the fact that the seismic data compilation of baseline data determined that the resolution was low. The end product of this work is the baseline favorability map which I will be presented at the Annual Geothermal Resource Council meeting in October 2011.

Response to Reviewer 25 -It is true that I could have provided more supplemental information and for this I apologize. As mentioned above, all the baseline work and the baseline favorability map will be presented at the Annual Geothermal Resource Council Meeting in both an oral and poster presentation.

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response to Reviewer 3 -This global statement by the reviewer is not accepted. The project has been organized in six tasks defined in the presentation. If the Geothermal Technologies Program desires, we are open to explaining in detail the tasks to the reviewer along with what has been done, and what is being done, and what we expect to achieve.

Response to Reviewer 25 - The only dataset that we planned to have which may not be available to the project is the thermal modeling component. We are making all efforts possible to work with the university team member to have said data available. In the worst case, that such a model may not be available, its overall impact to the project is not considered severe, since we can infer thermal conditions based on known well data and standard data interpolation and extrapolation.

Rebuttal Comments for "Overall" - Reservoir:

Response to Reviewer 3 - The comment is incorrect in that the presentation did not specify the overall goal of the project, which was to develop a favorability map based on the three primary EGS parameters of interest: stress, rock type, and temperature at depths ranging from surface to 5km. The reasons why we are investigating the stated techniques were covered in detail in our proposal. We assumed in the structure of our presentation, the reviewer had access to the proposal and that the presentation was to be focused on the results not what we proposed. We disagree with the "random grab-bag" classification of techniques. Each technique being investigated is either part of the baseline (―given") dataset or has been carefully evaluated and chosen for the potential to offer information at depth the study area such as ambient seismic noise. The goal of the both the baseline and enhanced assessments is to develop geologic and geophysical parameters which could be related to temperature, stress, and rock composition. This is the first study we are aware of which relates seismic models to heat flow and other geophysical parameters to an unprecedented resolution. One important aspect of our project is that it evaluates the results from these techniques by robust geostatistical analysis, which is a novel approach. Additionally, the geostatistical analysis uses a number of carefully chosen and independent data sets.

Response to Reviewer 25 - The project resolution scale for the favorability maps and their relevance to drilling targets has been discussed above under comments to Reviewer 25 under Rebuttal Comments for "Strengths" - Reservoir:

Reviewer 19: The weakness of the project lies in its complexity from a statistics point of view to be able to reach to a favorability map that shows us something we don't all ready know.

Response to Reviewer 19 - This remains to be determined.

Rebuttal Comments for "Weaknesses" - Reservoir:

Response to Reviewer 19- This remains to be determined.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response to Reviewer 3 -This will be fully described in the report being prepared for the Go/No-go decision between ***Tasks 4 and 5.***

Response to Reviewer 19 - See discussion above under the response to Reviewer under Comments Regarding Scientific/Technical Approach.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10904
Presentation Title: Integrated Chemical Geothermometry System for Geothermal Exploration
Investigator: Spycher, Nicolas (Lawrence Berkeley National Laboratory)

Rebuttal Comments for Relevance/Impact - Reservoir:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response to Reviewer 3 -We are aware of the potential difficulty of non-uniqueness in the inversion work. This difficulty is inherent to any inversion work involving the estimation of a large number of parameters. For this reason, we plan to first test inversions on systems requiring a limited number of unknown parameters (besides temperature), such as fluid mixing fractions using the composition of endmembers known though other means. We will then progressively increase the number of unknowns and correspondingly increase the number of system constraints by increasing the number of water compositions simultaneously considered. Even if it is found that the problem becomes intractable/too non-unique for a large number of unknowns, the inversion method for simpler systems, and the application of the geothermometry code to single features without inversion (or with manual calibration) still represent a significant improvement over classical geothermometers.

Response to Reviewer *25* -Although we did not specifically state in the plan that we will compare the two, in retrospect this was an oversight, we planned all along to compare the two approaches. We have done this for the Dixie Valley well waters studied so far. For example, for well 73B-7 (Apr 98 analysis), we predict a temperature of 176 ±2 C, which compares well with the reported sampling temperature of 174 C. The temperatures calculated using classical geothermometers for this fluid spans a range from 179 C (Li thermometer) to 294 C (Mg/Li), and 256 C by Na-K-Ca-Mg (as reported in Goff et al. 2002 Los Alamos Report on Dixie Valley). For well 76-7 (Oct 96 analysis), we compute a temperature of 192 ±2 C with the original fluid, which is then optimized to 180 C (back-dilution for better clustering), which is somewhat higher than the reported sampling temperature of 163 C. Classical geothermometers as reported in Goff et al. yield temperatures between 178 C (Li) and 260 C (Mg/Li), and 248 C by Na-K-Ca-Mg.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response to Reviewer 25 -See our reply to reviewer no. 3 (Scientific/Technical Approach) regarding non-uniqueness. Regarding spring samples, we are starting with the evaluation of spring water compositions. We agree that the compositions of these samples are much more complex than well water compositions. We are progressing one step at a time, with well waters being the first logical step for testing the approach.

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response to Reviewer 5- The postdoctoral fellow will help with the evaluation of the large hydrochemical data set existing for Dixie Valley and identify regions with increasing complexity of well/spring fluid compositions, such that the geothermometry system can be tested on more and more complex chemistries. The postdoctoral fellow will also help with reactive transport modeling to create synthetic data sets to test the integrated geothermometer.

Rebuttal Comments for "Overall" - Reservoir:

Response to Reviewer 3: *See response under* ***Comments Regarding Scientific/Technical Approach***

Response to Reviewer 25:This project is still in its first year. We hope to have additional convincing results by next year.

Rebuttal Comments for "Strengths" - Reservoir:

No Response Entered

Rebuttal Comments for "Weaknesses" - Reservoir:

Response to Reviewer 19 -See response to Reviewer 3 under Comments Regarding Scientific/Technical Approach.
We are fully aware of this and have started evaluating various forms of objective functions.

Response to Reviewer 25 -This project was designed with spring waters in mind, so we are keenly aware of the need (and planning) to develop/test this methodology with surface waters.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response to Reviewer 3 -We plan on reporting on these topics as we progress with this project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10906
Presentation Title: Development of Advanced Thermal-Hydrological-Mechanical-Chemical (THMC) Modeling Capabilities for Enhanced Geothermal Systems
Investigator: Wu, Yu-Shu (Colorado School of Mines)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response to Reviewer 3- Thanks!

Response to Reviewer 35 - Agreed.

Response to Reviewer 19 -Agreed.

Response to Reviewer 25 - Agreed.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response to Reviewer 3- The formulation implemented assumes that reservoir rock behaves as poro-thermo-elastic material and rock deformation is under the small strain assumption. These assumptions should adequately capture mechanical behavior of most enhanced geothermal reservoir formations.

Existing natural fractures and hydraulic (discrete) fractures could be modeled in a dynamic manner where their aperture and hydraulic properties are functions of the stresses, coupled with multiphase flow and heat transfer. However, the simulator should work other type of heterogeneous reservoirs for geomechanical coupling. We will report more progress on modeling rock deformation processes in a future review/report.

Response to Reviewer 35 - The lab and field applications are planned for the last phase of the project as our model validation effort and will be reported later. Basically, we will use existing laboratory and field data and results from literature to test and demonstrate the usage of the simulator

We have implemented several correlations between hydraulic properties and stresses, which are from laboratory and field studies in the literature.

Response to Reviewer 19 - The content of the presentation was limited and more technical contents will be reported in quarterly and other technical reports.

Response to Reviewer 25 - Thanks!

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response to Reviewer 3 - Thanks!

Response to Reviewer 35 - Agreed.

Response to Reviewer 25 - Agreed.

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response to Reviewers 3, 35, 25 - Agreed.

Rebuttal Comments for "Overall" - Reservoir:

Response to Reviewer 3- Thank you for the comment, we will try to contact the PI's of other Geothermal Technologies Program-funded projects and compare simulation cases.

Response to Reviewer 35 - The software document has been prepared. We have a few experimental data sets for the relationships between hydraulic properties, e.g. permeability, and stresses because limited data are available. Our simulator is applicable for 2-D or 3-D multi-dimensional modeling.

Response to Reviewers 19, 25 - Agreed.

Rebuttal Comments for "Strengths" - Reservoir:

Response to Reviewer 3 - Agreed.

Rebuttal Comments for "Weaknesses" - Reservoir:

Response to Reviewer 19 - We agree with these insightful comments in general. Note that the coupled reservoir simulator is developed for forward simulation and modeling studies. To include a fully coupled thermal-hydrological-mechanical-chemical (THMC) processes, many model parameters and correlations are needed, which presents challenges for model application. To make it a little easier for users to apply the code, we will include the suggested ranges and defaulted values of input parameters derived from published data. However, these model parameters could be field specific for a given EGS reservoir.

It should be mentioned that the model formulation and numerical solution will guarantee a unique solution when converged for the forward simulation.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response to Reviewer 3- Agreed. As our model can apply to a wide range of application, example runs for various specific applications will be included into the software manual, as well as in the technical reports. In addition, model applicability will be identified.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10907
Presentation Title: THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity
Investigator: Elsworth, Derek (Pennsylvania State University)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response : THESE COMMENTS ARE AN INTEGRATED RESPONSE TO ALL COMMENT CATEGORIES - HOPEFULLY THIS IS MOST CONVENIENT

We appreciate the comments of the reviewers, and respond briefly to both the positive and negative comments, *paraphrased below in italics*. We concur with both the positives and negatives and respond to the negatives below.

The positives include: *(1) Attempts to model the real complexity of geothermal systems; (2) Approaches contain both discontinuum (short-term) and continuum (long-term) approaches and process scalings; (3) Coupling existing (numerical) models allows a focus on process-based analyses; (4) Team and project are well focused and significant progress is apparent to date; (5) Significant outreach focus of presentations and publications; (6) Integration of educational component is laudable.*

The negatives include: *(7) Needs for validation using field data*

We concur. We are linked with the AltaRock Newberry Volcano project but realize that these data may not be available in a timely manner. We plan to use Soultz and Basel data in the interim, especially related to microearthquakes (MEQs).

(8) Validation and process coupling linkages are not clear to reviewer

The code has been extensively validated on a process level. These linkages are available in *Taron, Elsworth and Min (2009)*.

http://www.ems.psu.edu/~elsworth/publications/journals/2009_j_ijrm_egs_josh_1.pdf

(9) Not clear how achievements relate to individual proposal tasks nor what the spend plan is

We didn‘t do a clear job of explaining this. But indeed we are on schedule, have taken an extra excursion with regard to MEQs and remain under budget.

(10) Linkages between other similar projects may be helpful to GTP.

Agreed.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

See above.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

See above.

Rebuttal Comments for Project Management/Coordination - Reservoir:

See above.

Rebuttal Comments for "Overall" - Reservoir:

See above.

Rebuttal Comments for "Strengths" - Reservoir:

See above.

Rebuttal Comments for "Weaknesses" - Reservoir:

See above.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

See above.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10908
Presentation Title: Modeling and Simulation of EGS Reservoir Thermal Performance
Investigator: Desilets, Darin (Sandia National Laboratories)

Rebuttal Comments for Relevance/Impact - Reservoir:

Response -The comments seem to suggest that EGS sustainability simulations are highly relevant. I would agree with those comments.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

Response - One reviewer mentioned potential problems with the fully-coupled modeling (FCM) approach that was thought to be an important component of our work. It is apparent that I was not clear in stating the role of FCM in this project. As much as anything else we are trying to evaluate the applicability to geothermal simulations of concepts and models (such as the FCM) that were developed for waste disposal simulations. We therefore agree with the criticisms of the FCM, which were in fact highlighted during our presentation, but disagree strongly that the success of the project in any way depends on the validity of the FCM. A valuable outcome would be to show why the FCM is appropriate or inappropriate for simulations of reservoir sustainability, since it already is being used by others. That is precisely the type of conclusion that our project would like to produce, and it appears that the reviewer does believe that this has value.

Furthermore, we would like to point out that in the AOP we do not promise to model complex fracture networks. The purpose of the project is to find such strategies given the obvious difficulties. The fact that "no clearly appropriate strategy to include and model complex fracture networks has been identified and adapted" may relate to the fact that the project was not even half way completed at the time of the review. At this point we are not even certain that modeling complex fracture networks is necessary, but hope to know by the end of the project. For the most part we will be modeling fairly simple fracture systems, so the no/no-go point recommended by the reviewer does not make sense for this project.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

Response - As stated during the presentation, the project was put on hold for approximately four months, and had just been restarted seven weeks prior to the peer review by a new PI. A slowdown in work was obviously one consequence of this disruption. It appears that the same criteria applying to projects that are well into their second year were also applied to a project that is four months underway. This is completely unfair. At this early stage constructive feedback would have been far more helpful than stating what is unavoidably true--that the project hasn't progressed very far!

Rebuttal Comments for Project Management/Coordination - Reservoir:

Response - Restarting a project after the original PI has departed abruptly and unexpectedly obviously presents some challenges, especially when the project is broadly aimed but involves multiple people doing specialized components of the work. The new PI was requested to present his work for peer review after leading the project for only one week! Expectations should be modified accordingly given that a more significant transition period than one week is obviously needed to restart a project that has been on hold for nearly four months. I realize that this situation is neither the fault of the peer reviewers nor the Geothermal Technologies Program, but obviously a different criteria for success needs to be applied given the circumstances.

Rebuttal Comments for "Overall" - Reservoir:

Response - In reply to "this project is disorganised, unclear and at significant risk at present" I would like to point out, again, that I was requested to report results from a project that has hardly begun. This may well have contributed to the unfortunate perceptions of the reviewer.

In reply to "I remain concerned that no suitable modelling strategy has yet been identified that mitigates the limitations already identified." see response to scientific/technical approach.

In response to: "At least one of the other modeling projects has developed code that is better suited than the options discussed in this project to tackling the thermal drawdown problem. Ceasing this project and perhaps focusing additional resources on others that are demonstrably better able to tackle the drawdown problem may be appropriate."

And related comments, I find it hard to imagine that the reviewer was in the room during the presentation or took time to read the AOP. I clearly stated that we are not developing code, and furthermore that new codes are not needed. I also stated (verbally and on my slides) that we would probably be using FEHM, and maybe TOUGH2- two industry standard codes. It is our belief that sufficiently capable codes already exist, so diverting resources toward yet more code development would be a mistake. The project is aimed at investigating reservoir potential and reservoir structures -- something that is critical to EGS development strategies and predictions, and is a challenge that no other Geothermal Technologies Program-funded project is confronting. No other project is tackling the same issues.

In reply to "The value of continuing the project should be checked since the driving force of the project, the original PI, is no longer on the team."

I clearly stated verbally and on his slides that "former PI Charles Hickox will be brought back on to the project." This has been complicated by rules at Sandia National Laboratory (SNL) regarding contracts to former employees, but to our this will go forward. Hickox's expertise in heat transfer problems will add great value to the project.

Rebuttal Comments for "Strengths" - Reservoir:

No Response Entered

Rebuttal Comments for "Weaknesses" - Reservoir:

Response - "I would like to see communication with other DoE-funded projects developing couple THMC simulators as other groups look to have more sound software strategies."

It is no minor point that the emphasis of the project is not on thermal-hydrological-mechnical-chemical (THMC), but just thermal-hydrological (TH). Appropriate simulation tools (e.g. FEHM and TOUGH) have been around for many years. Nonetheless, further communication with the PI using Multiflux might be beneficial and will be pursued. Some THMC work was alluded to in the AOP as something that would occur "time permitting", but it is unlikely that this will happen given the disruption to the schedule.

Regarding comments on the management, there will obviously be some difficulty in transitioning between PIs on any single PI project where the PI has to leave abruptly. Reviewers need to be reasonable. One reason that the transition appears to have been more difficult than it was is that the peer review occurred in the middle of it.

Regarding the comment:"The diversion (by parties unknown) of a portion of the project resources to an unrelated purpose involving evaluation of single-well downhole heat exchangers. While the latter effort may be worthwhile, it should be independently justified and provided with its own source of funds."

I should make a few points. First, and most importantly, the additional work was done at the request of our sponsors, as stated by Sandia National Laboratory (SNL) management during the talk. Second, it does not appear to have represented a diversion of significant resources. Third, while it is true that the counter-flow heat exchanger is not the type of system that was originally contemplated for modeling, the work does indeed relate to the sustainability of a particular type of EGS, and therefore is appropriate to this project.

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

Response - In reply to "The vision needs to be clear and what the group actually plans to do with the rest of the funds needs to be specified for deciding if to continue funding this project."

Our vision has always been clear but a workplan had not been formulated at the time of the review. We will simulate idealized reservoir structures at an REV scale using the code FEHM. Two experienced FEHM modelers at Sandia National Laboratory (SNL) have been assigned this task.

In reply to "DOE and/or Sandia should seriously consider putting this project on "hold" with a no-cost time extension until such time as the original PI is again available to lead the project."

Let me say that participation of the former PI is expected and will be highly valued. However, this is not the only option available. We have expended much effort to reassemble the team and regain momentum. Putting the project on hold a second time would be counterproductive at this point.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10909
Presentation Title: A New Analytic-Adaptive Model for EGS Assessment, Development and Management Support
Investigator: Danko, George (University of Nevada, Reno)

Rebuttal Comments for Relevance/Impact - Reservoir:

No Response Entered

Comments Regarding Relevance/Impact of Research

Response to Reviewer 3 - Thank you.

Response to Reviewer 35 -- Thank you. Our project has so far delivered a converging solution of a complex, coupled problem in which the fracture aperture changes with temperature and pressure, and is time-dependent. We have matched well documented field measurements and matched data better than previously published model results. Our results are shown in slide #11 and #13. Our model in MULTIFLUX matches better than TOUGH2 alone. However, MULTIFLUC uses TOUGH2 as an internal component for the rock mass, but not for the fracture. Matching can be clearly seen by visual observation of the trends in slides 11 and 13.

Response to Reviewer 25: Thank you.

Comments Regarding Relevance/Impact of Research

Response to Reviewer 3**:** Thank you.

Response to Reviewer 35 -Thank you. Our project has so far delivered a converging solution of a complex, coupled problem in which the fracture aperture changes with temperature and pressure and is time-dependent. We have matched well-documented field measurements and matched data better than previous published model results. Our results are shown in slides #11 and #13. Our model in MULTIFLUX matches better than TOUGH2 alone. However, MULTIFLUX used TOUGH2 as an internal component for the rock mass but not for the fracture. Matching can be clearly seen by visual observation of the trends in slides #11 and #13.

Response to Reviewer 25 - Thank you.

Rebuttal Comments for Scientific/Technical Approach - Reservoir:

No Response Entered

Comments Regarding Scientific/Technical Approach

Response to Reviewer 3 -The entire MULTIFLUX model structure with coupling of sub-model elements and verification-validation is prior work over 15 years and over $1M. It had not been applied prior to this project to variable aperture fracture networks, nor had elements for a penny-shape or lens-shape planar fracture or system of such planar fractures. Code coupling is now being done to fracture aperture variation due to temperature and pressure as well as chemical deposition/dissolution. This is how MULTIFLUX, which has the importing capabilities from external models, using the numerical transport code functionalization (NTCF) technique, now reaches a thermal-hydrological-mechanical-chemical (THMC) model level.

Response to Reviewer 35 -Thank you. I agree. The fit is indeed judged by a visual comparison in the presentation but we will qualify it by root-mean-square (RMS) deviation in publication.

Response to Reviewer 19 -Thank you. I agree. We will elaborate on the error in root-mean-square (RMS) form as well as on the sensitivities in the upcoming publication.

Response to Reviewer 25 - Thank you.

Rebuttal Comments for Accomplishments, Results and Progress - Reservoir:

No Response Entered

Comments Regarding Accomplishments, Results and Progress

Response to Reviewer 3 -Thank you. I agree. We have reported only this part in year 1, phase 1.

Response to Reviewer 35 -Thank you. I agree. We are a bit behind with publications for EGS due to a lack of time. However, we just published a journal paper of coupling TOUGH2 with a turbulent computation fluid dynamics (CFD) model in MULTIFLUX.

Response to Reviewer 19 -Thank you. I agree. We will focus on these issues in the upcoming publication.

Response to Reviewer 25 - Thank you.

Rebuttal Comments for Project Management/Coordination - Reservoir:

No Response Entered

Comments Regarding Project Management/Coordination

Response to Reviewer 3 - Thank you.

Response to Reviewer 35 - Thank you.

Response to Reviewer 19 - Thank you.

Response to Reviewer 25 - Thank you.

Rebuttal Comments for "Overall" - Reservoir:

No Response Entered

Overall

Response to Reviewer 3 -Thank you. Your comments are very helpful. The lack of volume and time allowed for the presentation were part of the problem. Model fitting to Fenton Hill, Phase 1 was made by hypothesis tests through basically trial and error. You are absolutely right, our modeling approach is unique and we hope it will be more efficient in applications. For example, we are preparing templates for planar or lens-shaped fractures, the EGS building blocks, and they can be configured via a graphical interface with a mouse click. We are already comparing results with TOUGH-based EGS models, so we know firsthand what TOUGH can do and with it cannot do relative to MULTIFLUX. Actually, we have been coupling computational fluid dynamics (CFD) with TOUGH and NUFT in MULTIFLUX for 15 years and clearly see the opportunities for the MULTIFLUX technique.

Response to Reviewer 35 - We have been documenting our models in detail in appendices to our quarterly reports to the Geothermal Technologies Program. We will publish our model configurations and results in journal papers, but couldn‘t show these details due to lack of time and volume for our presentation. The method is 3-D with a 2-D component in the near field rock mass around planar fractures. The far field rock mass is 3-D in which the heat transport parallel to the fracture plane is significant.

Response to Reviewer 19 - Thank you for the positive comment.

Response to Reviewer 25 - Please consider the following clarification. The single, planar (penny- or lens-shape) fracture us the basic building block of an EGS. This is geometry in Fenton Hill, Phase 1 – the first well-documented EGS in the world. This is what we reported as a successful benchmarking exercise for MULTIFLUX in our phase 1. Our model in the report has real fracture characteristics with two different assumptions – penny-shaped or lens-shaped. Each has variable aperture with fully-integrated time, temperature and pressure. In addition, our fracture within the plan grows in diameter from the initial 120m to 150m in one exercise – see slide #11. This is as real as it can get. We are the first to show such a complex model. Can another modeler second it without applying MULTIFLUX? We have yet to see it. The Geothermal Technologies Program can ask for it. It is important? I think it is. This is how EGS works – it changes not just the fracture aperture during creation but also during operation due to thermal contraction. We have just modeled it, our model worked and matched the data excellently – see slide #11.

We have been working on the Fenton Hill, Phase II geometry with some 10 different fracture planes, intersecting with each other – see slide #16. This model also has real fracture characteristics, variable aperture, changing with time, pressure, temperature – the whole coupled physics in it. Who will second this with a fully-coupled thermal-hydrological-mechanical-chemical (THMC) model besides our MULTIFLUX model? The Geothermal Technologies Program can ask another group of modelers to match it within time and budget but we know how difficult it would be since we use TOUGH 2, TOUGHREACT and 3DEC/FLAC3 as well.

Rebuttal Comments for "Strengths" - Reservoir:

No Response Entered

Comments Regarding Strengths

No Response Entered

Rebuttal Comments for "Weaknesses" - Reservoir:

No Response Entered

Comments Regarding Weaknesses

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Reservoir:

No Response Entered

Suggestions for Improvement

Response to Reviewer 19 -Thank you. We will add that analysis in our journal publication.

Seismicity and Reservoir Fracture Characterization

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10500
Presentation Title: Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems
Investigator: Toksoz, Nafi (Massachusetts Institute of Technology)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response -We agree with the reviewers‘ comments on the relevance/impact of the research.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response - All four reviewers pointed out the importance of fracture detection and characterization as part of the project, yet the results pertaining to fractures were not presented. The reason for the absence is that fracture detection and characterization will be accomplished using local earthquake data obtained from the dense seismic station network installed over the reservoir. Because of the unexpected delay in obtaining the permits to install the stations, and because of the weather conditions, the final network installation was delayed until late November, 2010. All stations are working well and data quality is excellent. So far more than 800 local events have been detected. The analysis of these events is underway and the data will be incorporated into tomography, fracture mapping and source mechanism of local earthquakes. Accomplishing these tasks is the top priority in our studies over the next two months. As we have developed the methodology and software for these tasks, we feel confident that these analyses will be done.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

Response - Most of the comments in this section are related to those raised in the previous section, i.e. scientific/technical approach. The primary reasons for not presenting fracture geometry, anisotropy and attenuation are because these will be determined from seismic data obtained by the local network installed over the site. Since the network installation was delayed, getting the data has been delayed as well. We expect the network will continue to operate through August, 2011. Data will be at hand to answer the relevant questions raised by the reviewers. We agree with the reviewers‘ suggestions that we evaluate the effects of uncertainties of some data on the inversion results. We will take this into account, at least in a simple way, by doing multiple inversions.

Rebuttal Comments for Project Management/Coordination - Seismicity:

Response - We agree with the majority of reviewers‘ suggestions. However, we take exception to the comments made by Reviewer #18. We will be happy to discuss this topic with the DOE program managers if they wish to do so.

Rebuttal Comments for "Overall" - Seismicity:

Response - We agree with the overall assessment made by the three reviewers. We disagree with the reasons that are given by Reviewer #18. The delay of the joint inversion is primarily due to the delay of the equipment installation and the delay of obtaining the needed local seismic data.

Rebuttal Comments for "Strengths" - Seismicity:

Response - The comments related to the strengths and weaknesses are discussed in our responses in the previous sections. Further discussion on this topic will be repetitious.

Rebuttal Comments for "Weaknesses" - Seismicity:

Response - The comments related to the strengths and weaknesses are discussed in our responses in the previous sections. Further discussion on this topic will be repetitious.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response - We agree with and appreciate the suggestions made by the reviewers. We are very much committed to completing this project using all available data, including the important seismic data being obtained by the local network. These data will continue to be collected until the end of August, 2011. In order to carry out the analysis thoroughly, including the new data may require more time than the two months remaining in this project. For these reason, we will ask for a no cost extension of this project. We are committed to completing the inversion and fracture characterization using all available data including the latest local seismic data.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10501
Presentation Title: Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir
Investigator: Fehler, Michael (Massachusetts Institute of Technology)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

No Response Entered

Comments Regarding Relevance/Impact of Research

Response to Reviewer 38 - Reviewer comment regarding benefit from a laboratory leg to reduce uncertainty: I guess that one could conceive of a laboratory component for this project but such a component would require a huge increase in scope of the project. I am actually not even sure how one would conduct a laboratory-scale experiment. Some lab experiments have been conducted to look at induced seismicity and flow. The big problem with these experiments has been one of scaling: how to conduct a laboratory experiment in a material that has a representative sample of features like permeability, variations in geology throughout a reservoir, and the presence of fractures. Without such features that represent real heterogeneities in real reservoirs, laboratory experiments have little application to field results.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

No Response Entered

Comments Regarding Scientific/Technical Approach

Response to Reviewer 37- Reviewer comment regarding coordinating with waveform modeling being done by others at MIT: I have already begun discussions with others at MIT about their collaboration in waveform modeling. We will begin this work soon.

Response to Reviewer 38 - Reviewer comment regarding well data and injection history: We have access to these data and are only now beginning to use them in our interpretation.

Response to Reviewer 18 – Reviewer comment regarding number and location of stations not being sufficient for the study: One NEVER has enough data for any study, correct? We have to learn to make do with what we have. The number of stations and the distribution of stations for the injections being monitored are as good if not better than those used for monitoring other injections. Our goal is not only to evaluate the link between seismicity and geomechanical models but to also show how to use such data and concepts to better understand a real EGS system. If we have a perfect dataset, it will not be a good case study for real application. The available dataset is exceptional.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

No Response Entered

Comments Regarding Accomplishments, Results and Progress

Response to Reviewer 37 – Reviewer comment regarding waveform studies: I feel I addressed this above. We are quite interested in the moment tensor studies. During a recent visit by the PI (Fehler) to Chevron to discuss the results to date, Chevron expressed the same interest. This is why we will put an increased effort into the waveform analysis.

Response to Reviewer 38 – Reviewer comment regarding assessment of FEHM: I think this will become more apparent as we begin to tie the seismic observations to the geomechanical modeling.

Response to Reviewer 38 - Reviewer comment regarding larger study area: Perhaps a wider study area would be useful. So far we have limited our work to one injection to keep the project focused. Going to a larger study area, which would be available with the current dataset, would be nice once we better understand the injection we proposed to study (AWI-18).

Response to Reviewer 18 – Reviewer comment regarding linking of seismic and reservoir modeling*:* This work is planned for the upcoming year. We are on schedule according to our initial project plan.

Rebuttal Comments for Project Management/Coordination - Seismicity:

No Response Entered

Comments Regarding Project Management/Coordination

Response to Reviewer 37 – Reviewer comment regarding interaction between two MIT projects: We are now at a stage where we will work together between the projects, particularly in the area of waveform modeling as has been previously mentioned.

Response to Reviewer 18 – Reviewer comment regarding project coordination and being behind schedule: This comment is quite unfair. We communicate regularly with Los Alamos. We are exactly where we intended to be according to our proposed project schedule. When we proposed the project, we anticipated a period of time for developing enhanced modeling capability and to become familiar with the seismic data.

Rebuttal Comments for "Overall" - Seismicity:

No Response Entered

Overall

Response to Reviewer 18 – Reviewer comment on project management being inadequate: This comment seems to be related to the view that the project is behind schedule and that the data are not up to the task that we proposed to perform. These issues have already been addressed above.

Rebuttal Comments for "Strengths" - Seismicity:

No Response Entered

Rebuttal Comments for "Weaknesses" - Seismicity:

No Repsonse Entered

Comments Regarding Weakness

Response to Reviewer 18 – Reviewer comment overall: These comments have been addressed above. We always have uncertainty in data and application of data to models. Our goal is to find ways to match data and models in ways that enhance their strengths to provide a model that has minimum uncertainty.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

No Response Entered

Suggestions for Improvement

Response to Reviewer 18 - These comments have been addressed above. We always have uncertainty in data and application of data to models. Our goal is to find ways to match data and models in ways that enhance their strengths to provide a model that has minimum uncertainty.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10503
Presentation Title: Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks
Investigator: Hardage, Bob (The University of Texas at Austin)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response - Reviewer comments here expressed concern but were not harsh criticisms. I am comfortable with what the reviewers say.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response - This is an observation by Reviewer 37 that questions the basic thesis of our research, so it merits a comment. The reviewer is correct that surface-wave noise can be removed from seismic data, but only IF that surface wave makes only one pass along a series of receiver stations. A single pass of a surface-wave is what geophysicists call ―organized noise", and such noise can be attenuated by appropriate velocity filtering of the data. However, the problem we are studying is one common to geothermal prospects where there are numerous surface-based and/or near-surface anomalies that cause surface waves to backscatter and make repeated passes across receiver stations. When surface waves make multiple passes across a series of receiver stations from different azimuth-approach directions and at different time delays, the resulting overlap of many surface waves is what geophysicists call ―unorganized noise". There are no known velocity filters that can remove dominating unorganized noise from seismic data. Sometimes a simple frequency-limiting filter can remove some low-frequency components of this unorganized noise and allow a bit of signal to emerge. Our objective is to acquire seismic data in a way that will allow the basic physics of surface-wave backscatter to be characterized and hopefully surface-wave noise to be better attenuated, so reflection signals from geothermal targets can emerge from the noise-dominated data.

Response - I agree totally with all of these comments, suggestions, and criticisms. We had SH data for only a month before the peer review so there was no time to do extensive SH data analysis. Our intent is to extract maximum information from the SH mode as the project goes forward.

Response - There is nothing ―geothermal" about the university test site. The site did not have to be geothermal in nature because it was used only to: (1) collect data that illustrated the relative quality of data generated by a suite of seismic sources, and (2) recorded by a variety of recording systems and sensors. The university test site is structured for exactly this type of equipment testing. It would have been far, far too costly to mobilize the large amount of test equipment we utilized to a geothermal site that would be acceptable to this reviewer (Reviewer #18).

The Big Bend site is almost a perfect geothermal site. It is true that there is no geothermal production in the Big Bend area, however, the heat flow gradient around Big Bend and the associated Texas Lineament is quite high, similar to that at geothermal prospects across Nevada. The geology consists of complex faulting, igneous rocks, numerous extrusions of volcanic rock, and an Earth surface varying from soft sediment cover to hard, high-velocity carbonates and basalts. The Big Bend test site we chose is an excellent proxy for many geothermal areas.

Response -_I disagree. I have been in O&G exploration for 45 years. This problem of imaging beneath surface-exposed high-velocity rocks is one of the unsolved problems in O&G exploration.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

Response - As explained in monthly telephone discussions with our DOE project manager, the start of the research was delayed four months as the University of Texas and DOE finalized our contract. In our soft-money environment, we are not allowed to work on a project until funding is in place. We had to wait until the contract was signed before we could charge time to the project and initiate work.

A second delay occurred after a few months because of the inordinately long time it took the university to approve a sole-source contractor to acquire our seismic research data. A sole-source contract was required because only one seismic contractor had the SH horizontal vibrators needed for our seismic data acquisition. The amount of sole-source paper work required for a State agency to approve a sole-source contract is unbelievable. As a result, we did not get the seismic data acquired until a month before the Peer Review program.

Rebuttal Comments for Project Management/Coordination - Seismicity:

Response - All reviewers seemed to be comfortable with the management and coordination of our research.

Rebuttal Comments for "Overall" - Seismicity:

Response to Reviewer 18 -_Reviewer is quite harsh in his/her rejection of the Big Bend test site as not being representative of geothermal geology. As stated above in the "Scientific/Technical Approach" section, the Big Bend test site represents a wide spectrum of geological conditions found at numerous geothermal fields. It would be difficult to find a better test site to develop seismic technologies for geothermal exploitation.

Rebuttal Comments for "Strengths" - Seismicity:

Response - I agree with all reviewer comments on this topic.

Rebuttal Comments for "Weaknesses" - Seismicity:

Response - The preceding rebuttals address criticisms mentioned here also.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response - I agree with all reviewer comments her. They are apparently peeking into our work plan without my knowledge

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10505
Presentation Title: Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments (GEYSERS)
Investigator: Ghassemi, Ahmad (Texas A&M University)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response - Lab tests are a key component of understanding rock behavior in response to pore pressure and stress. We do appreciate the issue of scale and field conditions in our efforts to understand mechanisms that contribute to MEQ. We are in an early phase of the work. As more tests are done and more data become available, we will provide more interpretations and analysis.

We plan to do wave form analysis with the aim of helping similar analyses in the field.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Seismicity:

No Response Entered

Rebuttal Comments for "Overall" - Seismicity:

No Response Entered

Rebuttal Comments for "Strengths" - Seismicity:

No Response Entered

Rebuttal Comments for "Weaknesses" - Seismicity:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response - We are planning to do MEQ monitoring during our "injection" tests and to record MEQ activity as a function of time. This is going to be the last phase of the work. In preparation for that we are developing test protocols and monitoring schemes. Details will be provided as they become available. At this stage, we are focusing on tests to measure rock parameters that are needed for other aspects of the work and hence the report focused on that.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10506
Presentation Title: Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions With Microearthquake Data for 3D Velocity Structure, Earthquake Locations, and Moment Tensors in Geothermal Reservoirs
Investigator: O'Connell, Daniel (Fugro Consultants, Inc.)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response to Reviewer 5 -The primary reason we are using L1 is its general insensitivity to outliers, which provides better delineation of multiple modes (picking biases) relative to L2.

Response to Reviewer 18 -We have begun working with Larry Hutchings and his group to provide them with the tools we develop to do testing with data from The Geysers to expand the scope of geothermal data and experts we directly work with during the project.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Seismicity:

No Response Entered

Rebuttal Comments for "Overall" - Seismicity:

No Response Entered

Rebuttal Comments for "Strengths" - Seismicity:

No Response Entered

Rebuttal Comments for "Weaknesses" - Seismicity:

Response to Reviewer 18 -While O‘Connell and Denlinger have extensive experience working at The Geysers (we both did our dissertation work there), we acknowledge that we need to actively work with a wider spectrum of geothermal experts with long-term ongoing geothermal experience. Toward that end we have begun collaborating with Larry Hutchings at the Lawrence Berkeley National Laboratory and Calpine to transfer and test our approaches with data from The Geysers and obtain feedback from a wider segment of the geothermal community.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response to Reviewer 18 -We agree that the operators of at least two geothermal areas should be involved in the interpretation of the data. We will be meeting with the Coso Operating Company division of Terra-Gen Power to coordinate our work at Coso with them and will be working with Calpine and Larry Hutchings at the Lawrence Berkeley National Laboratory to transfer and test our approaches with data from The Geysers.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10507
Presentation Title: Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems
Investigator: Gritto, Roland (Array Information Technology)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response to Reviewer 5 -The technology, once developed, can be used to assess seismic hazard associated with any reservoir operations including geothermal, CO_2 sequestration and oil and gas production. It is unlikely that reservoir operators will agree to use the technology if it is not required by state or federal regulators. Nevertheless, the technology, through its unique combination of methods, provides a means to assess temporal changes in the reservoir as well as delineate stress changes and hence pathways for fluids, which is of interest to reservoir operators. Therefore, our effort will develop technology that is applicable beyond the hazard aspect that is often associated with this project.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response to Reviewer 37 -Our moment tensor procedure does utilize low frequency waves whose bandwidth depends upon station distance and magnitude. The work done to date has focused on the larger events enabling the use of the standard passband (0.02 to 0.10 Hz) and utilizing data from stations located more than 100 km from the Geysers. To study smaller events we have several plans. One is to utilize the local station data from stations at 1 to 20 km with corresponding higher low-pass filter corners. This will require evaluating the signal to noise of the local data and to find the lowest possible lowpass corner frequencies. We can combine these results with first motion data to further constrain the mechanism. At these higher frequencies we have capability to convolve source time functions with the Green functions to enable broader band inversions utilizing information at and above the source corner frequency. This introduces additional free parameters (source rise time as well as the shape of the source time function) that will be tested using a grid search. Second, we have investigated the method utilized by Baig and Urbancic (2010) and plan to test it for smaller events as necessary.

Baig, A., and T. Urbancic (2010). Microseismic Moment Tensors; a path to understanding frac growth, *The Leading Edge*; March 2010; v. 29; no. 3; p. 320-324; DOI: 10.1190/1.3353729.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Seismicity:

No Response Entered

Rebuttal Comments for "Overall" - Seismicity:

No Response Entered

Rebuttal Comments for "Strengths" - Seismicity:

No Response Entered

Rebuttal Comments for "Weaknesses" - Seismicity:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response to Reviewer 5 -As mentioned during the presentation and in the SOPO, waveform correlation with subsample precision will be applied to the waveform data.

Fracture mapping was not proposed in the project and we were told that we cannot stray from the work proposed in the SOPO. However, I agree that this is a very important and exciting subject, and we have plans to look at the fracture orientation/density in the future, as we already have published a similar study.

Likewise, 3-D attenuation was not proposed in our project and will be covered by LBNL in a separate parallel effort. On a side note: The seismic sensors and digitizers of the LBNL network have been upgraded throughout the past years such that the amplitudes of the recorded waveforms will be difficult to compare and estimates of temporal changes in reservoir attenuation might be ambiguous.

We will investigate methods to assure evenly distributed ray coverage including weighted ray paths during the inversion.

Response to Reviewer 37 -See comments under Scientific/Technical Approach above.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10508
Presentation Title: Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing
Investigator: Templeton, Dennise (Lawrence Livermore National Laboratory)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response - We thank the reviewers for taking the time to comment on our Matched Field Processing (MFP) research. We realize that significant clarification is necessary.

Response to Reviewer 5- We agree with the reviewer that this method is relevant to the problem of detecting small or overlapping micro-earthquakes and thank Reviewer 5 for suggesting that we quantify the advancement that this method exhibits over existing methods. We are currently planning to perform a small study where we apply a correlation detector to the same data that we applied the MFP method and compare the results of the two methods. A correlation detector method is one of the “existing methods” that Reviewer 5 refers to in the comments.

Response to Reviewers 37, 38 - We believe that both reviewers are commenting on the mistaken assumption that the MFP operation is being conducted in the frequency-domain. Although the slides of the actual presentation indicated that the calculations were being conducted in the time domain, during the Q and A session after the talk, the PI mistakenly said that the calculations were being conducted in the frequency domain, so the confusion is understandable. The time domain is the “more useful domain for analysis” that Reviewer 38 is referring to in the comments and we are performing the calculations in the time domain.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response to Reviewer 5 - While it is true that matched field processors are closely related to subspace detectors, the point of processing in many narrow bands is to make the processor relatively independent of source time history. The source time function is a combination of the rise time and rupture time of an earthquake. If we can remove or down-weight the importance of having similar source time functions between master events and previously unidentified events when performing the matching algorithm, then this would be an obvious improvement over currently available methods.

By forcing independence among the constituent frequency bands, phase coherence from band to band is eliminated and the processor should respond equally well to sources with widely divergent source time histories. Something like independence can be achieved with subspace detectors, but it is more straightforward to do so with matched field processors. As implemented in the current program, the processor is very closely related to frequency-domain beamforming, but with calibrations to correct for unmodeled (i.e. non-plane wave) propagation effects. This should give it the capability to detect and map continuous sources in addition to discrete events—another improvement over current available methods.

It is not clear that spectral leakage is a significant problem for our application. Our goal is not to estimate the spectral structure of the signal (for which substantial leakage would be a problem), but rather to combine signals coherently across a spatial aperture with phase/amplitude calibrations to correct unmodeled effects of propagation. Adjacent frequency bands in the detector do have substantial overlap, but this is not an issue if the source spectrum is smooth and slowly varying from band to band, as it should be for very short-duration sources such as those that we are interested in identifying (the events are small, with high corner frequencies). However, if leakage turns out to be a problem it can be combated by using prolate spheroidal windows for template construction (this was the additional subroutine alluded to) and/or by increasing the number of bands by decreasing the width of each band. The latter solution, of course, would reduce time-domain resolution. However, reduced temporal resolution may not be significant if the goal is to image the spatial distribution of emissions to delineate a developing fracture or map long-term induced seismicity. Even for real-time monitoring of a treatment, it is only really necessary to image activity around the fracture on time scales of tens of seconds. The physical processes generating microseismicity probably will not change their locus more rapidly than that.

Lastly, as stated earlier, we plan to perform a small study where we quantify the improvement between an existing method and the MFP method to address the concerns of the reviewer.

Response to Reviewer 37 -The reviewer states that there could be a common path problem in the case of local seismic monitoring which the MFP method may have difficulties with and suggests that ―with enough templates, it may be possible to locate the small events as well". This is exactly our approach to this potential problem. We identify enough template events to densely sample the source volume to locate events by measuring which template best focuses the energy emanating from the source region. By having a reasonably dense sampling, the ―common path" problem that the reviewer points out is removed – we only need to be close to the nearest master event among hundreds of master events for the assumption to be valid. Additionally, as we showed in our presentation, it is possible to identify such a dense sampling of template events in a geothermal area, which in the specific case of Salton Sea Geothermal Field seismicity during January 2010, identified over 335% more events than were in the official earthquake catalog.

The reviewer is correct in that, although we intend for MFP to be insensitive to source time history, it will be sensitive to source mechanism. Our proposed solution to the problem of indeterminate mechanism is twofold – first to seek master events that are collocated, but have different mechanisms, and to build the empirical templates. The templates can then become multidimensional (subspace). Designing the templates using several events with different mechanisms in theory should allow matches to previously undetected events with different mechanisms in the linear span of the master event mechanisms.

Our second approach to this problem is to perform model-based matched field processing. In this case, one can synthesize the appropriate signal subspace with forward calculations through a model. The model-based approach also will allow us to design the set of points sampling the source volume (for which templates are developed) on a nicely uniform grid. Of course, this approach trades one problem (indeterminate mechanism) for another (finding a suitable velocity model) and we will have to be very careful in our choice of velocity model. We are in the process of applying this approach to the Salton Sea Geothermal Field. To obtain a suitable velocity model we are working with collaborators on an adjoint tomography inversion for this field using the larger events.

In the event that the model still does not produce usable templates, it may be possible to try a (possibly large) number of perturbations to the model, produce a template for each model realization and assemble the collection of templates as a single multidimensional subspace template. This approach risks significant loss of resolution, but would make the template less sensitive to model error. To reduce the loss of resolution would require deploying larger numbers of observing stations. We do not propose to try this approach in the current project, but mention it as an approach to mitigate the obvious problems with getting the model right.

As mentioned previously, the MFP algorithm is performed in the time domain, not the frequency domain. We are not interested in the source spectrum, but rather break the signal into narrowband components in order to eliminate dependence on any particular spectral structure. The processor is realized with a bank of multichannel narrowband filters, where the only matching operation is a phase/amplitude correction for each (complex analytic) channel. Consequently, there is no match to the temporal structure of the signal. The weighted outputs of the narrowband filters are summed across channels (in one band) to form a beam, then the squared magnitude of the resulting beam is computed and finally summed across bands.

The goal of MFP is to detect events using master templates without the onerous task of picking individual phases for new events and determine a preliminary location (which will be attached to the master event used in identification) for the newly identified events. Picking phases in a traditional network location approach is problematic when events occur so rapidly that the signals are superimposed or if their signal-to-noise ratio is low.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

Response - We believe that a 335% improvement in the number of events that can be detected in the Salton Sea Geothermal Field during January 2010 is impressive. However, we agree with a previous suggestion of Reviewer 5 that quantification of this level of improvement relative with other current methods is necessary.

Rebuttal Comments for Project Management/Coordination - Seismicity:

Response - We agree with the reviewers that the project management is sufficient for this project.

Rebuttal Comments for "Overall" - Seismicity:

Response - As described above, we believe that Reviewer 37 is commenting on the mistaken assumption that the MFP operation is being conducted in the frequency-domain. The calculations are in fact being performed in the time-domain.

Rebuttal Comments for "Strengths" - Seismicity:

Response - We agree that MFP method can be used to detect weak events and that we are closely examining the data to verify that we are identifying true events and not noise.

Rebuttal Comments for "Weaknesses" - Seismicity:

Response - As described above, we believe that Reviewer 37 is commenting on the mistaken assumption that the MFP operation is being conducted in the frequency-domain. The calculations are being performed in the time-domain.

As stated above, although the slides of the actual presentation indicated that the calculations were being conducted in the time domain, during the Q and A session after the talk, the PI mistakenly said that the calculations were being conducted in the frequency domain, thus the comment of Reviewer 5 is understandable. This mistake will not be repeated in the future.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response - We thank Reviewer 37 for his/her input. Reviewer 37's suggestions in this section were also included in their comments in the Scientific/Technical Approach section and we have commented on them in that earlier section.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10509
Presentation Title: Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in EGS Reservoirs
Investigator: Huang, Lianjie (Los Alamos National Laboratory)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response to Reviewer 37 - Our use of model calibration software (PEST) allows us to perform not only optimization but also sensitivity analysis to guide data collection.

Response to Reviewer 18 - It is very important to develop novel imaging and modeling technologies for EGS. We are still in the data collection, discerning and understanding phase. While we do have preliminary models, we are not in the position to advise current decisions; we are working towards this position. In addition, the Brady‘s EGS has not yet started.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response to Reviewer 37 -The thermal-hydrologic-mechanical (THM) simulation of fractured geothermal reservoirs has progressed significantly is the past few years thanks to this and other DOE projects. The use of both dual continuum and DFN models along with appropriate permeability stress relationships will allow us to quantitatively link seismic and flow in operating geothermal fields.

We calculate for each measurement, P, S1, SV, Bulk modulus, Shear modulus, Young‘s modulus, and Poisson‘s ratio. We will incorporate and use the P/S ratio in our analysis.

Response to Reviewer 38 - We use the core data and other data to develop the Discrete Fracture Network that allows us to couple the fracture flow simulations with reservoir THM simulations. Our unique approach involves in development of Mohr-Coulomb based permeability-stress relationships that can be used for THM modeling.

Currently, there are no data available for time-lapse EGS monitoring. The Brady‘s EGS has not yet started. Originally, our collaborator will collect time-lapse seismic data for the Brady‘s EGS field, but he only obtained funds for the baseline data acquisition. We will apply our algorithms to real data as soon as they are available.

Response to Reviewer 18 -

The project involves in three related research topics: EGS reservoir imaging, modeling, and Discrete Fracture Network. Lack of detail was directly associated with presentation length limitations. A list of publications was provided for detailed technical information. Our numerical examples clearly demonstrate that our double-difference waveform inversion schemes greatly improve quantitative estimations of EGS reservoir changes compared to conventional inversion schemes. The Brady‘s EGS has not yet started, and the real data are not available. Even if the real data are not available now, the development of new, robust imaging techniques is important for future applications to EGS.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Seismicity:

Response to Reviewer 18 - LANL reported 47% spent with 50% of work completed when the calendar is at about 50%. NETL reported 36% spent with 36% complete because the NETL funding arrived later than originally anticipated. This has not hindered research but did delay the start date for NETL to September, 2010. We will complete all tasks by the end of the project.

Rebuttal Comments for "Overall" - Seismicity:

No Response Entered

Rebuttal Comments for "Strengths" - Seismicity:

No Response Entered

Rebuttal Comments for "Weaknesses" - Seismicity:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10510
Presentation Title: Joint Seismic-EM Inversion (LBNL)
Investigator: Newman, Gregory (Lawrence Berkeley National Laboratory)
Panel: Rebuttal - Seismicity & Reservoir Fracture Characterization
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Seismicity:

Response to Reviewer 18 -We do not accept Reviewer #18 claim that MT brings little to joint imaging of geothermal systems. It is well established that MT is the most widely accepted type of geophysical measurement to identify geothermal resources. While it does not provide a direct indication of fluids, it identifies zones of high temperature clay alteration which are clearly identified with reservoir fluids. While MEQ data can provide direct indications of fluids, significant seismicity is required along with adequate array coverage. The resolution provided by MEQ tomographic imaging is also significantly lower than MT (5 to 10 times). It therefore makes sense to combine these methods in a joint imaging framework to improve the resolution of the geophysical attributes (resistivity, velocity and earthquake hypocenter locations). There is also clear evidence that these attributes are coupled, as we have shown at the Coso field.

Rebuttal Comments for Scientific/Technical Approach - Seismicity:

Response - While Reviewer 5 does not like our approach we strongly disagree with his/her claim that our approach is not joint inversion. We are constraining the velocity and electrical resistivity to have common geological structure. This is joint inversion and we are implementing it in several stages; the first approach we are implementing is a leap from scheme, followed by fully coupled approaches. Note each geophysical data type is contributing to refining the shared structure in the attributes. Reviewers 5 and 37 think we should use more of a rock physics approach to link fluid saturation properties to the geophysical attributes. This will not work as such rock physics models are unreliable in fractured crystalline rocks. It therefore makes more sense to link the attributes structurally, and there is very strong evidence for such an approach based upon structurally correlated images of velocity and resistivity at the Coso field. Appraisal of the joint image developed from our approach is a separate problem, but we feel confident that there will be a significant reduction in model uncertainty with our approach to joint imaging compared to geophysical imaging of the MEQ and MT data sets in isolation.

We have proposed to use gravity in the analysis of the three high temperature systems we are analyzing in this project. Gravity data will be included in our analysis of the baseline models, but only after we complete the MT and MEQ baseline models.

Rebuttal Comments for Accomplishments, Results and Progress - Seismicity:

Response to Reviewer # 5 - Reviewer states up front that he does not like our approach to joint inversion and will therefore not be thrilled with the accomplishments. We would ask Reviewer #5 to keep an open mind and wait for the results before passing judgment.

Because of time limitations at the presentation we had no time to provide a complete interpretation of our accomplishments to date. Programmatic points were given the priority as demanded by the review guidelines. However, we are quite satisfied with our accomplishments thus far, in particular the new high resolution resistivity images of the two Icelandic systems Krafla and Hengill. In fact, the 3D resistivity image developed at Krafla is a first; and at Hengill we have been able to image the reservoir at a scale at significant more detail, 10x better than has been previously published. We plan to submit two manuscripts for publication detailing the baseline MT interpretations at Krafla and Hengill this coming year. Other accomplishments include the augmented MEQ array at Hengill and the new development of a joint imaging capability for seismic velocity and electrical resistivity and MEQ hypo-center focal locations.

Rebuttal Comments for Project Management/Coordination - Seismicity:

Response - We have provided cost share and budget information to GTP program managers. The participation of multiple institutions and companies makes this a challenging project to manage. Nevertheless, in October 2010 we have had several meetings between key project participants at MIT and LBL and all parties in Iceland. We are planning another meeting in Iceland in October 2011.

Rebuttal Comments for "Overall" - Seismicity:

Response to Reviewer 5 -_We strongly disagree with Reviewer #5. Our approach to tackling the joint inverse problem involves a systematical approach as outlined clearly in our project proposal and view favorably by the other referees.

Rebuttal Comments for "Strengths" - Seismicity:

Response - We feel our progress thus far on the baseline interpretations are significant and plan to submit two papers describing out 3D MT resistivity imaging experiments at Hengill and Krafla. In both systems we have imaged the magmatic systems that feed the respective reservoirs and at unprecedented resolution. We are also making several presentations at the Geothermal Resources Council and Society of Exploration Geophysicists meetings in September and October 2011. So we do not agree with Reviewer #18 that our results have been negligible at this time; if that were the case our abstract submissions to these technical conferences would not have been considered and accepted for presentation.

Rebuttal Comments for "Weaknesses" - Seismicity:

Response to Reviewer 5 -We disagree with comments made by Review #5. We wish we could have provided more details of our joint imaging approach in the GTP review presentation, but programmatic issues were forced to take precedence over our technical approach. It needs to be emphasized once more that MT is the most widely accepted type geophysical measurements to identify geothermal resources. While it does not provide a direct indication of fluids, it identifies zones of high temperature clay alteration which are clearly identified with reservoir fluids. To not include MT data in a joint inversion experiment would lead to a significant loss in the resolving power of a joint imaging experiment using only gravity and MEQ data. Finally the idea we should pursue a linkage of the fluid saturation properties of the reservoir through a rock physics model has serious drawback as described previously. It has motivated the use of a common structural constraint in joint inversion framework.

Rebuttal Comments for "Suggestions for Improvement" - Seismicity:

Response - We will be including gravity data in the Krafla and Hengill studies as soon as we complete the background MT imaging. For Coso we will accelerate our processing of the MEQ data so we can start joint imaging of Coso data first, followed by Krafla and then Hengill.

Specialized Materials and Geopolymer Sealing Materials

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10600
Presentation Title: Geopolymer Sealing Materials
Investigator: Butcher, Thomas (Brookhaven National Laboratory)
Panel: Rebuttal - Specialized Materials & Geopolymer Sealing Materials
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Specialized Mats:

Response to Reviewer 84 - The developed sealer was formulated without the use of any Ordinary Portland Cement (OPC). Manufacturing one ton of OPC causes the emission of 0.873 metric ton of CO_2 and a great deal of mercury, strongly suggesting that our cementitious sealer eliminates this carbon footprints and alleviates the environmental impact. Similarly, our usage of slag and fly ash resources has beneficial environmental effects. According to U.S. Geological Survey, in 2000, U.S steel industries generated 8.9 million tons of slag as wastes and by-products, and in 2009, 5.7 million tons of fly ash by-products were yielded from U.S. coal combustion power plants. Of these amounts, 5.1 million tons of slag and 2.2 million tons of fly ash were recycled into industrial products. Thus, the abundant resource of these by-product cementitious sealer starting materials assures local availability across the U.S.A.

At present, no self-degradable cementitious material (as a new-type of cement) is commercially available worldwide, nor can the cost be compared with any other. Our cost reduction effort will focus on decreasing ~ 15 % of the current raw material cost (~10¢/lb) of OPC-based lost circulation control materials, including bridging and foaming additives. Based upon a lower raw material cost of ~5¢/lb for slag and ~2¢/lb for fly ash (compared with ~ 7¢/lb for OPC), the best approach to cost reduction is to formulate fly ash-rich cementitious materials.

Response to Reviewer 83 - I agreed with the Reviewer‘s opinion. No self-degradable cementitious material (as a new-type of cement) is commercially available worldwide. Thus, this R&D project has a high potential to initiate the development of other self-degradable cements.

Response to Reviewer 11- Our cost reduction effort will focus on decreasing ~ 15 % of the current raw material cost (~10¢/lb) of OPC-based lost circulation control materials, including bridging and foaming additives. Based upon a lower raw material cost of ~5¢/lb for slag and ~2¢/lb for fly ash (compared with ~ 7¢/lb for OPC), the best approach to cost reduction is to formulate fly ash-rich cementitious materials.

Response to Reviewer 61 - As was shown, and verbally described in my presentation, the self-degradation of Brookhaven National Laboratory (BNL)-developed cement was promoted by chemical interactions between the NaOH derived from the hydrolysis of sodium silicate and the reactive gaseous species including CO_2, CH_3COOH, et al. emitted by the thermal decomposition of sodium carboxymethyl cellulose (CMC) as a self-degradation promoter in an aqueous media. So, if this cement is applied to well casing cement, CMC would be eliminated from this formula to avoid self-degradation.

Based upon the lower raw material cost of ~5¢/lb for slag and ~2¢/lb for fly ash (compared with ~ 7¢/lb for OPC), the best approach to cost reduction is to formulate fly ash-rich cementitious materials.

On this point, we don‘t yet have a field-applicable formula. This formula will be established from the outcomes of in-house scale-up experimental work in collaboration with our industrial partners. Once the formula is optimized, the economic feasibility study, including the cost estimate of total raw materials, will be accomplished by the industrial partners.

Response to Reviewers 80, 62 - Thank you.

Rebuttal Comments for Scientific/Technical Approach - Specialized Mats:

Response to Reviewer 84- Thank you.

Response to Reviewer 83 - In this innovative self-degradation technology, there are two key chemical elements to promoting the self-degradation of cementitious materials: One element is free NaOH, derived from the hydrolysis of the sodium silicate as the alkali activator of pozzolanic reaction cements (such as slag and fly ash); the other is the reactive gaseous species including CO_2, CH_3COOH, et al. emitted by the thermal decomposition of sodium carboxymethyl cellulose (CMC). The interactions between these two elements in aqueous media generates the exothermic reactions leading to the disintegration of pozzolana cements. In an attempt to evaluate the applicability of this technology to conventional Ordinary Portland Cement (OPC)-based well cements like Class G and H, the same amount of two chemical reactants (sodium silicate and CMC) as that used in our self-degradable cement system was incorporated into Class G and H well cements. However, no self-degradation was observed from Class G and H cements, suggesting that OPC, which develops a cementitious structure through its hydrolysis-hydration reaction processes, does not have any compatibility with sodium silicate, causing no dissociation of free NaOH. However, although there is no experimental evidence, if OPC is to be blended with slag or fly ash, such blended cements may be degraded by sodium silicate and CMC. If the funding of this project continues in FY2012, we will incorporate additional plans to design such self-degradable blend cement systems into this project.

Response to Reviewer 11 - As mentioned at the review meeting, currently, our emphasis is being directed towards completing two tasks: One task is to define an appropriate amount of expansive additive to provide a desirable volume expansion of cement without cracks under pressures up to 1500 psi; the other task is the technology transfer to Halliburton. With respect to the latter task, BNL provides technical assistance to their own evaluation and in-house scale-up work of this technology. Our effort to assist ranges from the modification of the original formula, based on the industry's request, to the analysis of industry-made samples.

Response to Reviewer 61- The self-degradation of this temporary sealer was designed to take place shortly after water comes in contact with thermally heated cement. Without this heating process, there is no self-degradation under the hydrothermal condition. Thus far, all specimens were heated for 24 hours at temperatures ≥200°C before contacting water. Next, we plan to assess the efficacy of a heating time <24 hours in initiating self-degradation. This information may lead to an appropriate heating time needed to cause disintegration through water contact.

Response to Reviewer 80- All background regarding this material system, which was formulated in the previous DOE-funding project aimed at developing cost-effective acid resistant well cements, has been described at the FY 2010 DOE overview presentation. As such, we did not repeat background information in order to avoid a duplicate presentation at this year's DOE peer review meeting. I apologize for a lack of explanation of why this system was chosen along with the technical strategy. The adaption of CMC as a self-degradation promoting additive originally came from self-degradable biocompatible bone cements. In this cement system, environmentally benign CMC was incorporated as a biodegradable additive into bone cements. In contrast, our interest here in using CMC was its thermal degradation. However, although CMC was thermally decomposed in the cement system, this decomposition energy was not enough to disintegrate the whole cement in an oven at temperatures ≥200°C. Afterward, we found that the water-catalyzed exothermic reactions between the reactive gaseous species emitted from CMC decomposition, and NaOH from hydrolysis of sodium silicate, served in promoting a self-degradation of cement in an aqueous medium.

Response to Reviewer 62- As described in two of our published interim progress reports entitled ―Self-degradable cementitious sealing materials," BNL-94308-2010-IR, (October 2010), and ―Self-degradable slag/class F fly ash-blend cements," BNL-94911-2011-IR, (March 2011), we tested a wide range of additive contents and slag/Class C and F fly ash ratios. Although there was no information on the usefulness of various cellulose-based additives as self-degradation promoters supplied from Dow Chemical Company in these reports, we previously evaluated the ability of various cellulose-based additives to promote self-degradation. As a result, we selected CMC as the most effective additive from among the cellulose compounds.

Rebuttal Comments for Accomplishments, Results and Progress - Specialized Mats:

Response to Reviewers 83, 84: Thank you.

Response to Reviewer 11- In compliance with suggestions from our industrial partners, prior to a field demonstration and validation test, our next work will be to conduct a modified API lost circulation slot test at a small scale of 0.3 gallon cementitious sealer at BNL. There are three important factors needed to be investigated. The first factor will be that of the ideal penetration distance of the temporary sealer from the inlet of fractures in EGS. It will be as short as possible to guarantee the completion of its self-degradation. The second factor will be the down-hole pressure in EGS wells, which is up to 1000 psi. Therefore, the sealer must be capable of plugging the fractures under a high pressure of 1000 psi before it is set and hardened. The third factor will involve the different widths of the fractures. Thus, the following test conditions, along with the modification of the standard API slot test, will be adapted; a 6 inch-long slot will be used, and the four different widths (0.04, 0.08, 0.16, and 0.24 inches) of slots will be employed, while we will apply five different pressures, 20, 50, 100, 500, and 1000 psi to the sealer during the plugging operation. The filtrate loss of the sealer will be measured under this test condition. The satisfactorily filled sealer occupying the slot will be cured in a hydrothermal environment at 200°C, following by a heat treatment at temperatures ranging from 200°C to 300°C. The heated sealer then will come in contact with water under pressure of up to 1000 psi to ensure that the sealer will adequately disintegrate.

Response to Reviewer 61- In this temporary sealer system, there were two key chemical elements to promoting the self-degradation of cementitious materials: One element is free NaOH which is derived from the hydrolysis of the sodium silicate as an alkali activator of pozzolanic reaction cements, such as slag and fly ash; the other is the reactive gaseous species including CO_2, CH_3COOH, et al. emitted by the thermal decomposition of sodium carboxymethyl cellulose (CMC). The interactions between these two elements in an aqueous media generated the exothermic reactions leading to the disintegration of pozzolana cements. DSC was used to reveal what temperature initiates the thermal decomposition of CMC and also to find the end temperature of its decomposition. In addition, to identify the gaseous species generated during the thermal decomposition of CMC, we conducted FT-IR study along with a survey of literatures provided by Dow Chemical Corporation, which manufactures CMC.

Regarding environmental issues, at present, CMC-related materials are often being used as an anti-filtration additive in drilling fluids in geothermal, oil and gas wells, and also thermal decomposition of CMC-related materials remaining in such wells if expected at temperatures >160°C. The major gases emitted from CMC are CO_2 and CH_3COOH. On the other hand, the geothermal wells commonly contain a great deal of CO_2 and H_2S, so, the environmental concern is minor.

Response to Reviewer 80 - As of July 26, we have nearly completed the study to determine the volumetric expansion of temporary sealer by MgO under pressures up to 1500 psi. Currently, the preparation of a report covering all information on the expansive temporary sealing materials is under way.

Response to Reviewer 62 - Yes, our published interim report entitled ―Self-degradable slag/class F fly ash-blend cements," BNL-94911-2011-IR (March 2011) included the results from the SEM morphological study at a micro-level that visualized the self-degradation.

Rebuttal Comments for Project Management/Coordination - Specialized Mats:

Response to Reviewers 11, 83,84: Thank you.

Response to Reviewer 61 - We apologize for a lack of indicated go/no go decision points. Our original plan for this decision was contingent upon the self-degradation technology, if this technology was unable to be developed, a no-go decision would be made.

DSC was used to reveal the temperature that initiates the thermal decomposition of CMC as well as the decomposition end temperature. In addition, to identify the gaseous species generated during the thermal decomposition of CMC, we conducted a FT-IR study as well as a survey of literatures provided by Dow Chemical Corporation, which manufactures CMC.

Response to Reviewer 62 - We tried to interpret the concerted industrial coordination in this limited presentation however our effort may not be enough to comprehensibly explain this coordination.

Rebuttal Comments for "Overall" - Specialized Mats:

<u>Reviewer 114:</u>

Response to Reviewers 11, 83, 84: Thank you.

Response to Reviewer 61 -Based upon the lower raw material cost of ~5¢/lb for slag and ~2¢/lb for fly ash compared with ~ 7¢/lb for Ordinary Portland Cement (OPC), the best approach to cost reduction is to formulate fly ash-enriched cementitious materials.

As described in two of our published interim progress reports entitled ―Self-degradable cementitious sealing materials," BNL-94308-2010-IR (October 2010) and ―Self-degradable slag/class F fly ash-blend cements," BNL-94911-2011-IR (March 2011), in this innovative self-degradation technology, there are two key chemical elements to promoting the self-degradation of cementitious materials: One element is free NaOH derived from the hydrolysis of the sodium silicate as the alkali activator of pozzolanic reaction cements, such as slag and fly ash; the other is the reactive gaseous species including CO_2, CH_3COOH, et al. emitted by the thermal decomposition of sodium carboxymethyl cellulose (CMC). The interactions between these two elements in aqueous media generate the exothermic reactions leading to the disintegration of pozzolana cements. In an attempt to evaluate the applicability of this technology to conventional Ordinary Portland Cement (OPC)-based well cements, like Class G and H, the same amount of two chemical reactants as that used in our self-degradable cement system (sodium silicate and CMC) were incorporated into Class G and H well cements. However, no self-degradation was observed from Class G and H cements, suggesting that OPC, which develops a cementitious structure through its hydrolysis-hydration reaction processes, does not have any compatibility with sodium silicate, causing no dissociation of free NaOH.

Regarding environmental issues, at present, CMC-related materials are often used as an anti-filtration additive in drilling fluids in geothermal, oil and gas wells. In addition, thermal decomposition of CMC-related materials remaining is expected in such wells at temperatures >160°C. The major gases emitted from CMC are CO_2 and CH_3COOH. However, the geothermal wells commonly contain a great deal of CO_2 and H_2S so the environmental concern is minor.

Response to Reviewer 62- We published two interim reports entitled ―Self-degradable cementitious sealing materials," BNL-94308-2010-IR (October 2010) and ―Self-degradable slag/class F fly ash-blend cements," BNL-94911-2011-IR

(March 2011). These reports, covering all information on the assignment's progress, may help the reviewers to understand the project's background and current progress.

Rebuttal Comments for "Strengths" - Specialized Mats:

Answer to Reviewers 11, 62, 84: Thank you.

Response to Reviewer 83- We plan to evaluate the other types of cellulose-based biopolymers supplied by Dow Chemical

Rebuttal Comments for "Weaknesses" - Specialized Mats:

Response to Reviewer 84 -Unanswerable.

Response to Reviewer 83 -Although there is no experimental evidence, if OPC is to be blended with slag or fly ash, such blended cements may be degraded by sodium silicate and CMC. If the funding of this project continues in FY2012, we will incorporate an additional plan to design such self-degradable blend cement systems into this project and will study the water-catalyzed self-degradation mechanisms of OPC/slag/ fly ash systems by sodium silicate and CMC to prepare widely applicable cements.

Response to Reviewer 11 -Contingent upon the results from the API slot test, if successful, we will deploy a field-applicable temporary sealer in EGS wells to conduct a field trial test.

Response to Reviewer 62 -We tried to interpret the concerted industrial coordination in this limited presentation. However, our effort may not be enough to comprehensibly explain this coordination.

Rebuttal Comments for "Suggestions for Improvement" - Specialized Mats:

Response to Reviewers 11, 62: We plan to conduct a modified API lost circulation slot test at small scale of 0.3 gallon cementitious sealer at BNL. There are three important factors needed to be investigated. The first factor will be that of the ideal penetration distance of the temporary sealer from the inlet of fractures in EGS. It will be as short as possible to guarantee the completion of its self-degradation. The second factor will be the down-hole pressure in EGS wells, which is up to 1000 psi. Therefore, the sealer must be capable of plugging the fractures under a high pressure of 1000 psi before it is set and hardened. The third factor will involve the different widths of the fractures. Thus, the following test conditions, along with the modification of the standard API slot test, will be adapted; a 6 inch-long slot will be used, and the four different widths (0.04, 0.08, 0.16, and 0.24 inches) of slots will be employed, while we will apply five different pressures, 20, 50, 100, 500, and 1000 psi to the sealer during the plugging operation. The filtrate loss of the sealer will be measured under this test condition. The satisfactorily filled sealer occupying the slot will be cured in a hydrothermal environment at 200°C, following by a heat treatment at temperatures ranging from 200°C to 300°C. The heated sealer then will come in contact with water under pressure of up to 1000 psi to ensure that the sealer will adequately disintegrate.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10601
Presentation Title: High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells
Investigator: Fabian, Paul (Composite Technology Development, Inc.)
Panel: Rebuttal - Specialized Materials & Geopolymer Sealing Materials
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Specialized Mats:

Response:

Proprietary Information

Several of the reviewers mentioned the lack of information given in the Peer Review slides and presentation due to the proprietary nature of some of the work on this program. Composite Technology Development, Inc. (CTD) is acutely aware of the need to protect its IP to maintain a competitive advantage in an industry (oil and gas) that is highly competitive when it comes to innovative ideas and processes. To address this, CTD has filed a U.S. Patent Application (61/448,560) to protect the various design concepts for this method of zonal isolation. Specific seal and trigger material formulations and chemistries will continue to be held as proprietary but this information should not be necessary to fully evaluate the work being done for this program.

Environmental Concerns

CTD is aware of the increasing concern to use environmentally friendly substances whenever possible for any aspect of downhole exploration, drilling, fracking, and circulation. While the chemical trigger mentioned in the presentation is not benign, it is an accepted substance that is commonly used in the industry and is easily neutralized in the field. However, CTD will continue to explore alternative materials and/or solutions that can achieve the same results but that are considered less hazardous and friendlier to the environment.

Rebuttal Comments for Scientific/Technical Approach - Specialized Mats:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Specialized Mats:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Specialized Mats:

No Response Entered

Rebuttal Comments for "Overall" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Strengths" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Weaknesses" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Specialized Mats:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10602
Presentation Title: Temporary Bridging Agents for Use in Drilling and Completion of Engineered Geothermal Systems
Investigator: Watters, Larry (CSI Technologies, LLC)
Panel: Rebuttal - Specialized Materials & Geopolymer Sealing Materials
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Specialized Mats:

Response to Reviewer 61- Environmental effects of degradation products are currently considered in the screening and evaluation process. Full commercialization will entail a comprehensive evaluation of diverter and degradation product impact on the environment.

Rebuttal Comments for Scientific/Technical Approach - Specialized Mats:

Response to Reviewer 83 -The particle size distribution and fracture width correlation is being addressed during the final portion of the project. A correlation relating PSD to frac width will be a project deliverable. Mechanical properties relationships are included in the correlation being developed. We are starting with published properties provided by the material suppliers such as Young's Modulus, Poisson's Ratio, and flexural modulus.

Response to Reviewer 80 -The candidate selection and application design strategies will be presented in final project documentation.

Rebuttal Comments for Accomplishments, Results and Progress - Specialized Mats:

Response to Reviewer 61 -The PSD analysis is underway and will be the final task accomplished. It is true that larger particle size increases porosity and decreases bridging effectiveness. However, the proper mix of particle size lowers porosity and improves seal effectiveness. Thus, porosity of the diverter mix appears to correlate to the seal effectiveness.

Rebuttal Comments for Project Management/Coordination - Specialized Mats:

Response to Reviewer 84 -The time required to develop effective test methods and generate sufficient data to correlate PSD and sealing effectiveness slowed progress.

Rebuttal Comments for "Overall" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Strengths" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Weaknesses" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Specialized Mats:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10603
Presentation Title: Development of an Improved Cement for Geothermal Wells
Investigator: Trabits, George (Trabits Group, LLC)
Panel: Rebuttal - Specialized Materials & Geopolymer Sealing Materials
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Specialized Mats:

Response to Reviewer 11 - The project team lost a significant amount of time while the negotiations with TCI went on for over 6 months. When the negotiations failed, the project team had to find a new industry partner (Halliburton) and shift a significant scope of work to UAF. DOE was engaged in those discussions and is well aware of the TCI scope of work being shifted to UAF and thus the delays, which caused the project to be at about 30% completion.

Response to Reviewer 61 - The question of whether the cement developed under this project will be cheaper than current options is extremely difficult to address until the project is completed. Even beyond the completions, the economics will be dictated by the economies of scales (are you going to make 100 lbs of cement or 100's of thousands of pounds?).

It took several decades to develop oil field cement and we still continue to make improvements. If Geothermal energy, as a renewable resource, is expected to be there, the drivers, such as this project, are needed to conduct safe, long-term operations by minimizing bad cement jobs and associated extra rig time and thus lower energy cost. Thus, the cost issue, while important, is a function of several other factors above and beyond the scope of this project.

Zeolites with Si/Al ratio of greater than 3.8 are highly temperature stable and the zeolites with Si/Al ratio less than 1.28 show very low thermal stability. The stability of the intermediate range is not dependent on the Si/Al ratio alone. The thermal stability in this region can vary from very low to very high. Analcime, Chabazite, Clinoptilolite and Ferrierite have high thermal stability with a very small cell shrinkage and have a structural collapse temperature of around 800°C. In the case of cements, Silica can be added to the cement to prevent or decelerate strength retrogression for HPHT conditions.

Rebuttal Comments for Scientific/Technical Approach - Specialized Mats:

Response to Reviewer 61 - Indeed, the PI could have answered all the questions for the sake of reviewers, provided the opportunity to have a few more slides and extra time for presentation and Q&A was provided by the DOE.

Given the thermal stability of most zeolites, the addition of zeolite to a high temperature cement should act to reduce strength retrogression.

Response to Reviewer 62 - More data will be available for next year's review.

Rebuttal Comments for Accomplishments, Results and Progress - Specialized Mats:

Responseto Reviewer 11- The delay has been explained in response to earlier reviewer comments; ~70% of the work is remaining.

Response to Reviewer 61- Natural zeolites are geographically widely dispersed on a world-wide basis. Zeolite as a natural mineral deposit will certainly differ in quantity and quality. Historically, zeolite production has been small tonnage into markets for applications such as odor control. Most, if not all zeolite mines are surface operations using mining methods that closely compare to sand and gravel operations. Using zeolite in large tonnage applications such as well cement would serve to lower production costs by increasing volume. Economic analysis indicates that it is reasonable to expect zeolite production and processing to be about the same cost as cement.

The project has very good chances of success and developing the zeolites concept further. Several other reviewers have commented to that effect.

This project is the only project of its kind funded by the Geothermal Technologies program. It truly represents a partnership between Industry, University and the Government. One of the objectives of the geothermal technologies program is build the awareness and develop future engineers and interest among engineering and scientific communities in order to prepare the workforce for advancing the knowledge and appropriate technology transfer to the industry. Naturally, academia plays a huge role in this. The Trabits Group has formed this unique collaboration. The students, who are a big part of this research, need to be brought up to speed and the appropriate starting task is to begin with a literature review to understand the current state-of-the-art so advances can be made and knowledge gaps can be filled.

Response to Reviewer 62 - The results will be available in due course.

Rebuttal Comments for Project Management/Coordination - Specialized Mats:

Response to Reviewer 84 - Zeolites can be difficult to identify in the field. Zeolites tend to be cliff forming formations and being hygroscopic stick to the tongue when licked. Specific identification is a laboratory process. For the Analcime, the deposit was referenced in literature as Analcime. Based on the literature reference it was expected to be Analcime so the large sample was collected. A two-step process could have eliminated the bulk sample collection but a two-step method would have required two trips to the location. In actuality the ―Analcime" bulk sample was collected on the same trip as the Chabazite bulk sample and was on the route taken to get to the Chabazite.

Rebuttal Comments for "Overall" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Strengths" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Weaknesses" - Specialized Mats:

Response to Reviewer 83 - The type of zeolite to be used was based on several criterions. The first consideration was how common the type was and if it was widely available. Second, the open ―void volume" of the zeolite was considered. A primary effect of zeolite in the cement blend is water adsorption. The zeolite types for the cement development project were selected to have a large percentage of open void volumes with the exception of Analcime which has a very small void volume but is a very common zeolite. Chabazite has the highest void volume but is also rarely found in large economic deposits. This leaves Clinoptilolite and Ferrierite as commercially available and with a large void volume. The base technology was developed using Chabazite making the Chabazite for the research necessary as a bench mark for performance with previous work. The last criterion was thermal stability: all the zeolite types selected have high thermal stability.

Response to Reviewer 11- This has been addressed earlier, the delays have been duly noted, the project team has a new industry sponsor, and the scope has been appropriately moved to the university. Finally, the project team is confident that it will meet the objectives/goals in a timely manner.

Response to Reviewer 62- This project is the only project of its kind funded by the Geothermal Technologies program. It truly represents a partnership between Industry, University and the Government. One of the objectives of the geothermal technologies program is build the awareness and develop future engineers and interest among engineering and scientific communities in order to prepare the workforce for advancing the knowledge and appropriate technology transfer to the industry. Naturally, academia plays a huge role in this. The Trabits Group has formed this unique collaboration. The students, who are a big part of this research, need to be brought up to speed and the appropriate starting task is to begin with a literature review to understand the current state-of-the-art so advances can be made and knowledge gaps can be filled.

Rebuttal Comments for "Suggestions for Improvement" - Specialized Mats:

Response to Reviewer 11 - The project team is working on this goal and hopes to accomplish it soon, once the equipment is available and testing of material begins. The students have completed training provided by Halliburton Energy Services.

Response to Reviewer 62- This project is the only project of its kind funded by the Geothermal Technologies program. It truly represents a partnership between Industry, University and the Government. One of the objectives of the geothermal technologies program is build the awareness and develop future engineers and interest among engineering and scientific communities in order to prepare the workforce for advancing the knowledge and appropriate technology transfer to the industry. Naturally, academia plays a huge role in this. The Trabits Group has formed this unique collaboration. The students, who are a big part of this research, need to be brought up to speed and the appropriate starting task is to begin with a literature review to understand the current state-of-the-art so advances can be made and knowledge gaps can be filled.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10604
Presentation Title: Evaluation of Thermal Spray Coatings as Pressure Seals
Investigator: Henfling, Joe (Sandia National Laboratories)
Panel: Rebuttal - Specialized Materials & Geopolymer Sealing Materials
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Specialized Mats:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Specialized Mats:

Response to Reviewer 61 -Reviewer 61 commented on the economic viability of using different thermal spray processes. The cost to purchase the thermal spray equipment varies considerably depending on the process. As such, our approach is to start with the most economical process that is feasible for this application and work to more advanced processes, if required. The project initially utilized the twin wire arc thermal spray system. This is a relatively inexpensive system that is readily field deployable and is routinely used to spray bridges with corrosion-resistant coatings, such as zinc. The sprayed coating using this system was too porous and an adequate seal was not obtainable. We are currently testing another cost effective thermal spray process called HVOF (high velocity oxygen fuel). To date, this process is showing promise. It is also field-deployable. The cost for either system is less than $40k. Once the process is defined, many companies can potentially apply the coating. The next step up in cost and complexity is an atmospheric plasma spray system. This system is not field-deployable and is three or more times the cost. Again, many companies have such a system and once the process is defined, they could apply the coating. Other systems, such as cold spray and vacuum plasma spray, are considerably more expensive and if these processes are required to obtain an adequate seal, the process may only be used in specialized high-end applications. Our goal is to develop a procedure to utilize a system that is field-deployable. Such a system could then be used in many varied aspects of drilling and logging activities. Each process has many variables that can be adjusted to optimize the coating characteristics, depending on the application. As such, it takes considerable time to rule out a process.

Response to Reviewer 80 - Reviewer commented on the technical strategy for the material choice and the spray process, go/no go decisions, and Sandia‘s experience. The following is a discussion of each concern. The material will be a nickel-based alloy. The exact alloy is under investigation and will be chosen based on the availability of the alloy for a given thermal spray process along with consideration of its corrosion and adhesion properties. The thermal spray processes being considered were presented and additional detail was outlined in the paper. It is difficult to express every consideration due to the length limitation for both the presentation and paper. In general, thermal spray processes have many parameters that can be varied to optimize the coating for a particular application, and it is beyond the scope of this review to include the details. Go/no go decisions are based on the success/failure of an adequate seal. This is not a project where one can contact a thermal spray coating shop and expect an answer on how to spray a coating or what the spray parameters should be. It takes sectioning and polishing of the coating to determine if the coating shows potential for success, and it takes pressure testing of several samples to validate a suitable spray process and spray parameters. Sandia‘s experience does help shorten the process of determining the validity of a spray process and optimizing the spray parameters. While others in the thermal spray community have experience in spraying coatings, Sandia has extensive experience based on a wide variety of spray processes, and applications beyond those normally encountered in industry. Most thermal spray facilities do not have the funding to support material scientists with emphasis in thermal spray technology. This expertise is required to help ensure success of this project.

Rebuttal Comments for Accomplishments, Results and Progress - Specialized Mats:

Response to Reviewer 80 – Reviewer commented on his uncertainty regarding the means of deposition, mechanism of failure, and scientific process (make and test instead of rigorous scientific process) related to this process. As presented and specified in the paper, two main processes have been utilized to date. They include the twin wire arc thermal spray system and the HVOF system. To help establish a baseline for the required coating properties, a few additional samples were coated using an atmospheric thermal spray system, cold spray system, and a flame spray (using a fusible powder) system. To date, the mechanism of failure is porosity. This was identified through the evaluation of micrographs prepared of the deposited coating. A preliminary look at porosity indicates less than 0.5% porosity is required. The micrographs indicate the adhesion to the substrate appears to be adequate. Due to a limited budget for this project a comprehensive study of every option is not feasible. The project is based on experience, which helps to control the size of the matrix and makes this project doable with the available funding.

Rebuttal Comments for Project Management/Coordination - Specialized Mats:

No Response Entered

Rebuttal Comments for "Overall" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Strengths" - Specialized Mats:

No Response Entered

Rebuttal Comments for "Weaknesses" - Specialized Mats:

Response Reviewer 83 – Reviewer comments that we have not fully investigated the effects of thermal expansion and how it may affect the integrity of the seal. This was briefly covered in the presentation, but the material selection was made with consideration of the intended base metal (PH17-4). The coefficient of thermal expansion (CTE) of PH17-4 varies from 6.0 to 7.2 x 10¯6in/in/°F (depending on the heat-treat condition and temperature), and the CTE of the nickel alloys range from 6.8 to 8.0 x 10¯6in/in/°F. The CTE is nearly matched and, at this stage of the project, appears to be adequate. Once a coating has been identified, the mock tools will be temperature cycled and micrographs will be prepared to verify the thermal cycling is not a cause of failure. Thermal mismatches tend to result in separation at the coating interface. Failures of this type will also cause the seal to fail, resulting in a pressure leak (easily revealed in the temperature cycling tests).

Rebuttal Comments for "Suggestions for Improvement" - Specialized Mats:

Response to Reviewer 11- A suggestion from reviewer 11 is to broadly communicate the results of this project. Our plan is to present the results at the GRC in 2012. Also, industry has an interest in this project and is willing to provide the service to the geothermal community. Through the field demonstration tests, the results will be broadly communicated.

Stimulation/Fracture Prediction Modeling

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10300
Presentation Title: Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs
Investigator: Carrigan, Charles (Lawrence Livermore National Laboratory)
Panel: Rebuttal - Stimulation/Fracture Prediction Modeling
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Stimulation/Fracture:

Response -The thrust of this entire effort is to develop a computational test bed for evaluating mechanical methods of permeability enhancement in engineered geothermal systems that provides a quantitative understanding of these enhancement methods before they are applied, via costly experiments, in the field. To save time and development costs we leverage, where possible, on existing Lawrence Livermore simulation capabilities to develop this test bed. We have one more year to complete in the development and testing program in this 3-year effort. This is the first full review of this project.

Response to Reviewer 35 - correct in stating that the full relevance/impact/significance will only be realized when the work is complete and the test bed is applied to problems of interest.

Response to Reviewer 10 - makes some good comments about relevance and impact. However, we must emphasize that broad capability development does not occur uniformly. Capabilities, such as thermal stress feedback in mechanical models, are generally added one at a time. We have made exceptionally significant strides during the first half of this test bed development project by creating a unique hydrofracture propagation capability that can simulate the early-time response of a geothermal zone to hydrofracture and we are now attempting to verify this behavior by comparison to analytical models and lab experiments. Only as these existing capabilities are verified, will we add new capabilities as suggested by the reviewer. As expressed in the supplementary slides, we have already added thermal feedback by advection but also agree with Reviewer 10 that we will need to add thermal stress feedback. Regarding the use of high explosive (HE) propellants referred to by Reviewer 10, we agree that it could be useful but its value is indeed undetermined. We neither endorse the use of this enhancement technique nor discourage it. We are only trying to develop the computational means of testing many different ideas, such as the use of borehole propellants, in different types of geothermal regimes before actually taking these ideas into the field to test. We regret that the principal objective of developing a computational test bed may have been unclear to this reviewer. The purpose of this work is not model development or exploring hypotheses. It is to develop a sound computational test bed (i.e., linked computer programs to form a comprehensive simulator) for evaluating methods of permeability enhancement in initially specified geothermal target zones.

Response to Reviewer 16 -We agree with Reviewer 16 that the use of this test bed for modeling permeability enhancement approaches will permit a more precise decision-making process.

Rebuttal Comments for Scientific/Technical Approach - Stimulation/Fracture:

Response - To date, the focus of our work has been on the development of a viable test bed for simulating hydromechanical processes. We have not attempted to justify the realism of models of geothermal target zones used in developing and making preliminary evaluations of this test bed. Such geothermal target zone models represent the initial conditions that are input into the test bed. One concern in developing this test bed is that, while we can adequately represent the initial conditions of a target zone pertinent to the application of a given mechanical enhancement process, we do not attempt, at this stage, to justify that the initial conditions we employ are necessarily the most appropriate to represent a given geothermal system.

Given the above statement, we agree with Reviewer 35. We hope to do some realistic evaluations of permeability enhancement using data available from our industrial partners in the final year of this effort.

Response to Reviewer 10 - Reviewer 10 brings up a good point that the verification of the response of a model with real data is a big challenge. However, this challenge exists mainly because of the limitations on obtaining adequate subsurface data (i.e., the available data are often sparse). This sparseness of the available data result in grossly under determined or under defined geothermal models. Such poorly determined regimes can be dealt with using an uncertainty quantification approach. We are using this uncertainty quantification approach in a variety of earth science areas at LLNL and plan to integrate it into our test bed capability during a subsequent project. The Large Block Test (LBT) mentioned by Reviewer 10 is only supposed to provide rudimentary information (fracture aperture, fracture density, orientation, etc.) about a fracture regime at this stage of the project. Currently our test bed is very useful for providing insight into how hydrofracturing can affect a given or even random distribution of fractures in a geothermal target zone.

Response to Reviewer 16 – Reviewer is correct in stating that our approach results in a test bed that allows examining dynamic fracturing processes. While there is always an element of challenge in incorporating a new feature, such as multiphase fracture flow, we already have the coding on hand to do this. Also, we can adjust fluid viscosity with our current capability.

Rebuttal Comments for Accomplishments, Results and Progress - Stimulation/Fracture:

Response to Reviewer 35 -We are pleased that Reviewer 35 recognized that our work is on track. In fact, it is probably slightly ahead with regard to stated milestones.

Response to Reviewer 10 - We agree with Reviewer 10's assessment in this category. We are attempting to get useful data sets from our industrial partners to use in the final year of this effort.

Response to Reviewer 16 -We mostly agree with Reviewer 16's summary, but also state that flow between fractures and matrix will be added as a feature before completion of the project and we hope to use other examples of initial conditions than those derived from the Large Block Test (LBT).

Rebuttal Comments for Project Management/Coordination - Stimulation/Fracture:

Response to Reviewer 35 -We agree with Reviewer 35's assessment on project management. Thanks. Regarding benefits reaped from communication with industry, we are still in the early stages and expect to have more tangible "gleanings" by the end of the project. The last year of this effort is focused on working more closely with industry as we now have a modeling capability to bring to the discussion table.

Responset to Reviewers 10 , 16 - Thanks

Rebuttal Comments for "Overall" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Strengths" - Stimulation/Fracture:

Response to Reviewer 10 - We agree with Reviewer 10's comment

Rebuttal Comments for "Weaknesses" - Stimulation/Fracture:

Response to Reviewer 10 - We mostly agree with Reviewer 10's comment. However, we reiterate that we make every effort, where possible, to verify our test bed capability against real data. Unfortunately, quality data from a well-defined system is currently available (for the most part) only from well controlled laboratory experiments and not from real geothermal systems. Some of the other Geothermal Technology Program projects that are funded (e.g., tracking the progress of hydrofracture using induced seismicity) have the potential to provide additional data from real geothermal systems, and we hope to use this data to evaluate our test bed capability.

Rebuttal Comments for "Suggestions for Improvement" - Stimulation/Fracture:

Response to Reviewer 10 - In response to Reviewer 10, our stated plan in the third year is to use the best available geothermal data that is available to us through our industrial partners.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10302
Presentation Title: FRAC-STIM: A Physics-Based Fracture Stimulation, Reservoir Flow and Heat Transport Simulator
Investigator: Podgorney, Robert (Idaho National Laboratory)
Panel: Rebuttal - Stimulation/Fracture Prediction Modeling
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Stimulation/Fracture:

Response to Reviewer 35 - Evaluating the code against field data is underway and will be documented in the final report and at the GRC meeting this fall.

Rebuttal Comments for Scientific/Technical Approach - Stimulation/Fracture:

Response to Reviewer 35-Agreed, there simply wasn‘t enough time allotted for the presentation to delve into that level of detail. I did provide about 10 citations at the end of the presentation where this information has been presented (at Stanford, GRC, GSA, etc.) and would be happy to provide PDFs of all the papers and presentations

Response to Reviewer 10 -Thank you for the kind words regarding the commendable approach. For clarification however, we can and do leverage ―legacy” thermodynamic databases (such as IAPWS steam tables) and published/common constitutive models (such as relative permeability functions, etc.) We are working on developing physics based models for stimulation response, fracture permeability, etc.

Rebuttal Comments for Accomplishments, Results and Progress - Stimulation/Fracture:

Response to Reviewer 16 - The instabilities I mentioned during the presentation relate to very high thermal Peclet number flows, common with all continuum-based methods. These instabilities are not a significant problem as the code is functional in its present state, but addressing the instability will make the code easier to use and allow for simulating much higher velocity flow in fractures. This issue is being worked on as a high priority and should be addressed before the end of the project. We are implementing Stabilized Upwind Petrov Galerkin (SUPG) solvers, among others, to address this issue.

Rebuttal Comments for Project Management/Coordination - Stimulation/Fracture:

Response to Reviewer 16 - We submitted a software distribution plan to GTP prior to the peer review but after submission of the peer- review materials. The plan was acceptable to GTP. Basically we will distribute an install disk to interested parties.

Rebuttal Comments for "Overall" - Stimulation/Fracture:

Response - There was no comment here but I wanted to use this opportunity to thank the reviewers for their insightful comments and GTP for putting on the peer-review. I found it very informative and beneficial. The working group sessions on Friday were also well done and timely.

Rebuttal Comments for "Strengths" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Weaknesses" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Stimulation/Fracture:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10303
Presentation Title: Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.
Investigator: Pritchett, John (Science Applications International Corporation)
Panel: Rebuttal - Stimulation/Fracture Prediction Modeling
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Stimulation/Fracture:

Response to Reviewer 35 - notes that *"… it is unclear to me how the DOE will facilitate use once the product is completed."* We have similar concerns. In the past, DOE didn't seem to have a definite procedure in place for the dissemination of DOE-supported software developments (and associated documentation) to the user community. The same issue is likely to come up regarding the other software-development projects presently being supported by DOE, not just this one. It is our hope that the new DOE Geothermal Data Repository will be capable of hosting copies of such software and documentation on its servers for download by prospective users.

Rebuttal Comments for Scientific/Technical Approach - Stimulation/Fracture:

Response to Reviewer 35- expresses the hope that we will be able to use data from the European Soultz field for verification and validation of the new simulator. Since our Swiss GEOWATT partners have already used their HEX-S simulator to model the stimulation of the fracture system at Soultz, we are confident that we will be able to use the same data set to test the new simulator.

Response to Reviewer 10 -commenting about the electrokinetic SP aspects of the new simulator, expresses concerns about whether such signals will be detectable under practical circumstances, and also makes similar remarks under ―overall comments" (see below). Previous studies have shown that the electrical signal strength caused by high-pressure hydrofracturing operations will be well above detection thresholds and that the SP transients will appear within a few weeks at most after well stimulation, as long as the sensors are located within a few hundred meters of the stimulated fracture. This means that the electrodes will have to be located downhole in nearby shut-in ―observation" wells, not at the earth surface. After stimulation has been completed and during subsequent routine production/injection operations, there will also be ongoing underground SP-transient signals, but these will be of relatively low amplitude and may not be useful for diagnostic purposes, which mainly depends on reservoir permeability and the proximity of a suitable electrode array. The main purpose for incorporating the SP capability was to permit the strong electrical signals caused by high-pressure fracture stimulation operations to be characterized so that these data may be combined with microseismic data and any available tracer results to try to appraise the detailed fracture system structure. Any relatively low-amplitude SP information obtained later would be a bonus, and could also be modeled and interpreted using the new simulator.

Response to Reviewer 16 - makes several comments. This reviewer correctly notes that the software under development is restricted to single-phase fluid flow – this was deliberate, since the considerable complications involved in using a multiphase treatment (e.g. STAR) are not really needed for the deep, high-pressure and moderate temperature systems of most probable interest for EGS applications. At 4 kilometers depth, for example, the hydrostatic pressure will probably exceed 300 bars, and even if the temperature at that depth is as high as 250 degrees Celsius, the bubble-point pressure will be less than 40 bars. It is exceedingly unlikely that downhole production pumps will be capable of reducing the reservoir pressure from 300 bars to only 40 bars, and even if they do, such a large pore pressure reduction would almost certainly cause the permeable fractures to collapse, rendering the reservoir impermeable again and terminating field operations.

Reviewer 16 expresses uncertainty about whether or not the thermoelastic module is *"fully coupled."* It is not. The thermoelastic module is driven by the pore pressure, partial density, and temperature changes which are computed by the thermohydraulic module, and provides estimates of the changes in regional stress over time. These stress changes then influence the change of "fracture patch apertures" and thus the temporal changes in reservoir permeability. In the HEX-S code (a direct ancestor of the present software), these temporal changes in regional stress were not taken into account, but that code was nonetheless capable of carrying out a successful simulation (and forecast) of the growth of the fracture system at Soultz. We are taking the next logical step forward.

Reviewer 16 comments, *".. no new developments, adopted existing software codes."* It is certainly true, as we noted in our presentation, that the new simulator is based in large part on techniques used in earlier simulation software developed by the present project team including STAR, HEX-S and SPFRAC, however the new code is being written entirely from scratch in Fortran 90 (both STAR and SPFRAC are Fortran 77 codes), and incorporates features that none of its predecessors could treat (see above regional stress discussion, for one example). Neither HEX-S nor SPFRAC incorporate an energy equation, so those codes cannot consider either thermal rock contraction or thermal breakthrough phenomena. Of the three, only HEX-S incorporates a full tensor representation for rock permeability; this capability is included in the new simulator. A more flexible treatment of production/injection wells is used in the new simulator than in any of the existing codes. No other geothermal reservoir simulator exists to our knowledge that can treat the combined influences of fluid flow, heat flow, non-equilibrium transient heat transfer between fluid and rock, anisotropic fracture permeability, nonlinear fracture aperture changes, tracer transport, and electrokinetic effects.

Reviewer 16 comments that: *"The influence of the ‚fracture patches' depends on the size of the 'disks', especially their flowing capability via interconnectivity. This has been apparently overlooked."* Actually, the role of the "fracture patches" in the present simulator, as in HEX-S, is to represent fracture locations, orientations, and apertures, and to permit aperture changes to be computed. Then, the instantaneous tensor permeability components for each macroscopic grid block are obtained by a "census" procedure involving those "fracture patches" which lie wholly or partially within the grid block. Permeability is thus defined relative to the grid blocks, not the "fracture patches". In a highly fractured region, there will be numerous "fracture patches" within each grid block. In this fashion, a continuous distribution of fracture permeability is obtained.

Rebuttal Comments for Accomplishments, Results and Progress - Stimulation/Fracture:

Response to Reviewer 10 - notes that: *"There may be issues related to the readiness of adequate field data at the time this project reaches completion."* We recognize this difficulty; the only reasonably complete data set that is presently available is that from Soultz, which we definitely plan to use for code validation. We had hoped that one or another of the ongoing DOE-supported U.S. EGS field projects would be far enough along to be useful for modeling purposes, but to date this has not been the case. Other possibilities include trying to find other foreign data sets and/or asking DOE for a no-cost time extension to await U.S. project results. The problem is not yet urgent, but will have to be dealt with one way or another by about a year from now.

Rebuttal Comments for Project Management/Coordination - Stimulation/Fracture:

Response to Reviewer 16 - comments: *"Non-existent, single person effort."* Although the SAIC PI is a major participant in this project, two other full-time members of the SAIC senior technical staff have made significant contributions to the work, and SAIC has now twice employed PhD-candidate graduate students as summer interns to work on the project as well. In addition, two senior members of the GEOWATT technical staff in Switzerland are significantly involved.

Rebuttal Comments for "Overall" - Stimulation/Fracture:

Response to Reviewer 10 - comments are addressed under ―scientific/technical approach" (above).

Rebuttal Comments for "Strengths" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Weaknesses" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Stimulation/Fracture:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10304
Presentation Title: Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs
Investigator: Ghassemi, Ahmad (Texas A&M University)
Panel: Rebuttal - Stimulation/Fracture Prediction Modeling
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Stimulation/Fracture:

Response - We appreciate the reviewer‘s time and find the comments and questions to be useful in completing the remaining part of the projects.

Rebuttal Comments for Scientific/Technical Approach - Stimulation/Fracture:

Response - Fracture/natural fracture interaction is a very important and complex problem. We have used our approach in 2D with success. Extension to 3D is ongoing.

Rebuttal Comments for Accomplishments, Results and Progress - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Overall" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Strengths" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Weaknesses" - Stimulation/Fracture:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Stimulation/Fracture:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10305
Presentation Title: Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems
Investigator: Gutierrez, Marte (Colorado School of Mines)
Panel: Rebuttal - Stimulation/Fracture Prediction Modeling
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Stimulation/Fracture:

Response to Reviewer 35 - Comments on the progress of the project are given below. There seemed to be some misunderstanding on the main objective of the project which is to produce a true-3D hydraulic fracturing and proppant flow/transport computer code. All other tasks, such as the experimental work, application to case histories and PFC3D modeling, provide supporting roles for the code development. One role of the supporting tasks is to clarify some aspects of model formulation (e.g., role of heterogeneities on fracturing, and the role of settling, segregation and clogging on proppant transport). The other role is to provide data to validate the computer code. To date, the programming of the computer code is only slightly behind schedule while the other tasks are on or ahead of schedule.

Response to Reviewer 10- This is a very valid comment and we agree that the DD formulation puts some limit on how to account for heterogeneities on fracture propagation. However, as discussed in our proposal and in the outline of the model given in the peer review presentation, different types of heterogeneities will be directly and indirectly accounted for in the model. These include layered rock formations (e.g., a larger fracture will form faster in weaker/softer formations than in more competent formations), local changes in in-situ stress, and rocks with spatially different rock mechanical and fracturing properties. The presence of existing fractures can determine fracture propagation and this will be done by giving fractured rocks lower rock mechanical properties and fracture toughness than intact rock. Already, the scope of the project is lofty (as noted by Reviewers 35), which is that of modeling 3D fracture propagation, and as a result, other aspects of fracture propagation have to be simplified. Despite the simplifications, the PI believes that the 3D hydro-thermo fracturing and proppant transport will be a valuable tool for planning of EGS reservoir stimulation. We note that our work is directly in response to a problem reflected in the DOE FOA.

Response to Reviewer 16 -This comment is in direct contradiction with Reviewer 35 who stated that our goal is ―lofty" and ―perhaps out of reach." We respectfully disagree with Reviewer 16 and feel the comment may have been made without a full understanding of our project goal. As was listed in the PowerPoint presentation given during the peer review, the following are the main innovative components of the proposed 3D hydro-thermal fracturing code: 1) Truly three-dimensional, 2) Able to model coupled hydro-thermo-mechanical (HTM) processes involved in EGS reservoir creation, 3) Incorporates thermally induced stresses and fracturing, and temperature-dependent fluid and rock properties, 4) Can deal with the entire process of the hydraulic fracturing and proppant flow and transport, 5) Can deal with layered formations with different rock mass properties, 6) Considers deviated boreholes with arbitrary deviation angles, 7) Incorporates non-Newtonian rheological behavior of the fracturing fluid and proppants, and 8) Considers variable injection rate and proppant concentration. As noted in the presentation, to the PI's knowledge, a true 3D hydro-thermal fracturing and proppant simulation code is not commercially available.

Rebuttal Comments for Scientific/Technical Approach - Stimulation/Fracture:

Response to Reviewer 35 - We appreciate the concern that the project appears to be addressing/attempting too many topics. We assure the reviewer that all the project tasks are essential to ensure the success of the project's goal of developing a true 3D hydro-thermal fracturing and proppant simulation code. The progress of the project will be discussed further below. The issue of relating rock material parameters to hydro-thermal fracturing is being addressed by conducting laboratory rock mechanical and index tests on core samples of the materials that will be used in the scale model tests. In this manner, rock index properties and mechanical strength can be correlated with fracturing toughness and strength. Also fundamental research is being done to relate basic rock mechanical properties to fracture toughness using discrete element modeling and PFC3D. The issue of scale effects is always a challenging one. Strictly, the model to be developed in the project should be validated only using field data however a major problem in field tests is the precise delineation of the extent and geometry of an induced fracture. This is why we are performing scale model tests, to accurately characterize the geometry of the fracture and compare the fracture geometry with model results. By using both scale model test data and data from full-scale field tests, we are confident that the proposed model can work on different scales.

Response to Reviewer 10 - We thank Reviewer 10 for this comment. We agree that our research addresses a difficult problem and that the proposed code cannot address all types and geometries of hydraulic fracturing in EGS reservoirs, and to do so within reasonable time and budget is not possible. However, our work should provide significant advancement toward a true 3D hydro-thermal fracture modeling in EGS reservoir creation. As indicated in our response above, the proposed model will have capabilities to handle different types of heterogeneities.

Response to Reviewer 16 -The presentation given during the peer-review listed two publications resulting from the project with one more currently in review. As far as technologies are concerned, these are in progress as documented in our progress report for quarter ending in June 30, 2011, and research results will be delivered according to the project schedule.

Rebuttal Comments for Accomplishments, Results and Progress - Stimulation/Fracture:

Response to Reviewer 35 -We disagree. Our latest progress report for the quarter ending June 30, 2011 will document that the experimental device needed to carry out the experiments is now 95% complete, and in fact, we have now successfully performed our first scale-model hydraulic fracturing test. Results from this initial test will be included in our quarterly report.

With regards to the AE measurement system, we agree that development of such technique is very challenging for field applications. However, we did not intend to develop a laboratory AE monitoring from scratch. In fact, ordered a turnkey AE monitoring system which includes both the hardware and the software to analyze AE data from an establish AE monitoring company. We note that technology for laboratory AE measurements for such application material and damage detection is far more developed than large-scale field geological AE measurements. The AE system has now arrived and a student has already trained in its use. The AE system was utilized in our first hydraulic fracturing test and initial results showed good correlation between hydraulic fluid pressure and flow data with AE signals (i.e., AE signal followed the trend of fluid pressure increase and decrease with fracturing, indicating that the AE measurement system provides a reliable manner of monitoring the progress of hydraulic fracturing). Results was presented in our quarterly report for June 30, 2011.

The software development is slightly behind but we are still confident on the timely completion of the computer code.

Response to Reviewer 10 - The algorithm to couple DD and proppant flow and transport was presented during the 2010 peer review meeting and was outlined in the proposal. As a clarification, we are not coupling PFC with our DD code. The proppant flow and transport modeling is based on continuum mechanics and not discrete element modeling. The PFC code will be used to help in the formulation and validation of the continuum proppant flow and transport formulation, and the DD hydro-thermal fracturing code (please see our previous comment above on the use of PFC).

Response to Reviewer 16 - Finding ―good" students with the right background is not an excuse but a reality that every university research project faces. Moreover, it takes time to train students and to get them up to speed in the research.

Despite these initial challenges, we believe we are making good progress towards the timely and successful completion of the project.

Rebuttal Comments for Project Management/Coordination - Stimulation/Fracture:

Response - The PI has instituted a strict work schedule on all graduate students working on the project. Regular group meetings and meetings with individual students, and regular reporting were conducted for the project. Project tasks were clearly delineated, assigned and explained to students. The project is actually ahead or on schedule in most project tasks and only slightly behind on the code development.

The PI has provided timely and regular financial and technical reports to DOE and has diligently provided details of our on-going work. To date, we have not reported any substantial slip in our schedule.

The PI regrets that he has not been able to attend the June 2011 peer review meeting due to due to a very pressing prior commitment, and had to rely on a graduate student to give a status report of the project. As result, a comprehensive overview and presentation of the true status of the project may not have been made during the peer review meeting.

Rebuttal Comments for "Overall" - Stimulation/Fracture:

Response - We emphasize that our project is focused on a specific problem which is that of the development of a computer code that can simulate the creation of real 3D fracture propagation and proppant flow and transport in EGS reservoirs. This focus directly addresses one of the research areas identified by DOE in their FOA. We believe that the code will have several new innovative components not currently addressed in existing commercial hydraulic fracturing codes. Admittedly, there will be some limitations, in particular on the application of the code outside the scope of applicability of the code. We again reiterate that we are on track as far as the timely and successful completion of the project is concerned as documented in our progress report for the quarter ending in June 30, 2011.

Rebuttal Comments for "Strengths" - Stimulation/Fracture:

Please see our comments above.

Rebuttal Comments for "Weaknesses" - Stimulation/Fracture:

Please see our comments above.

Rebuttal Comments for "Suggestions for Improvement" - Stimulation/Fracture:

No Response Entered

Supercritical Carbon Dioxide/Reservoir Rock Chemical Interactions

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11001
Presentation Title: Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water
Investigator: Petro, Miroslav (Symyx Technologies, Inc.)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response- There appears to be limited consensus among the peers on the relevance of scCO2 EGS and what the research should address, so we appreciate all of the reviewers comments and suggestions and will try to respond better to the presented needs and expectations in our further work.

Response to Reviewer 44 - As mentioned at the review but apparently still unclear to most reviewers, the "hard-to-get" data are those from untested-yet territories such as mineral behavior in supercritical CO2 with traces of water or from known environments but more extreme pressure & temperature. That's based on our interaction with experts in the field and the Peer Review process is helping us to shape it up further.

Response to Reviewers15, 68 - Due to Novation, and because we had to build from scratch rather than simply use the originally proposed pre-existing system as it become unavailable, the program became front-loaded and its schedule has shifted for over 7 months. At the time of the review, we were just finishing the system validation and haven't started the experimental tasks yet. We understand the disappointment that comes from spending on building a system rather than generating data for benefit of the whole geothermal community, and will re-focus our effort to turn it around and show the usefulness of the system.

Response to Reviewer 68 - The reviewer doesn't seem to recognize or appreciate the unique feature of capturing fluid chemistry at high temperature-pressure in a high-throughput way. Per our knowledge, no available reactor system can do that and no specific system has been mentioned to us when several experts were asked.

The system is well capable of performing experiments in water-wet scCO2. It hasn't been executed by the review time, but we already experiment in those environments and will report on in the quarterly EERE updates.

Yes, the minerals addressed at the review are the most common, which was one of the reasons for their selection as a starting point. We plan to update our mineral / rock collection as we go. The truth is that we are still learning on weaknesses in the thermodynamic database, which takes time as some of the experts who could help us treat us as competitors.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response to Reviewers 44, 30, 15 - Useful suggestions. We plan to look at the high-temp CO2 phase behavior and extend our analytical sensitivity limit toward high dilutions. Regarding the extremely high pressures, unfortunately, reaching above 5,000 or 10,000 psi would be extremely difficult / costly, so will try to assess the pressure effect by extrapolating from measurements at gradually increasing pressures at much lower levels. This might still be accurate enough if no further phase changes are expected. Overall, no significant pressure effect is expected and it is in general a less interesting variable than temperature.

Response to Reviewer 45 - Even if the focus of our initial experimental tasks is on thermodynamics, rather than kinetics, we do see a difference in dissolution kinetics when comparing rates at which solubility equilibrium is reached and plan to compare two different particle sizes in our batch experiments for exactly the reasons stated by the reviewer. The kinetics will become our focus only after additional modification of the system, This modification is planned only after generating a volume of relevant thermodynamic data.

Response to Reviewer 68 - The $4M effort, representing the whole project with both DOE and our share over 3 years, goes much beyond what the reviewer comments. We do agree that water-wet scCO2 experiments could be the key, and are now equipped to go there. The fact that similar systems and studies were around for decades, but did not address those issues; this was the triggering moment for our proposal.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewers 44, 45, 30, 15 - There seem to be an understanding that a vast majority of our effort has been devoted to developing the instrumental capability..Some of the reviewers noticed the pause in the program and the shift in schedule, resulting in a lack of geothermal rock-fluid interaction. This is a correct observation, as the preliminary solubility data were presented at the Peer Review for system validation purposes only.

Response to Reviewer 68 - We remained within the originally proposed budget, even if we have to actually build all of the equipment instead of just adopting an existing system as was originally proposed. It isn't a simple suite of reactors in an oven that makes it unique and complex, but the on-line analytics that allows sampling and chemical fingerprinting while preserving the fluid composition at the specific conditions.

Barite is being used primarily as a calibrant in our study, but has a relevancy to the geothermal program. It is a common mineral introduced into geothermal sites as a weighting agent for drilling fluids, possibly causing severe problems by clogging the fractures, and lowering overall permeability. It is difficulty to clean and therefore is among the minerals of geothermal interest to at least some experts. www.petroleumnews.com/pntruncate/617082317.shtml

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Response to Reviewers 44, 45, 30, 15, 68 - We are encouraged by the reviewers comments recognizing the challenge of the program Novation and acknowledging that the transition to another company has been successfully accomplished. The subcontract with LBNL was signed just before the Peer Review, so the positive impact of their full engagement wasn‘t yet evident.

Response to Reviewer 68 – The "Project spending in line with timeline" statement contradicts all of the other spending comments of this reviewer, but we appreciate the acknowledgement.

Rebuttal Comments for "Overall" - Supercritical C02:

Response to Reviewers 45, 15 - Agree with the comments. We will align our efforts with the program objectives and clearly communicate progress via quarterly reports. We also recognize the overlap with other projects through our increasing participation in geothermal events. We intend to find areas complementary to others, as well as close some of the gaps in our program, as we progress further.

Response to Reviewers 30, 68 – The PI of this project has over 50 peer reviewed papers and more than 30 patents, most from the area of chemical interactions in other fields, such as the life sciences. Thermodynamic complexities, in general terms, are an inherent part of that experience. Also, other scientists of the PARC team are well recognized in their perspective fields of chemical analysis and chemical / electro-mechanical engineering. What we lack is the geological knowledge and geothermal expertise. For that, we rely on our LBNL partners, who will bring quickly bring our technical depth in the earth sciences up to the desired level.

Rebuttal Comments for "Strengths" - Supercritical C02:

No Response Entered

Rebuttal Comments for "Weaknesses" - Supercritical C02:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response - We will take into account and act upon all constructive criticism and suggestions for improvement - will communicate on our progress in EERE reports, interact more dynamically with and learn from those with geothermal experience, get deeper into inorganic thermodynamics, streamline our plans towards the overall objectives, and make our work to complement rather than repeat or compete with others.

Our thanks to all of the reviewers and DOE program managers.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11002
Presentation Title: An Integrated Experimental and Numerical Study: Developing a Reaction Transport Model that Couples Chemical Reactions of Mineral Dissolution/Precipitation with Spatial and Temporal Flow Variations in CO2/Brine/Rock Systems
Investigator: Saar, Martin (University of Minnesota)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response to Reviewer 44 -We may also investigate fractured media but focus on porous media as we are mostly interested in using CO2 as the geothermal working fluid in sedimentary formations. We will likely also investigate fluid-mineral reactions in the CO_2 phase; however we will focus on the water-phase as most reactions are expected to occur there.

Response to Reviewer 45 -Upscaling is tough and will be investigated.

Response to Reviewer 15 - Some significant results were presented (e.g., of geochemical data base, pH meter, LB simulations, PIV test of LB simulations).

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response to Reviewer 45 -PIV and LB methods are indeed needed as we need to investigate the small-scale permeability field change due to reactions. By taking X-ray tomography images before and after experiments and simulating fluid flow through such 3D pore space geometries, we can determine permeability field changes as lattice-Boltzmann methods do not require permeability field entries and can thus serve as numerical permeameters. The PIV experiments are needed to test our LB code to ensure it works properly.

Response to Reviewer 15 -See comment (above) concerning LB simulations. Regarding a maximum of 30 MPa pressure, that should not be a problem as the pH does not change much from 30 MPa to 50 MPa, thus the geochemistry should not change much in that range. However it should be noted that increasing pressures by that amount makes the experimental setup much more complicated, expensive, and dangerous. In addition, we are primarily interested in shallower sedimentary formations (as noted above).

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewer 45 -For PIV experiments, see justification above. They should be counted as an accomplishment. Pore-level simulations are being conducted.

Response to Reviewer 15 -Correct. At the moment we are mostly interested in CO2 sequestration targets with elevated temperatures. Samples from other sites may be included later.

Response to Reviewer 68 -See above comment.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Response to Reviewer 68 -Spending to date was provided in a slide that was presented.

Rebuttal Comments for "Overall" - Supercritical C02:

Response to Reviewer 45 -Good point. We have been modeling fluid flow in pore spaces for years; however, we are just now ready to start modeling fluid flow in the specific samples investigated.

Rebuttal Comments for "Strengths" - Supercritical C02:

Response - No negative comments were presented.

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response to Reviewer 45 -We believe the PIV experiments are a good way of testing the LB code in a rigorous way.

Response to Reviewer 30 -We believe most of the reactions will happen when water is saturated with CO2 or potentially to some level when CO2 contains some water. Dry CO2 is expected to show very little reaction with minerals. With that said, we still plan to run some dry CO2 experiments to test this hypothesis.

Response to Reviewer 15 -We are primarily interested in combining CO2 sequestration with geothermal energy usage and are selecting our sites accordingly. However, we plan to include some hard rock samples as well. The pressure issue was already addressed above. Increasing pressure is not expected to make a significant geochemical difference due to the leveling of the pressure-pH curve between 30MPa to 50MPa. Using increased pressures greatly increasing the costs and dangers of running such higher pressure CO2/water experiments.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response to Reviewer 45 -We were just granted ~$800K from the University of Minnesota (with Saar as co-PI) for our own X-Ray Tomography system which we plan to install in our department by the end of this year. Then, we can scan many samples and get 3D pore space geometries of samples before and after they reacted to fluids.

Response to Reviewer 30 -We may look at fracture issues in the future. Currently we are mostly interested in sedimentary basin CO2-geothermal applications.

Response to Reviewer 15 -See comment immediately above.

Response to Reviewer 68 -This is actually a misunderstanding. The sketch of the flow-through design was taken from one of Sally Banson‘s publications (and cited as such). She has separate inlets for water and CO2 as she looks at mixing within the core. We actually carefully designed our system to pre-equilibrate the water and the CO2 at relevant pressures and temperatures (including T>100 °C) before it enters the reaction cell as otherwise geochemical analyses of fluid-mineral reactions are not really possible. I apologize for providing a figure that is only roughly applicable and will make sure that next time the figure reflects our exact experimental setup.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11003
Presentation Title: Laboratory and Field Experimental Studies of CO2 as Heat Transmission
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response - We thank the reviewers for their comments. These comments will definitely be used to improve the project over the remaining project duration.

Response to Reviewer 45 - Reviewer inquired about the: ―*… relationship of project with presentation # 11004"*. Presentation # 11004 (an ARRA project, Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid) is an experiment initially designed for multiphase flow and reactive transport model development for CO2-EGS systems with fluid dynamics and heat transfer. Later, we thought we needed to understand water-rock reaction processes and to also have a field component. Therefore, we proposed this AOP-1 project using Japan's Ogachi dissolved CO2 injection as a field component. The comment that this work is the same as project #11004 is therefore incorrect. This AOP project includes field and modeling components of the Ogachi site (not included in the ARRA project). The ARRA project includes code development, natural analogues studies, simulations to investigate the general behavior of EGS/CO2, and setting criteria for a field application of EGS/CO2. These are not included in the AOP project. The laboratory component is primarily funded by the ARRA project. The results are shared by the current AOP project.

Reviewer 45 stated: *"Using only porous media in the lab experiments limits the applicability of the results to non-fractured media. Most geothermal sites, planned or operational, are fractured."* We purse a step-by-step approach, and use a porous media as a first step to setup a base and test facility. We will perform heat transfer lab tests using fractured-rocks. In addition, for the laboratory scale, the use of a fractured medium at the temperatures and pressures of interest adds additional complexity and would not be the best initial test.

Response to Reviewer 30 -Reviewer 30 stated. *"Japan is injecting a brine-CO2 mixture T=210 ^oC; P= 100 bar. Claims about the heat recovery were not substantiated by an engineering assessment."* The main objective of the field component using the Japan Ogachi site is to study mineral alteration and solubility and kinetic data of minerals in a two-phase (water-CO2) mixture conditions. The heat recovery aspect will be addressed in the laboratory component.

Response to Reviewer 15- Reviewer stated: ―The objectives are very ambitious and non-trivial. However, it is not clearly explained how the proposed work schedule is linked to these objectives." Laboratory studies are time consuming, and are occurring in parallel with other work. The objectives can be partially addressed by this project, but this project is closely related to other DOE-funded projects. The one project alone is hard to accomplish the goal of CO2-EGS. However, in this project we will perform more numerical simulations under filed conditions and sensitivity studies.

Response to Reviewer 68 – Reviewer noted: ―With uncertainty over the Ogachi field test, it is not clear that this project will achieve the original objectives. Part of the objective concerning mineral alteration under water/CO2 mixture conditions has been achieved Ssupercritical (sc) CO2 injection into Ogachi has been delayed because of the 2011 Earthquake in Japan. As a result, we will use data from SECARB's (Southeast Regional Carbon Sequestration Partnership) Cranfield CO2 sequestration site where the temperature has reached 120^{o}C. Alternatively we will use data from the Springerville/St.Johns natural CO_2 Dome in Arizona, which is a DOE geothermal program funded CO2-EGS demonstration site.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response - Regarding ―The uncertainty over the Ogachi field test" as commented by Reviewers 45, 30, and 15, part of the objectives on mineral alteration under water-CO2 mixture conditions has been achieved, scCO2 injection into Ogachi has been delayed because of Earthquake, as mentioned above we has adjusted this change and will use data from SECARB's (Southeast Regional Carbon Sequestration Partnership) Cranfield CO2 sequestration site and Springerville/St.Johns natural CO_2 Dome in Arizona.

Concerning about ―The modeling work on the experimental project needs some fundamental help", they may be less focused because of doing both. This is a possibility we are monitoring. The student has not been abandoned to work alone, however, and has several competent modelers and experimentalists to help when needed. If this becomes a problem, we will obtain help in the modeling.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewers 45, 15 and 68 – Reviewers noted that, *―The progress seems confined to some lab experiments in porous media, simulations of this lab experiment that are in the ball park of the right values and some 5-spot TOUGHREACT."* It took quite a while to setup this lab experiment facility. We will do the test using fractured rock in the future. For the modeling component, we have already performed a number of calibration, validation, numerical simulations, and sensitivity studies on fluid dynamics and geochemistry variations, but we did not present the details. We will do more modeling and sensitivity studies under field conditions and/or using actual field data. We thank the reviewers for their comments and recognize that a great deal more needs to be done to really make headway in the understanding of CO2's ability to act as the working fluid in an EGS situation.

A Review noted: *"Compared to Steam/water, CO2 could extract heat at 50% higher rates. However, this claim has not been substantially demonstrated even using available data."* This statement was cited from the paper of Pruess (2008), but 50% higher rates are under certain pressure and temperature conditions.

Rebuttal Comments for Project Management/Coordination - Supercritical CO2:

Response to Reviewer 30 – Reviewer requested: *"The reasoning behind having both the experimental and simulation lab scale work being done by the same student."* As in our response above, if needed we will get an additional person (a post-doc or graduate student) to perform the numerical simulation, letting the previous student focus on the experiment work.

Response to Reviewers 30 and 68 -*"Karsten Pruess is departing and he has been a driving force for this program."* LBNL Earth Sciences Division management has made a strong commitment to support this project and CO2-EGS research as a whole.

Response to Reviewer 30 – Reviewer questioned *"the coordination with PARC."* The PARC project has just started (being delayed because of a merger of the previous company). They have qualified people and some experimental facilities; we will help get them up to speed and fully use LBNL's resources and facilities.

Response to Reviewer 68 – Reviewer noted the *"uncertainty of Ogachi."* We will use data from one US CO2 sequestration site and one US CO2-EGS demonstration site as alternative sites for data.

Rebuttal Comments for "Overall" - Supercritical C02:

Response to Reviewer 45 – Reviewer noted: *"The majority of the work presented is numerical, not a lot of experimental backing, which seems odd given the title of the project."* The field experiments at Ogachi are separately funded by a Japanese Agency. Our project's objective, as designed in the original proposal, is to model aqueous and mineral changes induced by dissolved CO2 injection in the field experiment. Since Ogachi data may not be available, we did not present much on the field experiments.

Response to Reviewer 45- Reviewer noted: *"The goal is noble and seems reasonable, but the progress seems a bit slow and the focus on only CO2 flow in porous media (i.e. no fractures) seems limited."* This is only the first step. We will do lab tests using fractured rocks.

Response to Reviewer 30 – Reviewer noted: *"The project did a nice report on the 5-spot test over a multi-year period. Concluded that the fractured reservoirs have good properties for CO2 heat-transfer. The project objectives are ambitious."* We will do lab tests using fractured rocks and perform more numerical simulations and sensitivity studies to achieve the objectives.

Respoonse to Reviewer 15 – Reviewer stated: *"There has not been significant progress to produce results with significant impact. The findings about Peclet number are not significant and reflects a well- established phenomenon in forced convection. The innovation in the project is not clear. The planned laboratory test schedule and the field observations are not likely to produce results with significant impact."* We have pursed a step-by-step approach, and used a porous media as a first step to setup a base and test facility. Laboratory studies are time consuming, and are occurring in parallel with other work. We will perform heat transfer lab tests using fractured-rocks and numerical simulations under field conditions and sensitivity studies. Our showing of the Peclet number dependence was not to claim that we are the first to notice this, but rather to recognize that this is critical in scaling up.

Regarding *"The 5-spot production simulations are interesting but seem to have been done just to exercise the simulator and are not tied to a possible validation planned for execution in the field (or at least that was not made clear in the presentation)."* We will perform numerical simulations under field conditions and /or using field data.

Rebuttal Comments for "Strengths" - Supercritical C02:

Response to Reviewer 15 - Reviewer stated: *"This is a strong team and has yet chance to produce significant results in terms of a significantly improved TOUGHREACT. The improvements however may come not from testing in this project but from tests in other DoE-funded projects."* Yes, we have done a lot of code improvements to TOUGHREACT, especially dealing with high temperatures (up to 300 ^{o}C) using data from the literature and other projects. However, using the tests in this project we did improve solubility, thermodynamic and kinetic data of minerals embodied in the TOUGHREACT database.

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response - Regarding ―The Ogachi field ..." we have already stated that we will use two US alternative sites.

Response to Reviewer 30 -As suggested by Reviewer 30, we are refining the interpretation of the reactor experiments.

Response to Reviewer 15- Reviewer noted: *"The link with the experimental schedule and the model development is not well- established."* Our work schedule is linked to our objectives. For example, we have identified solubility and kinetic data of minerals through the Ogachi field modeling, which are a critical input of TOUGHREACT to handle mineral dissolution and precipitation. Laboratory studies are time consuming, and are occurring in parallel with other work.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response to Reviewer 45 -if needed we will get another person to perform numerical simulations.

Response to Reviewer 30 - we will perform stronger engineering assessments that will assist in aligning the experimental program goals with the end-user needs.

Response to Reviewer 15 -it will be great if the DoE Program Management can facilitate the collaboration among CO2-EGS project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11004
Presentation Title: Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response - We thank the reviewers for their comments. These comments and the verbal feedback we received will be used to improve the project over the remaining project duration.

The use of CO2 as a geothermal fluid is a potential game changing concept. There are many purely physical phenomena to investigate, as well as purely geochemical, and coupled processes. As such, application of such a concept should be well thought out in advance of any field test or application. The reviewers have brought up some of the many important considerations: the importance of properly validated quality simulations, flow in fractures, and the dryout process. These are topics that we have been diligently working to address.

- Clearly the construction of a robust simulator that is compared to and based on available data is a major success of the project. Continuing comparison to data as it becomes available will be performed to build additional confidence in the simulator (comments from Reviewers 44 and 68). Regarding Reviewer 44's comments, we agree that this work will be helpful to the program. We are currently performing simulations to investigate a number of conditions**,** dryout being only one of them.

- Regarding the comments (Reviewers 44 and 45) on the use of a porous medium instead of a fractured medium, for the purposes of performing a test to compare heat extraction from hot mineral medium by supercritical CO2 with numerical simulation using the appropriate simulator, a porous medium is perfectly adequate. For the laboratory scale, the use of a fractured medium at the temperatures and pressures of interest adds additional complexity and would not be the best initial test. The claim by Reviewer 45 that this limits the use of the results of these tests is overstated.

- The comment by Reviewer 45 that this is the same project as the previous presentation is incorrect. This project includes, among other things, code development (not included in the AOP project), natural analogue studies (not included in the AOP project), simulations to investigate general behavior of EGS/CO2 (not included in the AOP project), and setting criteria for a field application of EGS/CO2 (not included in the AOP project). This project does not include simulation of the Ogachi field project and several other facets of that project. There has been some overlap on the laboratory work, as both projects benefit from the same data.

- Our work schedule is linked to our objectives. We have added the capability of TOUGH2/TOUGHREACT to handle CO2 under the conditions of interest. This was very important for subsequent tasks. Studies of natural analogues are nearly complete, and along with current simulations will guide the criteria for field application of EGS/CO2. Laboratory studies are time consuming, and are occurring in parallel with other work.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response - Scale-up to the field scale is always difficult. Using a tool like a reservoir simulator that is able to simulate laboratory scale tests and has a track record for simulating field scale reservoirs is our method. Also, acknowledging the differences between scales (shown by the Peclet number dependence on heat transfer) aids in understanding the scale up. Different laboratory methods of investigating heat transfer in a fractured system are being considered. Reviewers 45 and 30 point out potential advantages and disadvantages of a single person performing the experiments and modeling (not code development which is performed by others). They may be less focused because of doing both. This is a possibility we are monitoring. The student has not been abandoned to work alone, however, and has several competent modelers and experimentalists to help when needed. If this becomes a problem, we will obtain help in the modeling. Reviewer 30 is concerned that the possibility of creating a reservoir cap is not supported by a convincing argument. We thank the reviewer for this comment and are rethinking this point. Regarding Reviewer 15‘s question of how lab tests of heat extraction from a sand pack help the project objectives, we apparently did not clearly state that performing laboratory tests and comparing them to well-modeled results builds needed confidence in the simulator. We agree that there are limitations to the experimental results, but understand the need for experimental data for model verification. In a field operation, the properties of CO2 could vary from subcritical to supercritical, and the simulator should be able to address such a change in conditions, thus the injection of cool CO2 in some of our experiments is acceptable. Our showing of the Peclet number dependence was not to claim that we are the first to notice this, but rather to recognize that this is critical in scaling up. We thank Reviewer 68 for comments that will improve our work and would like to assure the reviewer that we will certainly attempt to include suggested techniques considering pressure, temperature, sample size relevant for heat transfer, porous medium or fracture, x-ray transparency of vessels meeting the above criteria, and sample acquisition.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response - The presentation time was too short to show all the work accomplished to date, thus certain tasks were emphasized. We agree with Reviewer 44 that we are on the right track, and with Reviewers 45, 30 and 69 that more is needed in modeling our initial experiments. Indeed, more is in progress. Regarding the experiments being trivially simple to model with analytical solutions being available, the reviewer is assuming the properties of CO2 are constant over the temperature and pressure conditions of the test (the properties vary), that the vessel itself has no thermal mass (it is significant and spatially varied), that the heat input rate and/or insulation is ideal, and time invariant. Violations of these conditions require numerical solutions. In addition, a specific goal of the project is to build confidence in the simulator requiring comparison to a model using the simulator.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Response to Reviewer 15- Reviewer commented that plans include investigating the potential use of CO2 for chemical stimulation of water-based EGS is a major departure from the project objectives and needs to be clarified why is this required and how is it going to be done. Much of this work will occur as a consequence of investigating conditions for CO2/EGS. Conditions where permeability is enhanced or reduced and how this occurs will be noted.

Rebuttal Comments for "Overall" - Supercritical C02:

Response - We thank the reviewers for their comments, which have been mostly addressed above.

Rebuttal Comments for "Strengths" - Supercritical C02:

No Response Entered

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response to Reviewer 30 - Reviewer commented that the data in the literature for equations of state for CO2 under high-pressure should be explored before developing another model, particularly since this is not the strong expertise of the personnel involved. As part of this effort, we have been reviewing the literature on this subject. We are already aware of a number of existing models. All have their strengths and weaknesses. The main handicap of good existing models is that these are too computationally intensive for inclusion into a multiphase flow and reactive transport simulator. Therefore, our efforts have concentrated on looking for, and developing as necessary, computationally efficient and accurate models. Secondly, we do have the expertise to do this.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response - Thank you for your comments. We will use them to improve the quality of our work. Regarding Reviewer 15's comment, we would be delighted to include data and simulate tests performed by other organizations to build confidence in the simulator.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11005
Presentation Title: Synchrotron X-Ray Studies of Supercritical Carbon Dioxide/Reservoir Rock Interfaces (ANL)
Investigator: You, Hoydoo (Argonne National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewer 15 - Yes, we are trying to meet the schedule. At the moment, the flow-system ordered is delayed from the manufacturer. We expect the delivery within a month and expect to make significant progress before the end of FY.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

No Response Entered

Rebuttal Comments for "Overall" - Supercritical C02:

Response - We thank the reviewers for their comments.

Response to Reviewer 68 - Yes, we will work with our own rotating anode source or collaborate with other groups. At the moment, we are modifying our existing rotating anode suitable for this project.

Rebuttal Comments for "Strengths" - Supercritical C02:

No Response Entered

Rebuttal Comments for "Weaknesses" - Supercritical C02:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11006
Presentation Title: Carbonation Mechanisms of Reservoir Rock by Supercritical Dioxide
Investigator: Butcher, Thomas (Brookhaven National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response to Reviewer 44- Thank you.

Response to Reviewer 45-As described in our DOE interim report entitled ―Carbonation of rock minerals by supercritical carbon dioxide at 250°C," BNL-93722-2010-IR, June 2010, we adapted the powdered samples as the first approach to identifying the wet carbonation reaction products of EGS rocks in a short-term $scCO_2$/water exposure period of 3 days at 250°C. The powdered samples with a high surface area are especially useful to classifying distinctively the crystalline or amorphous carbonation products and by-products for each of the various mineralogical phases present in rocks.

The focus of our project centered on identifying the wet carbonation reaction products of rocks representative of EGS at 200°C and 250°C and on exploring the physicochemical behaviors of carbonated products in a long-term exposure period. As a result, we conclusively stated that EGS rocks had two different types of carbonation products: One was an erosion-type; the other was a scale-type.

Response to Reviewer 30 -Thank you.

Response to Reviewer 15- We adapted the compressive strength in our original approach to exploring the changes in mechanical behaviors of carbonated rocks. However, the carbonation-depth profiling study of rocks revealed that the rock's carbonation took place in its superficial layer in a static $scCO_2$/water environment. Although the carbonation reaction products for granite rock led to the development of a porous microstructure in a superficial layer, the rock still retained a brittle nature, causing a large deviation in compressive strength values. Thus, we will eliminate any measurements of compressive strength in a future work.

Response to Reviewer 68- In our current plan, we are building a sample environment suitable for in situ investigation of supercritical CO_2/water/rock and supercritical CO_2/vapor/rock interactions. The cell will be able to perform at pressure of 300 bar and temperatures up to 400 ºC and accommodate supercritical water or high-temperature brines. It will be able to withstand the highly corrosive environments which are created by concentrated chloride solutions at pH3. We are collaborating with Pam Whitfield from NRC in Ottawa and John Parise from Stony Brook University, who have experience in building sample cell environments. We plan to do in-situ investigation of carbonation mechanisms using this cell at NSLS (II), which is the next generation synchrotron tool, with unprecedented brightness, and improved energy, spatial and temporal resolution. We do think that such in-situ investigation can provide insight into carbonation reactions associated with supercritical CO_2 and mineral interactions, and help in advancement of sc-CO_2 energy technologies.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response to Reviewer 45- We adapted the compressive strength in our original approach to exploring the changes in mechanical behaviors of carbonated rocks. However, the carbonation-depth profiling study of rocks revealed that the rock's carbonation took place in the superficial layer under a static $scCO_2$/water environment. Although the carbonation

reaction products for granite rock led to the development of a porous microstructure in a superficial layer, the rock still retained a brittle nature, causing a large deviation in compressive strength values. Thus, we will eliminate any measurements of compressive strength in a future work.
Regarding the porosity measurements, if this project continues to be funded in FY2012, to validate the increase in porosity we plan to conduct two experimental works under dynamic flow $scCO_2$/water condition: One will measure the changes in density of rocks as a function of $scCO_2$-exposure time; and the other will detect ionic alkaline earth and alkaline metal elements dissociated by rock‗s carbonation in the water-laden $scCO_2$ fluid.

Response to Reviewer 30- Thank you.

Response to Reviewer 15- We believe that the rock‗s weight loss relating to the development of porosity microstructure at the outermost surface side of rock is an important evidence to judge whether rocks undergo wet carbonation-caused erosion. In EGS, if rock‗s erosion occurs in slim fractures with ~ 0.04 in. wide, concern is raised in the generation of a potential seismic force because of the increase in fractures‗ wide spaces and the sliding effect of massive rocks.

We are collaborating with team of mineral physicists (Dr Lars Ehm, Dr. John Parise, and Dr. Donald Weidner) from Mineral Physics Institute (MPI) at Stony Brook University (SBU) and Jeff Fitts (Geochemist) at BNL for our future efforts. They will provide extensive experience in mineralogy and petrography. We do agree with reviewers that bringing expertise in geochemistry and mineralogy will contribute significantly to the project planning.

Response to Reviewer 68- Unfortunately, it was very difficult to present all background information contributing to our current R&D progress status in keeping with the limited time of presentation and limited page in summary description. We have published two interim reports entitled ―Carbonation of rocks by supercritical carbon dioxide at 250°C," BNL-93722-2010-IR, June 2010, and ―Carbonation of clays exposed to $scCO_2$/water at 200° and 250°C," BNL-94369-2010-IR, November 2010. These reports were prepared to provide information on a fundamental understanding of the wet carbonation mechanisms for the various rocks and clays representative of EGS at 200°C and 250°C by the combined analytical methods including the conventional and National Synchrotron Light Source (NSLS) X-ray diffraction, FT-IR, and EDX. The integration of such analytical data allowed us to model the distinctive carbonation mechanisms of many different mineralogical phases present in the rocks and clays. Based upon this modeling, our emphasis was directed towards exploring and investigating these three factors, 1) the morphological alternations, 2) carbonation depth profiling, and 3) phase transitions, affecting the changes in porosity and weight of rocks in 8-month-long water-laden $scCO_2$ exposure test at 200°C. Thus, our focus at the review meeting reflected the presentation relating to these three factors, rather than to a fundamental understanding of the carbonation mechanisms of rocks and clays.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewer 45- Unfortunately, both the limited presentation time and limited summary page prevented the statement of a more detailed sample preparation. However, this information can be obtained from three of our published interim reports entitled ―Carbonation of rock minerals by supercritical carbon dioxide at 250°C," BNL-93722-2010-IR, June 2010, ―Carbonation of clay minerals exposed to $scCO_2$/water at 200° and 250°C," BNL-94369-2010-IR, November 2010, and ―Susceptibility of granite rock to $scCO_2$/water at 200° and 250°C," BNL-94638-2011, January 2011.

Response to Reviewer 30- Yes, there were two types of carbonation mechanisms: One was erosion-type; the other was scale-type.

Response to Reviewer 15- Thank you.

Response to Reviewer 68 -The issues of whether any spallation of carbonated scales from rock subsurface and any weight loss attributed to the increase in porosity takes place will be solved by two experimental works under dynamic flow, water-laden scCO2 with different velocities. One experimental work will measure the changes in the density of rocks as a function of scCO2-exposure time; and the other will involve an identification and quantitative analysis of the ionic alkaline earth and alkaline metal elements dissociated by the rock's carbonation in a water-laden $scCO_2$ fluid.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Reviewer 114:

Response to Reviewers 30, 45: Thank you.

Response to Reviewer 15 -We apologize to AltaRock for its misspelling. Regarding the concerted industrial coordination with AltaRock, our cooperative agreement has made it possible to exchange technical information and review the BNL-prepared report by AltaRock.

Response to Reviewer 68- Thank you for your effort to provide us with these valuable comments. We are collaborating with a team of mineral physicists (Dr Lars Ehm, Dr. John Parise, and Dr. Donald Weidner) from Mineral Physics Institute (MPI) at Stony Brook University (SBU) and Jeff Fitts (Geochemist) at BNL for our future efforts. They will provide extensive experience in mineralogy and petrography. We do agree with reviewers that bringing expertise in geochemistry and mineralogy will contribute significantly to the project planning.

Rebuttal Comments for "Overall" - Supercritical C02:

Reviewer 114:

Response to Reviewer 45- When the 8-month-long exposure test is completed in September, we will integrate all data relating to the quantity of crystalline and amorphous carbonation products, phase transition, and porosity. The integrated data will provide us with information leading to a detailed chemical modeling of CO2-rock interactions.

Response to Reviewer 30- Thank you.

Response to Reviewer 15- Contingent upon the DOE's continuing support of this project, we plan to conduct the carbonation study of the inner surfaces in rocks' fractures ~ 0.04 in. wide using a cyclic water-laden $scCO_2$ apparatus, which is designed to meet a real EGS operating condition. In this study, we will make the collaboration with a team of mineral physicists (Dr Lars Ehm, Dr. John Parise, and Dr. Donald Weidner) from Mineral Physics Institute (MPI) at Stony Brook University (SBU) and Jeff Fitts (Geochemist) at BNL for our future efforts. They will provide extensive experience in mineralogy and petrography. We do agree with reviewers that bringing expertise in geochemistry and mineralogy will contribute significantly to the project planning.

Response to Reviewer 68- Unanswerable.

Rebuttal Comments for "Strengths" - Supercritical C02:

Response to Reviewer 45- Thank you.

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response to Reviewer 30- Unfortunately, both the limited presentation time and limited summary page prevented the statement of a more detailed sample preparation. However, this information can be obtained from three of our published interim reports entitled ―Carbonation of rock minerals by supercritical carbon dioxide at 250°C," BNL-93722-2010-IR, June 2010, ―Carbonation of clay minerals exposed to $scCO_2$/water at 200° and 250°C," BNL-94369-2010-IR, November 2010, and ―Susceptibility of granite rock to $scCO_2$/water at 200° and 250°C," BNL-94638-2011, January 2011.

As seen in our published interim report entitled ―Susceptibility of granite rock to $scCO_2$/water at 200° and 250°C," BNL-94638-2011, January 2011, we had documented tangible evidence of weight loss for carbonated rocks in conjunction with the carbonation depth profiling study of rocks. Correspondingly, our approach to the validation of rock‛s weight loss was to identify the water-soluble carbonation reaction products based upon the wet carbonation mechanisms of rocks.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response to Reviewer 30 -If DOE extends funding in FY2012, our effort to further explore the rock‛s weight loss will be dedicated to two experimental works under dynamic flow, $scCO_2$/water condition: One is to measure the changes in density of rocks as a function of $scCO_2$-exposure time; the other is to identify ionic alkaline earth and alkaline metal elements dissociated by the rock‛s carbonation in a water-laden $scCO_2$ fluid.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11007
Presentation Title: Chemical Impact of Elevated CO2 on Geothermal Energy Production
Investigator: Carroll, Susan (Lawrence Livermore National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response -We concur with the reviewers' comments about the high relevance and impact of our work.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response -We concur with reviewers' comments about the strength of our approach. We only highlight that a successful field study requires the experimental program first.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response -We concur with the reviewers' assessment of our accomplishments on the lab studies.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Response -We will not be able to go in the field with this funding cycle. As mentioned in the presentation, the no-go decision on the field study transferred funds from this effort to significantly upgrade our in-house experimental facilities for CO2 experiments. The experimental program should allow a successful field program in the future.

Rebuttal Comments for "Overall" - Supercritical C02:

Response -We concur with reviewers' comments on the high quality of our proposal. We are also willing to collaborate with other efforts funded by the program on CO2-water-rock interactions to ensure that those efforts allow the program to provide the needed data to test the hypothesis that CO2-water-rock interactions will not impact CO2-EGS energy production.

Rebuttal Comments for "Strengths" - Supercritical C02:

Response - We will adopt recommendations suggested.

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response -We will adopt recommendations suggested.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response -We will adopt recommendations suggested.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11008
Presentation Title: Properties of CO2 Rich Pore Fluids and their Effect on Porosity Evolution in EGS Rocks
Investigator: Cole, David (Oak Ridge National Laboratory)
Panel: Rebuttal - Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Supercritical C02:

Response - A General Rebuttal comment is provided here, followed by specific responses under each category: Please note that ORAU/ORISE and DOE continue to list Dr. David R. Cole as the Principal Investigator for this project, even though that responsibility was transferred to Dr. Lawrence M. Anovitz of Oak Ridge National Laboratory in October of 2010. Dr. Anovitz also delivered the presentation described above, and is providing the rebuttal comments below. Many of the reviewer comments were highly complimentary and supportive of this project. We have chosen NOT to 'rebut" these very positive comments. The material included in this and the other categories below includes only rebuttal of comments that appear to require a response.

Response to Reviewer 44 Our research indicates that nano- and microporosity are indeed very important. There are two reasons for this. First, our research on non-geothermal rocks (i.e. those not typically encountered in conventional geothermal reservoirs) indicates that even in highly macroporous rocks (e.g., sandstones, limestones), micron and submicron porosity may make up a significant fraction of the total pore volume (Anovitz et al. 2009, Geochim. Cosmochim. Acta; Anovitz et al., in review, Geochim. Cosmochim. Acta). For examples, analysis of samples of the St. Peter sandstone (macroporosity up to ~ 30 percent) demonstrates that the nano- plus microporosity (1 nm to 10 micron range) may contribute up to 30 percent or more of the total porosity. Second, despite the fact that in many rocks fluid flow may be fracture-controlled, the geochemical reactivity is likely to be highly dependent on interactions of the fluids with the rock that occur through the nano- and micropore network that dominates the accessible surface area.

Rebuttal Comments for Scientific/Technical Approach - Supercritical C02:

Response -All review comments in this category were highly complimentary and supportive. Our studies are referred to as unique, highly innovative and among the best efforts in the program.

Rebuttal Comments for Accomplishments, Results and Progress - Supercritical C02:

Response to Reviewer 15 - While it may seem that neutron tomography provides only confirmatory support to other novel techniques such as neutron scattering and vibrating tube densimetry, it in fact has the potential to revolutionize our understanding of fluid flow and reaction in all types of host rocks. The key to this is the power of neutrons to detect the motion of water through the rock. Our effort to develop a high temperature-high pressure reaction cell complements a synergistic ORNL Geothermal Program project to push the neutron imaging capability down to the micron scale. Once fully deployed, this method will allow the validation of reactive-transport codes under development in other non-ORNL Geothermal funded projects. Note that the complementary technique of X-ray tomography is not sensitive to the presence of water in the rock sample and cannot be used to study water flow and permeation.

Response to Reviewer 68 -While our initial efforts focused on quantifying the interaction behavior of simple fluids in model matrices such as mesoporous silicas and aerogel, we are working on two parallel fronts to identify more complex solids. First, we continue to use neutron scattering and electron microscopy to measure the pore features in a wide variety of geothermal rock types with the goal to identify suitable candidates for high temperature-pressure SANS and vibrating tube densimetry studies. We also explore the use of various sintering strategies to produce nanoporous synthetic crystalline matrices of defined macroscopic size and shape. These samples will be used for the SANS measurements of the properties of pore fluids, and protocols of introducing the samples into the vibrating tube are being developed.

Rebuttal Comments for Project Management/Coordination - Supercritical C02:

Response - All review comments in this category were positive and supportive of our efforts.

Rebuttal Comments for "Overall" - Supercritical C02:

Response to Reviewer 45 - This is a very valid comment, one which we take very seriously. We have recently presented two papers at the 2011 Stanford Geothermal Workshop which are included in the workshop report. We are working on several follow-on papers that will provide more detail on our new methods and the results they yield. We note here that we have requested continued support for the efforts described in this project review through the AOP documentation and through a response to the recent Funding Opportunity Announcement. Therefore, we hope that we are not indeed nearing the end of this activity, which the reviewers recognize as been well run, highly innovative, and providing unique and critically needed information for EGS reservoir characterization and performance assessment.

Rebuttal Comments for "Strengths" - Supercritical C02:

Response -All review comments in this category were highly complimentary and supportive.

Rebuttal Comments for "Weaknesses" - Supercritical C02:

Response to Reviewer 68- We are using vibrating tube densimetry of porous materials to study the effects of fluid confinement in conjunction with other complementary methods including gravimetric adsorption, small angle neutron scattering, and neutron imaging. The results for CO_2 contained in the pore system of silica aerogel have revealed the relationship between experimental total adsorption and excess adsorption obtained gravimetrically. Another significant finding of this work is the lack of detectable lowering of the liquid-vapor critical point for CO_2 in this material, presumably due to relatively large average pore size. We expect to find such critical-point-lowering in materials with tighter pore systems. We are planning next to transition to materials with smaller average pore diameter and lower total porosity, starting with nanoquartz particles of different sizes tightly packed inside the vibrating tube. If successful, these experiments will be continued with other powdered minerals and rock samples. Finally, real geothermal reservoir rock cores will be placed inside straight vibrating tubes. We estimate that even with lower porosity samples and the possibility of presence of a small fraction of bulk fluid remaining inside the tube, the properties of the pore fluid, such as gas-liquid phase transitions, will still be detectable. The properties for confined fluid can be obtained by extrapolation of experiments with varying fractions of bulk fluid present.

Rebuttal Comments for "Suggestions for Improvement" - Supercritical C02:

Response to Reviewer 30 -The cell development for high pressure-high temperature neutron scattering is a non-trivial exercise. In addition to issues of strength and corrosion resistance, we also need to take into consideration the neutron scattering and attenuation properties of the material used. To the extent possible, the materials must be ―transparent” to neutrons to avoid or minimize potential multiple scattering by the cell that can reduce the resolution of the imaging. Metals such as Ti, Nb, Mo and Al (and alumina or sapphire) are preferred. Design and fabrication costs for any given cell will be reflected in the material of choice and the pressure-temperature range of interest. Our initial design targets modest P-T capability that satisfies the strict safety requirements established by the SNS facility.

Systems Analysis, Resources Assessments, Data Systems Development and Population

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10102
Presentation Title: Analysis of Low-Temperature Utilization of Geothermal Resources (WVU)
Investigator: Anderson, Brian (West Virginia University)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response - In the following pages, we will attempt to address each of the reviewers‘ comments. The comments are organized by category and by reviewer, just as the reviewers comments are organized. For convenience, the reviewer comments are identified by *italics* and the PI‘s comments are in normal text.

Comments Regarding Relevance/Impact of Research

Response to Reviewer 52 -Thank you for pointing this out. Yes, we agree that direct use can be incorporated at very low temperatures. As seen by the preliminary results that we report; however, the more economical use is at the higher temperatures due to the increased sensible heat available. Each direct-use site would need to be optimized for temperature and depth, depending on the end use. Our analysis is considering that all of the heat can be utilized, recognizing that some systems may be more cost effective at shallower depths if the heat demand is not sufficient to warrant the more heat produced with deeper depths.

Response to Reviewer 27 -The DOE GTP‘s mission is ―to establish geothermal energy as a significant contributor to America's future electricity generation by partnering with industry, academia and the national laboratories to discover new geothermal resources; research, develop, and demonstrate innovative technologies; and facilitate commercialization." The reviewer is correct that the impact of our project will not affect geothermal‘s deployment in the electricity generation portfolio. However, as demonstrated in Iceland and other countries around the world, direct-use applications can significantly increase the efficiency of the whole energy distribution and use system. Geothermal energy in the United States is underutilized for direct-use applications and a result of our study will be a supply curve for direct-use geothermal from low-temperature geothermal resources. This will help identify potential direct-use markets that have not been exploited yet, thus increasing the market penetration of geothermal energy.

Response to Reviewer 14 -In light of these comments, we are in constant communication with the WV state division of commerce and will continue this effort. As we identify potential low-temperature markets in states around the country, we will be sure to communicate these findings.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response - The WVU campus is currently heated and cooled by a distribution system of low-pressure steam. It is unique in that the steam is used in a distributed network of lithium-bromide absorption chillers for cooling and hot water systems throughout the buildings for heat. Additionally, a Personal Rapid Transit system has approximately 10 miles of tracks heated in the winter by a steam system. The entire university steam system could be provided with hot water from a low-temperature (120-150°C) geothermal system producing 100 kg/s. The current cost of steam to the University is ~$9 million/year, thus providing a potential cost-savings by switching to a geothermal district heating system. No retrofitting would be necessary.

The price of coal is largely irrelevant to a discussion of a district heating system, since it is used solely for electricity production. In both the summary document and the presentation, we reported a potential cost ($3-4/MMBtu) of geothermal direct-use for the WV resource (which is much lower gradient than the western US) that is competitive with natural gas prices.

Response to Reviewer 14 -We are not sure how to make the connection to ground source heat pumps as this technology has been moved to the building technologies program. Heat pumps do not provide primary energy, but increase the efficiency of heating and cooling, therefore it is difficult to include in this analysis.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 52 -Due to the limited time allotted for the presentation, this information was included in the summary slides for the reviewers only. Slides 21-25 broke down each task and subtask in the project and indicated the progress toward their completion. In the future, we will find a way to incorporate more information regarding the task progress into the body of the presentation.

Response to Reviewer 27 -The outcomes of Phase 1 include the preliminary assessments of direct-use, low-temperature geothermal energy for geothermal gradients relevant to the eastern United States. The result of this work is the economic analysis that illustrates that, with full utilization of the produced geothermal heat in a direct-use system, the economics can be favorable, even competing with natural gas.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response to Reviewer 52 -Delays in recruiting students at the beginning of the project were a function of the timing of the project. The funding was received in April of 2010 – near the end of the spring semester. Therefore, it is reasonable to assume that students would not have been able to start on the project until the beginning of the fall semester. Regardless of this delay, we have been able to stay largely on schedule. We apologize that the presentation was not available until the week before the review. The summary should have been available at the same time, as it was sent along with the presentation. The one and only email to notify the PI of the document uploading requirements, sent prior to the deadline, was not delivered. The second email notifying the PI of the requirements was sent on May 23rd and the presentation and summary documents were sent the following week.

Rebuttal Comments for "Overall" - Systems Analysis:

Response to Reviewer 27 -We disagree with the reviewer that this project is really four separate projects. The overall goal of this project is unified – to provide a supply curve for low-temperature geothermal utilization. Each of the institutions plays a vital role toward this common goal. Each institution plays an integrated role in this project and as illustrated on Slide 13, the project cannot be split into four separate projects.

Regarding the integration of biomass and geothermal, this was discussed in the summary document and the presentation. As described on Slide 9, the biomass pyrolysis system has been found to have clear benefits from integration with a geothermal system, e.g. less biochar used for steam upgrading, equipment reduction, and reductions in costs of the steam reforming loop.

It is unclear what the reviewer intended by ―there is no apparent or benefit other than the NREL assistance." Does he/she mean that only the NREL portion of the project should be funded, or that the only benefit provided by funding WVU, Cornell, and ISU is the assistance that these project partners are providing to NREL?

Rebuttal Comments for "Strengths" - Systems Analysis:

Response to Reviewer 14 -Thank you. Future work will include the use of CO_2 in low-temperature geothermal resources.

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 27 -Regarding employment, the co-PI at NREL will receive salary support from this project. Among the five co-PIs at the university partners, a total of three months' salary is supported by DOE funds; however, six and three-quarters months of salary is cost-shared by WVU and ISU. The co-PI's time at Cornell is also at no cost to DOE. Additionally, as this is an ARRA project, the five jobs created are considered a benefit.

The data generated by the project will include, but not be limited to, the data listed on Slide 15 of the presentation. As discussed during the merit review, multiple layers of geographically-located data such as resource and demand potential, as well as cost of low-temperature geothermal, will be entered into SEDS, ReEDS, and NEMS (Slide 6). From these regional energy analysis models, supply curves will be generated. These are the data that will be linked to the NGDS.

Due to time limitations, we did not provide all of the reservoir simulation details incorporated into the base-case reservoir simulation. We felt this would have been too much detail for a 15-minute merit review presentation. As for the location of the WVU campus in the geothermal resource, it is not in the center of the temperature anomaly, but at the edge. One of the wells exhibiting elevated temperature is approximately 20 miles from the campus. For the purpose of the case study, this temperature uncertainty is being included in error propagation analysis.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response - Although none of the reviewers provided suggestions for improvement, we will use the other comments to strengthen and improve our project as we proceed into Phases 2 and 3. We appreciate the time and effort provided by the merit reviewers as well as the organizers of the merit review.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10103
Presentation Title: Co-Production Risk Assessment (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 27- The risk assessment only included aspects of the co-production system that could be addressed and impacted by Research, Development, and Deployment (RD&D) efforts. Items such as the cost and difficulty of permitting and obtaining an electrical connection are important, but cannot be addressed or improved by RD&D efforts. System integration costs were covered by Technology Improvement Opportunity B ("Reductions in Component/System Costs") and C ("Lessons Learned from Demonstrations"). Further, discussions with experts indicated that a reduction in system integration costs via developing a "plug-and-play" system was one of the more promising avenues for reducing co-production system costs.

Response to Reviewer 54 - Response appears to have been cut off, not sure what the comment is supposed to be.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

Response to Reviewer 54 - As stated in response to reviewer # 27 in the Scientific & Technical Approach section, the risk assessment only included aspects of the co-production system that could be addressed and impacted by Research, Development, and Deployment (RD&D) efforts. Non-technical market barriers, such as early adoption rate, permitting and transmission barriers, financing barriers, etc. were outside the purview of this study since they could not be addressed by RD&D efforts.

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 27 - The focus of this study was on cost and performance of the system that could be imapcted by RD&D, and to determine the impacts that RD&D could have. Expanding this to a full analysis of all costs associated with co-production was not the objective of the study - that is the subject of a different GTP project.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response - Suggestions for improvement were noted and appreciated, but the budget and timeframe of the project do not allow for any of the improvements to be implemented. The suggestions will be considered as guidelines for future project topics.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10104
Presentation Title: Market & Policy Analysis (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response to Reviewer 2: In response to, *"The project's audience, so-called new entrants (developers and financiers) could not reasonably be expected to effectively use this project's information to finance and build a geothermal project."* The Guidebook to Geothermal Power Finance (―Guidebook") and accompanying website were never intended to be an exhaustive, step-by-step instruction manual for financing new projects. Rather, the information contained in the report and website convey useful information that is generally representative of the overall process and could be expected to give new entrants a leg up on understand issues that are unique to geothermal. As noted in the Guidebook, geothermal financing is a unique and company-specific venture.

In response to, *"Project should instead identify the primary sources of industry participants (e.g. banks, institutional investors, private equity, developers, real estate leasing companies (landsmen) and allow these experts to provide first-hand information."* We must not have communicated clearly as this was precisely the process for which the information in the Guidebook was gathered, interpreted and presented. In the course of the research, fifteen in-depth interviews were conducted to gauge the critical information gaps and messaging needed for financing geothermal power projects. Interview participants included: John Hancock Financial Services, Glacier Capital Partners, Islandsbanki, Ormat, ENEL, NV Energy, Ram Power, Good Energies, the Geothermal Energy Association and others.

In response to, *"By way of example, the use of the Section 1603 Treasury Department Tax Grant is currently exclusively used by geothermal project developers instead of the ITC and PTC. Congress should know this and be asked to extend the program"* and other similar-themed comments. As referenced in the feedback, the Guidebook does discuss the overwhelming popularity of the 1603 Cash Grant incentive amongst geothermal project owners. The relative costs and benefits between the various incentive options for renewable energy technologies, however, has been well documented elsewhere and is not the focus of the guidebook. For example, publicly-available comparisons of these incentives options include analyses by Congressional Research Services (http://www.cq.com/graphics/crsreports/R41635_2011-02-08.pdf), the Bipartisan Policy Center (http://www.bipartisanpolicy.org/sites/default/files/BPC_RE%20Issue%20Brief_3-22.pdf), national laboratories (http://eetd.lbl.gov/ea/emp/reports/lbnl-1642e.pdf and http://eetd.lbl.gov/ea/emp/reports/lbnl-3188e.pdf), various think tanks (http://investigativereportingworkshop.org/investigations/wind-energy-funds-going-overseas/story/most-wind-grants-go-overseas-firms/ and http://investigativereportingworkshop.org/blogs/shop-notes/posts/2010/apr/15/controversial-stimulus-cash-grants-wind-only-creat/), advocacy organizations (http://reffwallstreet.com/us-pref/wp-content/uploads/2011/06/RE-Tax-Equity-v2.1.pdf), industry lobbying associations (http://online.wsj.com/article/SB10001424052748703296604576005813229168204.html), and others (http://abcnews.go.com/Blotter/page?id=12048229). We note that asking Congress to extend a specific policy is far outside the scope of the project. NREL does not make policy recommendations, instead relies on objective analyses in the Guidebook to credibly inform the discussion for policy-makers.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 3 - In response to, *"Are you able to get [financial] info from other finance sources: like Bloomberg New Energy Finance and like Cleantech Group"*. We have access to these sources and use them, but to the best of our knowledge, specific geothermal financial data is quite limited and often not-publicly available. For example, Bloomberg New Energy Finance (BNEF) provides a quarterly market outlook for geothermal industry trends (See, Geothermal Market Outlook: Q2 2011, Bloomberg New Energy Finance), but tellingly, benchmarks geothermal financing data to wind financing data with an assumed geothermal risk premium. Moreover, BNEF data is available on a subscription basis only. Other sources, like Mintz Levin's *Renewable Energy Project Finance in the U.S.: An Overview and Midterm Outlook* provides a static snapshot of financing rates for geothermal projects, but does not appear to be updated on a regular basis (http://www.mintz.com/media/pnc/2/media.2372.pdf).

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

Response to Reviewer 2: In response to, *"The NREL reports and collection of information have sited the expensive costs associated with resource verification and drilling, but it does not make any recommendations to address these issues."* A more in-depth analysis of the issues of drilling barrier for geothermal is under consideration for future analysis but was not within the scope of the Guidebook. As previously described, NREL does not make policy recommendations, but may be able to provide insight into various options to help alleviate various market barriers.

In response to, *"[ed: A government lab could] simply gather the names of the people and organizations that conduct financing for a living and provide a platform that efficiently distributes that information to the industry."* This is an excellent and helpful comment that we will strongly consider in future analytical financing efforts.

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10105
Presentation Title: Decision Analysis for Enhanced Geothermal Systems (MIT)
Investigator: Einstein, Herbert (Massachusetts Institute of Technology)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response to Reviewer 42 - Geofrac and Fracman are indeed related (both are based on Ph.D. theses supervised by the PI). Geofrac, particularly the newest version, is more efficient regarding the formulation and intersection process - Regarding the DAT, numerous test runs have been conducted with this tool. They show that this works very well (a report on this has just been completed.)

Response to Reviewer 14 -Practical relevance is definitely a concern and this comment is very relevant. At this point one can only say that the past and ongoing practical applications of the fracture pattern model and the DAT show that these are not simply academic developments remote from practice. The PI will certainly bear the practical relevance in mind.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 42 - See rebuttal I-R42. Also, the high temperature environment is definitely a parameter in the DAT model.

Response to Reviewer 74- The PI is not quite certain what is meant with dynamic data. If it means that the variables change in time and space, then this is definitely considered in the DAT (both time and space) and in Geofrac (Space). This should have been made clearer. Also, it is definitely necessary to consider this when working on fracture flow etc.

Response to Reviewer 14 - The DAT examples are well related (not tunnel related).

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 74 -Unfortunately, it is not very easy to get cost breakdowns for proprietary reasons. This situation has improved lately.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

Response to Reviewer 42- PI will make a better effort to show what is different.

Response to Reviewer 74- Geofrac, as it is now, is much more efficient than its predecessor or comparable codes.

Response to Reviewer 14 - The PI would like to say how much he appreciates the very constructive and detailed comments by the reviewers.

Two points need to be made here:

1. The project is limited to the subsurface since this is where the expertise of the PI and his group resides. Also, this is where uncertainty, and how to formally consider it, is very important.
2. Nevertheless we will try to put this into the overall context of an EGS project, albeit with modifications in the parts we are not experts in.

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 74 - Delays in well drilling are considered with time and cost impacts in the DAT. Qualitative (subjective) inputs can be considered.

Response to Reviewer 69 - The fracture pattern model has been tested against real data in the past.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10106
Presentation Title: Geothermal Supply Curve Development (NREL)
Investigator: Augustine, Chad (National Renewable Energy Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

No Repsonse Entered

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 59- I share the reviewer‘s concerns. It is likely that the data gathered for a particular location may not be accurate, given the varying nature of the quality of the gathered data. However, I think the data in aggregate will give a reasonable snapshot of the size of near-term market potential for electricity production from co-production systems, assuming that any local errors are averaged out for the entire estimate.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 43 - As an update, someone has been identified to perform the evaluation of permeable basins and work has begun on that task.

Response to Reviewer 69 - As an update, the geopressured and undiscovered hydrothermal tasks are nearing completion. The permeable sedimentary task has a person identified and is started, and the EGS update is in the process of converting updated resource maps to update the analysis previously completed. The schedule is still aggressive, but work is proceeding.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response to Reviewer 69 - The geopressured and undiscovered hydrothermal tasks are nearing completion, the permeable sedimentary task has a person identified to work on it and is started, and the EGS update is in the process of converting updated resource maps to update the analysis done previously. The schedule is still aggressive, but work is proceeding.

Response to Reviewer 59 - Since the peer review, additional personnel have been added to the task. Specifically, someone has been identified to perform the permeable sedimentary work and has started on it, and each supply curve now has at least one person dedicated to it.

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 43-

1. Direct Use was not in the scope of the work. It was not considered a priority
2. Distinction between magmatic and amagmatic does not impact estimates of resource size, and methodology is not in place to see how it impacts estimate of cost, so this distinction is a low-priority update for the project right now.
3. Team is now assembled for all aspects of the project
4. Publication at Stanford 2010 meeting for original work, and reports are underway for several of the supply curves.

Response to Reviewer 59 - We are confident that quality work can be completed by September, but a better analysis can always be done with more time and budget. As such, we have requested to continue to perform improvements and updates on the supply curve work for the coming fiscal year.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response to Reviewer 59- Our understanding is that USGS is working on detailed resource assessments for many of the technologies in this task. We will work to incorporate their results as they become available.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10107
Presentation Title: National Geothermal Resource Assessment and Classification (USGS)
Investigator: Williams, Colin (U.S. Geological Survey)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response -The three reviewers' comments are uniformly positive on this aspect of the presentation.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewers 8 and 27 –

Reviewer 8 and 27 write positive comments in this section.

Reviewer 43 has some concerns, specifically *"Unfortunately, the supporting documents and presentation appear to leave several important questions hanging. Who is on the geophysical and geologic teams, for example--is this staffed internally from within the USGS or does it include various collaborators? Limited information was provided on the team members. Although certain areas have been selected for detailed study, it is unclear why such areas were selected over others. For example, is northeast Nevada (one of the study areas) representative of conventional or EGS systems in some way--if so, how? "* These are valid questions, but unfortunately the format specified for the Powerpoint presentations and the written summary did not leave much room to provide details on this project, as it is a large project that covers many topics under the overall umbrella of resource assessments. It would be better in future reviews if principal investigators were asked (or at least allowed) to provide more detailed supplementary information in the written summary. For example, to address the specific questions raised by the reviewer, the project is staffed primarily by USGS personnel, with 15 people contributing to the project at least part time. There is currently one contracted postdoctoral researcher from Temple University, which has been cost-shared between this DOE project and our internal funding, and we are proceeding with plans to bring another staff member on board to provide additional support for our sedimentary basin work. As far as detailed information on staffing in various teams and reasons for choosing study areas, space here is insufficient to provide a comprehensive list, but for the example of the new heat flow measurements in northeastern Nevada, the answer is that the new measurements are intended to address unresolved issues regarding both undiscovered hydrothermal resources and EGS. Heat flow measurements are sparse in northeastern Nevada and the available data are somewhat contradictory, most likely due to the thermal effects of ground-water flow in the regional carbonate aquifer system masking high background heat flow. If heat flow is high in northeastern Nevada, extending into western Utah, it will be strong evidence for significant levels of undiscovered hydrothermal resources (blind systems) and also strong evidence for significant EGS potential. Current USGS maps for temperature at depth in this region show high temperatures at depth, while equivalent SMU maps show lower temperatures. The new measurements should resolve this uncertainty.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 8 and 27- Reviewers are generally positive in this section. *Reviewer 8 notes some concern regarding the ambitious scope and timeline.* We are aware that there is relatively little slack in our schedule. We are monitoring progress carefully and will notify DOE of any significant deviations.

Response to Reviewer 43 -Reviewer 43 was concerned about the absence of details about the classification scheme. Again, there was little space in the prescribed Powerpoint format to provide that level of detail, but the classification information was referenced in the project summary (Stanford paper in 2011).

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response - Reviewer comments are generally positive except that *Reviewer 43 raised the same issue about staffing details.* See rebuttal comments from the Scientific/Technical Approach area.

Rebuttal Comments for "Overall" - Systems Analysis:

Response - Overall comments are generally positive.

Rebuttal Comments for "Strengths" - Systems Analysis:

Response - Comments on strengths are generally positive.

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 43 - Reviewer 43 reiterates concerns regarding the level of information provided on the make-up of the research team, the details of the research studies, and whether there should be a more systematic approach to data analysis and synthesis. As previously noted, these are legitimate questions that are difficult to answer in a few slides. If desired by DOE, we can prepare a more detailed description of the work plan for the project, laying out how the data synthesis and analysis will be handled for each of the major assessment components.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response to Reviewer 8 -Reviewer 8 suggests better coordination with NREL and clearer explanation of the USGS role with respect to the NGDS. Regarding NREL, the suggestion is timely. Recent communications with NREL staff have highlighted some important areas of overlapping interest, particularly with respect to geopressured geothermal systems. We will be coordinating with NREL to avoid duplication of effort and leverage their existing work. Regarding the NGDS, we anticipate that the USGS will be operating both as a data "node", with web service interfaces for assessment products and some supporting data, as well as transferring some data and related information to other institutions of the NGDS to integrate with their data services.

Response to Reviewer 27 - Reviewer 27 makes a number of useful, specific suggestions regarding potential components of assessment results. We will consider these in detail. I note one misstatement, in that the reviewer suggests our work in the sedimentary basins of California, specifically the Los Angeles, Ventura, Santa Maria, San Joaquin, and Sacramento basins, is not actually in sedimentary basins. These are most certainly sedimentary basins (as commonly defined in the greater geologic community, as defined by the USGS Geologic Names Committee, and as defined by the California Department of Conservation), so I can only guess the reviewer misunderstood a statement in the presentation or summary.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10112
Presentation Title: GETEM Development (INL)
Investigator: Mines, Greg (Idaho National Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

Response -

- As indicated by the reviewers, the lack of industry feedback/validation is an issue that has to be resolved. Since industry has not provided feedback voluntarily, it may be necessary to _pay‘ for this feedback.
- A simpler version of this model is needed for the GTP staff who do not have the time to spend to become _expert‘ Users. This should be a priority moving forward.

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10113
Presentation Title: Life-cycle Analysis for Geothermal Power Systems (ANL)
Investigator: Wang, Michael (Argonne National Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response - Efforts were made to obtain data on CO_2 concentration of geofluids and water quality from existing geothermal plants, stakeholders, and open literature. These efforts will be continued to enhance LCA input data and output results.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response - See the above comment regarding obtaining data from existing geothermal plants.

Efforts will be made to reduce or eliminate technical gargons in presentations for better communication. Details of LCA of conventional power systems are presented in our technical reports.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response - Addressing baseline conventional power systems is a key aspect of this project for the purpose of fair comparison of geothermal power against conventional and other renewable power systems. Our technical reports documenting key issues for other power systems will enable the understanding of the LCAs of these other systems. By the way, continuing efforts are addressing additional power systems.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response - Thanks. No comment.

Rebuttal Comments for "Overall" - Systems Analysis:

Response - Thanks.

See comments under ―Accomplishments" which discuss obtaining data from existing geothermal plants.

Rebuttal Comments for "Strengths" - Systems Analysis:

Reviewer 195:

Response - Thanks. No comment.

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response - Thanks for the detailed comment on air vs. water cooling systems and resulting differences in plant construction and operation. We will look into these issues and address them in our future updates.

In the future, we will streamline our presentation for better communication.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response - Thanks for pointing out the need to get data from existing geothermal plants. We will continue to pursue this.

Viability and uncertainty are key issues in our LCA. We will continue to address them systematically.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10114
Presentation Title: Water Resource Requirements for Geothermal Energy Production (ANL)
Investigator: Wang, Michael (Argonne National Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response - Thanks. No comment.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response - Industry provided input in the drilling and construction stage of the analysis. Operational information was obtained where available from state agencies reporting data provided by industry. Current and future efforts will continue to seek input from industry regarding the developed scenarios for geothermal technologies.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response - Future work in EGS water issues will include the examination of losses that occur in the sub-surface, in addition to surface operational losses.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response - Thanks. No comment.

Rebuttal Comments for "Overall" - Systems Analysis:

Response - Thanks. No comment.

Rebuttal Comments for "Strengths" - Systems Analysis:

Response - We are coordinating with NREL to incorporate results of a survey of geothermal power plant operators into our analysis.

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response - Although the performance of ESP technology is limited at high temperatures, ESPs were considered in some scenarios due to well depth and the required pump depth as determined in GETEM. Line shaft pumps were also evaluated and used in the design where appropriate.

Future work will explore additional water issues including sub-surface loss in EGS, assess availability of water for geothermal projects, and continue to analyze water quality issues.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response -Thanks. No comment.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10115
Presentation Title: Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems (ADI)
Investigator: Turaga, Uday (ADI Analytics, LLC)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response to Reviewers 27 and 14 - Thank you for affirming the rationale, relevance, and impact of our project. It will, indeed, advance DOE GTP Goals by *inter alia* gathering and analyzing EGS costs and enabling economic impact-based prioritization of technologies.

Response to Reviewers 64 and 69- We agree that DOE projects must add value and, therefore, carefully reviewed DOE GTP goals to ensure that they are supported by our project outcomes. As a result, we are confident that our project will have a significant impact on both knowledge gaps and program goals. For example, the program goal of demonstrating a flow rate of 20 kg/s by 2015 will require new technologies, whose commercialization may be hindered by unclear economic benefits. Task 2 addresses this gap by clarifying the economic impact of new technologies. Similarly, achieving the program‘s R&D goals—ranging from drilling systems to stimulation operations—will depend on continual measurement of technological progress, which is one objective of our work on patent analytics (Task 3).

Similarly, we share the reviewers‘ concern that DOE projects should not duplicate other efforts. Therefore, we have made a concerted effort to review literature and other projects and believe that our project does not overlap with other projects. Specifically, we are unaware of any projects that overlap with the goals of Tasks 2, 3, and 4 on economic benefits of technologies, patent analytics, and novel process configurations, e.g., EGS-IGCC, respectively. Even so, we will welcome any references the reviewers can share regarding goals of Tasks 2, 3, and 4.

Task 1 (independent assessment of the cost structure of EGS) may overlap with other projects but is unavoidable because we have to develop a baseline for the follow-on tasks. Even so, Task 1 is invaluable because (1) geothermal energy technology is changing rapidly due to new investment and continual evaluation of costs is helpful and (2) multiple cost estimates developed in consultation with different experts enables a more representative assessment of costs.

Importantly, we note that this project is not ―relying heavily on the costs in GETEM." In fact, we are developing our own cost estimates from expert elicitations, literature analyses, and demonstration projects and using them to replace cost estimates in GETEM, whose use was specifically requested by DOE to ensure a consistent modeling framework across all projects.

Regarding the scope, size, and cost of our project, we would like to clarify that developing an independent assessment of the cost structure of EGS (Task 1) is *only one* out of a total of six tasks. We proposed these six interrelated tasks in our original proposal that was funded by DOE with the goal of comprehensively furthering the knowledge base on EGS costs (Task 1), economics of new technologies (Task 2), patent data-based EGS insights (Task 3), novel process configurations such as IGCC-EGS (Task 4), and student and community outreach (Task 5). Given the continued relevance of these goals coupled with our well-defined tasks, team size and qualifications, and integrated and coordinated efforts, we believe that our project is of the appropriate scope, size, and cost.

Finally, Tasks 2 and 3 have been designed and executed as interlaced activities with considerable overlap and coordination. For example, economically-promising technologies identified in Task 2 are being benchmarked with other technologies using patent analytics in Task 3. Of course, we welcome additional suggestions on this front.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 14 - We appreciate your support of our methodology, tools, and data sets. Regarding expert elicitation, our plan is to continue interviewing additional experts to build a larger pool of views and will welcome suggestions or references for additional expert interviews.

Response to Reviewer 27 **-** Thank you for validating our scientific/technical approach. In regard to Scitech, they have searched, retrieved, categorized, and mapped nearly 6,000 geothermal energy patents. Further, they have closely collaborated with the project team concerning the conduct of patent analytics to generate insights. Therefore, Scitech is an important member of our team, helping us use patent data for benchmarking technology, defining gaps, identifying technology improvement opportunities, and drawing learning curves.

Response to Reviewer 64- We fully understand the reviewer‘s concern regarding the expert elicitation process. We have consulted 45-50 experts so far across a broad range of technical, functional, and organizational domains. Thus, we have enough diversity in the expertise we consulted, for the expert elicitation to give us credible results. Further, we have consulted the literature to estimate, validate, and triangulate key metrics. As a result, we have built broad ranges of estimates for key metrics and have not relied on any single point-of-view for our analyses. This effort has drawn from the team‘s experience in conducting numerous expert elicitations as well as DOE best practices and training material. Therefore, we believe that our expert elicitation methodology is robust and sufficiently addresses the kind of potential bias about which the reviewer is concerned.

Regarding the patent analytics and IGCC-EGS results, as the reviewer would appreciate, there is only so much detail one can provide within the 15-slide limit imposed for the Peer Review. In due course, we will submit detailed technical reports to DOE describing our patent analytics and IGCC-EGS results. Meanwhile, we are presenting a paper on each topic at the 35th Annual Meeting of the Geothermal Resources Council in October 2011 that will provide greater detail with appropriate peer review scrutiny.

Response to Reviewer 69 **-** Previous comments have shown how our project (1) creates significant value, (2) is scoped appropriately, and (3) does not overlap with other studies.

Regarding the EGS-IGCC work, our team brings unique skills and qualifications in both EGS and IGCC, which allowed us to conceptualize and propose this task in the first place. For example, the team includes two distinguished researchers – holding full-time faculty positions at Penn State University – each of whom brings over 25 years of experience apiece in EGS and IGCC. This domain expertise is complemented by the process modeling and economic analysis expertise of an additional two researchers each of whom brings nearly 15 years of industrial and academic experience. More importantly, combining IGCC and EGS expertise is unusual and quite different (we believe unique) relative to other projects that restrict themselves to the reservoir-specific issues related to the use of CO_2 as a working fluid. As such our project brings unique capabilities in integrating EGS with IGCC in comparison to evaluating the subsurface reservoir-engineering implications alone.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 14 - Thank you for your encouragement and validating the quality of our work.

Response to Reviewer 64 **-** We hope that the previous comments have shown how some overlap of Task 1 with other projects – while still invaluable – is unavoidable because we have to develop a baseline for our follow-on tasks, none of which overlap with other studies. More importantly, we would like to note that our results from Task 2 are not ―cost reduction requirements" but an estimate of cost reductions that can be potentially achieved through new technologies. As such, our work is identifying the efficacy of new technologies, which, in the words of Reviewer #14, is ―very useful for assessing, ranking and prioritizing the development of technologies".

Response to Reviewer 27- In accordance with our plan, Task 4 has only been in progress for a few months but will receive greater attention in the second half of our project.

Response to Reviewer 69 **-** We would like to clarify that our Peer Review presentation included highlights of results from all six tasks, including EGS cost structure, economic benefits of new technologies, patent analytics, and IGCC-EGS. Our previous comments, hopefully, show that Tasks 2, 3, and 4 do not overlap with other studies and also identify our plans to further describe the results of patent analytics results in greater detail in forthcoming reports and papers.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response - We thank all the reviewers for their positive recognition of our project management / coordination efforts, which we will strive to maintain.

Rebuttal Comments for "Overall" - Systems Analysis:

Response to Reviewer 64 **-**We hope that the previous comments have shown how our project (1) creates significant value, (2) is scoped appropriately, (3) does not overlap with other studies, (4) employs robust methodologies and tools, and (5) plans to present detailed results in forthcoming reports and papers.

Response to Reviewer 27**-** Thank you for your technical suggestions, which will be integrated in Task 4. In accordance with our plan, Task 4 has been running for only a few months but will receive greater attention in the second half of our project. Further, the 15-slide limit imposed by the Peer Review prevented us from discussing our results in greater detail. However, as indicated earlier, forthcoming reports and papers will report our results in greater detail.

Response to Reviewer 69 **-** We hope that the previous comments have shown that our project (1) has a total of six tasks*, only one* of which is an independent assessment of EGS costs, (2) does not overlap with other studies, (3) is not ―relying heavily on the costs in GETEM", and (4) has the appropriate cost given its scope, goals, tasks, outcomes, and team. Even so, we will welcome references to projects whose goals overlap with ours, in particular those of Tasks 2, 3, and 4.

Rebuttal Comments for "Strengths" - Systems Analysis:

Response - We appreciate the positive recognition of our project‗s strengths, in particular the value of an independent assessment of EGS costs and development of learning curves, use of ―sound engineering principles", ―a very high probability of success", project management, on-schedule progress, and team qualifications.

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewers 64 and 69 -We have addressed these comments in previous paragraphs. To summarize, we have shown how our project (1) creates significant value by generating new, unique, and in-depth information, (2) does not overlap with other efforts, (3) is of the appropriate cost given the scope, goals, tasks, outcomes, and team, and (4) has a team with unique skills and qualifications for the on-going work.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response to Reviewer 64 - We hope that the previous comments have shown how our project is being executed at the appropriate breadth and depth consistent with the team's resources and qualifications and commitments made in its proposal.

Response to Reviewer 69 - We believe that our project is addressing knowledge gaps and adding significant value to program goals by utilizing robust methodologies (consistent with best practices and DOE guidance) and delivering outcomes consistent with the quality and schedule identified in our proposal. Correspondingly we reiterate the new, unique, and in-depth contributions that this project has already made (see papers-to-date from project below) and will make in providing an independent appraisal of the cost structure of EGS (Task 1), evaluating economics of new technologies (Task 2), benchmarking technology and learning curves through patent analytics (Task 3), assessing the feasibility of novel IGCC-EGS configurations (Task 4), and promoting student and community outreach (Task 5).

PAPERS-TO-DATE FROM PROJECT

1. Towards affordable geothermal power: Economic impacts of innovation and new technology, V. Shembekar and U. Turaga, 35th Annual Meeting of the Geothermal Resources Council, 2011
2. Pairing of an Integrated Gasification Combined Cycle power plant (IGCC) with CO2-EGS as a strategy for deployment in arid regions, U. Turaga et al., 35th Annual Meeting of the Geothermal Resources Council, 2011
3. Assessing innovation in geothermal energy technologies: A review of the patent landscape, U. Turaga et al., 35th Annual Meeting of the Geothermal Resources Council, 2011
4. Combined scCO2-EGS IGCC to reduce carbon emissions from power generation in the desert southwestern United States (New Mexico), D. Chandra et al., 35th Annual Meeting of the Geothermal Resources Council, 2011
5. Combined scCO2-EGS IGCC to reduce carbon emissions from power generation in the desert southwestern United States (New Mexico), D. Chandra et al., In preparation for *Geothermics*

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10116
Presentation Title: Baseline System Costs for 50.0 MW Enhanced Geothermal System (GEECO)
Investigator: Dunn, Paul (GEECO)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response - I have reviewed the set of comments and thank DOE for the input. The additional items mentioned by reviewers will be addressed in the final report, but for reasons of brevity / time limit simply could not be addressed at the time of the Peer Review. Again, thank you for the feedback.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10117
Presentation Title: Economic Impact Analysis for EGS (EGI)
Investigator: Gowda, Varun (University of Utah)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response to Reviewer 14 - The project is divided into several phases and we are on time as per schedule to deliver a beta version by the end of the 4th Quarter of 2011. Phase 2 was 30% complete during the time of the review. The real tools can only be delivered at the end of Phase 2, even in a beta version. We will do our best to speed up this process to have an early version of a model that can estimate economic impacts.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 14 -We have indicated the standard methodology of input-output modeling in slide number 8 of the presentation. The standard methodology being followed was also explained to reviewers.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 64 -We recognize that parasitic power losses are a very important component of costs. We welcome the comments and will factor the parasitic loss evaluation into the model.

Response to Reviewer 14 - The focus is on EGS, hydrothermal and co-produced fluids as per the scope of the project and contract signed with DOE. All necessary cost elements have been assessed.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response to Reviewer 8 - We welcome the suggestion to use an iterative/incremental project management approach. We will ensure that we build a mechanism to periodically show DOE the preliminary results. We will start this by the next GSPAWG meeting.

Response to Reviewer 14 - A clear and transparent assessment of economic impact begins with identifying key cost drivers so that we can build a input-output framework that can suitably allot the cost components to appropriate industries where the impacts are propagating. The method applied here is an industry standard and is a best practice of economic impact modeling.

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 64 - O&M costs will be factored into the model as per suggestions. We recognize that pump costs and O&M costs could be a major cost driver for EGS projects.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response to Reviewer 64 -Parasitic power will be factored into the model.

Response to Reviewer 8 - We will work with DOE to find similar efforts and validate the model when the preliminary results are ready.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10118
Presentation Title: Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment and The Potential Employment, Energy, and Environmental Impacts of Direct Use Applications (BLA)
Investigator: Battocletti, Elizabeth (Bob Lawrence & Associates, Inc.)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

Response to Reviewer 1 - Barriers will be discussed extensively. Key barriers that have previously been noted (see proposal and the ORNL report referenced therein) and which will be further discussed include adequate data and information on performance, installation challenges, and the need for qualified installers.

Response to Reviewer 56 - Costs in other countries are useful but cannot be employed in a direct cost comparison for a cost-benefit analysis in the United States because cost profiles are unique to this country. As well, most European countries have a relatively uniform energy mix and geology, allowing simple analysis. The U.S. is much more heterogeneous in terms of energy mixes and geological properties, thus making comparisons with European experience difficult. The importance of soil thermal conductivity is underestimated in this comment by the reviewer – soil properties can easily change cost by 20% to 50%. For a cost-benefit analysis to have any real use, such uncertainty must be addressed explicitly and quantitatively. Hence, assuring that soil thermal conductivity is directly considered is justified.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewer 1- Data analysis is a key part of this project – it is only through a careful data analysis effort that accurate cost-benefit can be accomplished. The approach to measuring the ―economic, social, and environmental benefits" includes inter alia job generation, stabilization of markets and energy use, diminishing reliance on price-volatile fuels, reducing greenhouse gas emissions, and reducing the environmental footprint of fuel production and use for building HVAC services – all of which will be explicitly addressed quantitatively. All of these are underway and part of the overall approach.

Response to Reviewer 46 - The technical assistance being conducted is in direct response to emails, phone calls, and visits to the Geo-Heat Center (GHC). These three communication mediums account for almost 100 percent of the GHC‘s technical assistance activity. The Geo-Heat Center responds to general questions about geothermal heat pumps from homeowners to more detailed questions about how to implement a geothermal greenhouse operation. The GHC provides technical assistance on small-scale power generation, direct use applications, and geothermal heat pumps. A bulletin article and a project described in an article are both considered technical assistance.

Tracking the GHC‘s technical assistance inquiries provides the necessary information to help GHC staff determine which papers or articles would be the most useful to respond to future inquiries. The GHC is publishing the state reports in its quarterly bulletin, which would not be considered a project, but it also publishes articles about projects. The vast majority of people on the GHC mailing list are not included on the Geothermal Resources Council‘s or Geothermal Energy Association‘s mailing lists. The GHC bulletin is also posted on the website, providing information to the general public.

Response to Reviewer 56 - *"The project has good scientific/ technical resources within the defined scope. What is missing is input on energy system issues."* Not sure what this refers to.

Response to Reviewer 70 - *"The analysis approach and assumptions for the building analysis in various locations was not well enough defined. I am concerned that they have underestimated the challenge and may not be able to complete the scope with credible results."* This is a challenge, but it has been addressed. Building characteristics are readily obtained from a variety of sources, and NREL has available sophisticated software for establishing detailed building loads. We are using these, along with detailed national weather databases, to establish building characteristics for each metro area. Yes – a challenge, but also tractable and already dealt with. Using these building loads for each region, we can then conduct model runs for each area, which is currently underway.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 1 - *"...but no information about the actual progress toward data collection and analysis."* Data collection and analysis are key parts of this effort, and the basis for a credible cost-benefit study. Slide 7 mentions some of the work, as did slide 22. The point was made that nearly all of the data are in hand. Admittedly, we did not provide a detailed description of available data (e.g., soil and groundwater temperatures, local hydrology, regional soil and rock thermal conductivity, local climate, building properties, software test runs, analyses of sensitivities, etc.) but these data are in hand and form the basis of simulations for the cost-benefit analysis.

Response to Reviewer 70 - *"I was disappointed with the progress shown for data collection and the analysis results for various locations."* See response to comment above. Also, the results by metropolitan area are rapidly moving toward completion. The data collection and analysis has been emphasized to assure adequate data coverage and quality. Results by metropolitan area will be presented at the Geothermal Resources Council meeting in October 2011. The rate of progress is appropriate for this stage of the project.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response to Reviewer 70- *"Downgraded from good to poor because I felt the PI did not recognize the challenges of modeling and had not got team far enough along on that activity."* The emphasis in the initial stage of the project has been to assure the adequacy and quality of the available data in order to have a credible cost-benefit analysis. The modeling of the systems, although complex, was always intended to use standard, industry-approved modeling methodology, in order to assure compatibility with existing industrial standards. Emphasis was therefore placed on discussing the status of data collection and analysis rather than the modeling activity. The modeling is well underway and on schedule, despite the absence of direct discussion of it in the presentation.

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 1- When you are limited to the how many slides and pages that are allowed for the peer review process it is hard to be able to summarize everything, especially considering there are three components (BL&A, CGEC, and GHC) happening at the same time. This project will combine two of the components together but it is not like other projects where you have to wait until step 1 is done before you go on to step 2. At this point in time we actually have several steps going on concurrently. The peer review summary and presentation is geared more towards outlining step 1, step 2, step 3, step 4, and so forth.

Response to Reviewer 56 -*"The weakness of the project is that it does not deal with the compatibility of heat pump installations with the grid, the housing stock nor the contemporary technologies for buildings and building service."* Actually, these issues will be directly discussed in the project report. At this point, these issues cannot be addressed without the modeling results and survey results in hand (as they are needed to quantify the impacts and challenges).

Response to Reviewer 70 - *"More thought needed on building analysis."* This issue is part of a detailed regional analysis of building characteristics, which is an integral part of being able to conduct adequate modeling of geothermal heat pump (GHP) systems. We are developing a database of building properties along the lines of NREL and ASHRAE standards and software needs. These form the basis of our GHP designs, along with soil properties, local climate conditions, and fuel sources.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

Response to Reviewer 1- *"The project would be improved greatly if there was a clear path for data collection and analysis was identified*." The path has been developed, but perhaps not sufficiently detailed in the presentation. The data collection and analysis are nearly complete, and the modeling is underway. As noted above, many data resources have been accessed, data completely organized and vetted for quality, and then utilized in the modeling effort. Data will be transferred to the NGDS at the completion of the project and made web-available via the CGEC website.

Response to Reviewer 46- The GHC provides more detailed information on the types of technical assistance in the quarterly and yearly reports. The GHC does not receive feedback concerning the technical assistance its staff provides. It would be difficult to quantify how much one single act of technical assistance would/could reduce a perceived or real barrier to geothermal.

Response to Reviewer 56- *"In the final reporting the questions of system aspects and compatibility should be addressed and if they cannot be treated thoroughly, a road map for complementary research should be provided. Also, alternative strategies, like gas driven heat pumps, and other heat exchange configurations than drilled holes should be considered."* Items which are not beyond the pre-defined scope of work will be discussed in the final report.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10119
Presentation Title: National Geothermal Student Competition (NREL)
Investigator: Geiger, Jesse (National Renewable Energy Laboratory)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:

No Response Entered

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

No Response Entered

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response - In regards to funding and cost:

We understand the concerns about funding limitations of this project and how it could be sustainable in the future. The majority of the funding used in-house at NREL was one-time costs centered on the development of the competition and the climbing the learning curve to how best to design and implement the project. Now that the major learning is complete we anticipate that NREL management of a future, similar competition (including payment for the venue, lunches, field trip, and other expenses) to be reduced by 50% or more. We were quite pleased to be able to raise $5,500 in industry contributions toward prize money given that this was a pilot program. In the future we see the potential to raise a much more significant cost share from industry and nonprofit organizations. Properly approached in a better economic environment, a significant contribution from competition hosting regional State and local organizations should also be possible.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

No Response Entered

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response - In regards to the comments about tracking progress:

We have gathered subjective data through surveys from each of the students, once at the beginning of the competition and once afterward, to assess the impact of the student competition on learning and on their general disposition toward geothermal. We collected names on each survey so we will be able to track the evolution of each student.

In regards to the timing of the project:

We clearly understand that the timing of the project could be better; in this pilot year we initiated the project with funding that became available October 1. Given that constraint, the fact that the competition was held at all during the current academic year was quite an achievement. If DOE decides to continue the effort in the future it will be important to break the project cycle from the government fiscal year, allowing an announcement in the Spring, awards in Summer, and initiation in Fall.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 10120
Presentation Title: National Geothermal Academy (UNR)
Investigator: Calvin, Wendy (University of Nevada -- Reno)
Panel: Rebuttal - Systems Analysis, Resources Assessment, Data System Develop. & Popula
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Systems Analysis:.

Response to Reviewer 31 - I disagree and think that education of a new generation of ―geothermalists" is critical to the GTP's mission to find, access and use the Nation's geothermal resources. With an aging workforce, development of a smart, skilled labor pool is required to assure success in current and future exploration, development and EGS endeavors.

Rebuttal Comments for Scientific/Technical Approach - Systems Analysis:

Response to Reviewers 31 and 57 - As noted in our slides, no single University in the US system has the capacity to teach the diverse array of aspects covered in the Academy. This is the motivation for a summer program, when academics can come from their home institutions to teach in their area of expertise. Both reviewers share a misconception that merely reviewing slides on line will impart the same level of content and understanding as an active and interactive course format. It is clear that the problems assigned, working through them in a group context, give and take through active question and answer with the expert instructors and in person assistance from faculty and teaching assistants is invaluable and irreplaceable as a method of learning complex, detailed and multi-layered material.

We will make non-proprietary material widely available, but based on the high level of interaction observed in the group this summer, a strictly on-line course will never be able to provide the depth of understanding the students are achieving through in-person and in-depth immersion in the content.

Rebuttal Comments for Accomplishments, Results and Progress - Systems Analysis:

Response to Reviewer 31 - Without a detailed assessment from the industry on the number of individuals they expect to hire and in what fields, it is pure speculation to say whether or not the 54 students taking advantage of this content are too small a pool or too large. Based on this summer's enrollment, just under ½ are industry professionals or in academic research positions. We have very few undergraduates and, given the current job openings that focus on a highly trained professional work force, we will focus less on undergraduates in the future. I don't know the number of working professional scientists and engineers in the geothermal area, but my guess would be that this year's summer students represent probably 10% of that professional pool, which is going to have a large impact on the future of the field.

Additionally, fully 50% of the students taking advantage of the content are only here for one or two weeks; they haven't had to commit to the entire 8-week session. This also broadens the impact and allows working professionals to get specific content they need in a shorter period of time.

Rebuttal Comments for Project Management/Coordination - Systems Analysis:

Response to Reviewer 31 - Absolutely. Mechanisms are in place to gather data on both individual module instructor and content as well as the program as a whole.

Rebuttal Comments for "Overall" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Strengths" - Systems Analysis:

No Response Entered

Rebuttal Comments for "Weaknesses" - Systems Analysis:

Response to Reviewer 70 -Sustainability over time will hinge on initial support by DOE to refine the content and to support the faculty experts who are sharing their knowledge. As teaching professionals well know, it takes two or three iterations to get the content and format fitted to the student audience. Long term sustainability has been an issue in New Zealand and Iceland programs, but we will have a better idea what ―sustainable" will require once we know the specific costs for this first summer.

Rebuttal Comments for "Suggestions for Improvement" - Systems Analysis:

No Response Entered

Tracers and Tracer Interpretation

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11200
Presentation Title: Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics
Investigator: Tang, Yongchun (Power Environmental and Energy Research Institute)
Panel: Rebuttal - Tracers and Tracer Interpretation
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Tracers:

Response - This project targets *the "Tracers and Tracer Interpretation" subtopic (16), e.g. "To adapt or develop reservoir tracers and/or tracer interpretation techniques capable of being used at temperature up to 300 ^oC that provide information beyond well-to-well connectivity, such as fracture surface area or fracture* spacing", which was identified in DOE's original solicitation. We fully agree with reviewers' comments that *to help achieve project objectives, a "mixture of theory, experiment, field trials and interpretation tools might provide a useable produce and make significant impact on industry" (Reviewer 38).*

We also agree with *Reviewer 58's comments that there are many low-cost, low toxicity tracers available*. But after reviewing 4 classes of material, and up to 29 commonly used tracers, we believe that only those tracers with distinguished molecular structures, those that reflect different tracer-rock interaction patterns and diffusion paths, could provide geothermal reservoir information beyond the well-to-well connectivity. For these classes of tracer (organic chemicals such as carboxylic acids), the pre-concentration techniques that we have developed will be critical in terms of cost-saving and being environmentally benign so that they might eventually be used under real geologic conditions.

As correctly pointed out by *reviewers 71 and 50, using "smart" tracers to understand fracture properties (subsurface porosity, migration distance, fractural spacing and surface areas, etc.) requires better knowledge of the reservoir conditions and well-calibrated theoretical models.* Our proposed Task 6, which covers the second half of the project period (from Jul. 1, 2011 to Dec. 31, 2012), is to establish the tracer interpretation system. This will include combining molecular modeling and molecular dynamics to build up relationships between geothermal fracture properties and the tracer performances from both laboratory core flooding experiments and field trials. The reviewers' comments are important to us to carry out these tasks as planned.

Rebuttal Comments for Scientific/Technical Approach - Tracers:

Response - Tasks 1 to 3 in our phase I project (from Jan. 1. 2010 to Jun. 30, 2011) for ―*Proof of Concept for Tracer Arrays from Advanced Laboratory Simulation*" mainly focused on development of laboratory protocols and theoretical modeling methods to demonstrate the feasibility of using ―smarter" tracers for EGS applications. We used silica as our initial rock model because it represents one of the most common Hot-Rock structures occurring in the EGS applications, and also because it is the most abundant rock type in the Mt. Princeton Hot Spring geothermal reservoir in which our field trial is planned. We agree with *Reviewers' comments that there are many fundamental questions needed to be addressed, and some of these questions could be better answered when we include different geothermal rocks with various surface areas and porosities in our studies, in particular, the interaction of the developing tracers with the rock samples collected from the Mt. Princeton Hot Spring reservoir and other commonly seen reservoir conditions.*

Rebuttal Comments for Accomplishments, Results and Progress - Tracers:

Response - The main objective in the Phase I study is to study and plan for the field work. As been pointed out by Reviewers 50, 58, and 38, we believe our project is on-track to meet the originally proposed milestones including tracer selections, detection method development, theoretical modeling and tracer-surface interactions, with many innovative approaches. Reviewer 71's concern about establishing coordination between the laboratory's studies with more realistic geologic conditions should be addressed in more detail in our Phase II studies.

Rebuttal Comments for Project Management/Coordination - Tracers:

Response - The success of our integrated project requires strong coordination among all participants. This not only requires collaborations between PEER Institute with several subcontractors (Caltech and Mt. Princeton), but also involves the interdisciplinary coordination among all subdivision groups inside the PEER Institute. The PI, Dr. Yongchun Tang, is currently the director of PEER Institute. He has been working hard on planning, directing, and monitoring R&D activities in PEER. His leadership ensures positive contribution from PEER's internal R&D studies towards the successful execution of proposed project tasks. Through decades of collaboration with the Materials & process Simulation Center (MSC) at Caltech, PEER Institute has been considered as the ―Experimental Arm" of MSC/Caltech. There has been a long history of theoretical/experimental collaboration between PEER and MSC/Caltech.

Rebuttal Comments for "Overall" - Tracers:

Response - This three-year project has been divided into two phases. Phase I which covers the one and one half year R&D laboratory effort and focuses on establishing laboratory protocols and theoretical models to demonstrate the feasibility of using an array of tracers to probe the reservoir properties beyond well-to-well connectivity. Improving the detection limits using the pre-concentration procedure coping with the GC measurements represents the most advanced and innovative approach, which we believe could significantly boost the applicability of developing ―smart" tracer systems in EGS applications. Development of the tracer interpretation system has been set as the main objective of our Phase II studies. This includes more studies to establish the theoretical models to connect laboratory's observations with real geologic conditions, and to conduct the field works to validate and improve our tracer system.

Rebuttal Comments for "Strengths" - Tracers:

Response - The extremely high sensitivity tracer detection method developed from our Phase I studies is important for our field application of the tracer system. We believe that these works have important in both science and engineering.

We highly value *Reviewer 58's comments concerning collaboration with a hydraulic fracturing service provider*. One of our industrial partners, BJ Energy Service, now part of the Baker Hughes company, is among the top leaders of fracturing services worldwide. We will continuously work with BJ/Baker Hughes to get more industrial feedback on the applicability of our developing tracer systems.

Rebuttal Comments for "Weaknesses" - Tracers:

Response - Our developed HF-LLME method for the tracer pre-concentration methods is not intended to be a real-time field application yet. Instead, geothermal brine samples will be collected on-site and sent to our lab for further calibration and tests. Therefore, the methods developed so far should be effective. Other detection methods for commonly used tracers, such as dyes or fluoresces, are also available. It is not our intension to develop the HF-LLME method to become a cure-all method. However, other artificial chemical tracers which have similarities with carboxylic acids could also benefit from our developing HF-LLME methods.

Rebuttal Comments for "Suggestions for Improvement" - Tracers:

Response - Based on the valuable comments from reviewers, we will improve our Phase II studies in the following ways:

1. Continuously improve our fundamental understanding on how the tracers work under surface conditions using both laboratory and molecular modeling. We are working on a few new tracers which should reflect more details of subsurface chemistry.
2. Conduct slim-tube laboratory tests on different rock surfaces which are closer to the realistic geothermal reservoir conditions;
3. Develop tracer interpretation systems which focuses on establishing the reservoir properties (porosity, migration distance, surface areas, etc.) with the tracer performance under both laboratory and field conditions;
4. Work with industrial partners, BJ/Baker Hughes and Mt. Princeton, and with geoscientists and geothermal engineers with field experience.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11201
Presentation Title: Quantum Dot Tracers for Use in Engineered Geothermal Systems
Investigator: Rose, Peter (University of Utah)
Panel: Rebuttal - Tracers and Tracer Interpretation
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Tracers:

Response to Reviewer 71 – The reviewer complains that there is an overlap of goals and objectives between two projects that I have been awarded. I thought that cooperation between projects was a good thing and that if one project benefits from another then both projects gain.

Response to Reviewer 50 - The reviewer complains that ‗developing a novel new tracer will take time'. In response, if we only undertake easy objectives, then we might always succeed but our success will be shallow.

Response to Reviewer 58 - The reviewer claims that ―This high-cost, difficult to engineer trace (sic) compound is questionable". No one told me in advance that I should undertake only easy goals.

Rebuttal Comments for Scientific/Technical Approach - Tracers:

Response to Reviewer 81 - The reviewed claims that ―field comparison with performance of cheaper, readily available tracers (e.g. fluorescent dyes) need to be conducted."

Indeed, we intend to conduct such field experiments when the quantum dots are ready for such field tests.

Response to Reviewer 71 -The reviewer complains that a review of temperature data, which was presented to set the stage, should not be presented herein. However, without sufficient background, it is impossible to describe the relevance of this project. This reviewer also complains that ―expecting diffusion to estimate surface area in EGS doesn't seem feasible if EGS targets are still crystalline rock". The reviewer may be unaware of a fundamental aspect of EGS: that fractures in EGS and geothermal reservoirs are lined with porous minerals—NOT CRYSTALLINE ROCK. Solutes are free to diffuse into these porous rocks, whereas colloids such as quantum dot tracers are not. This contrast in behavior is a fundamental property that we are trying to exploit in the use of such tracers. The reviewer complains that ―it is not clear why we should be estimating near well surface area." Near-wellbore fracture creation is essential to the creation of highly fractured EGS reservoirs. The higher the fracture density the more efficient the heat extraction process and the fewer number of wells will be required. This has been shown in studies too numerous to list.

Rebuttal Comments for Accomplishments, Results and Progress - Tracers:

No Response Entered

Rebuttal Comments for Project Management/Coordination - Tracers:

Response to Reviewer 71 – Reviewer claims that ―interdependence on other projects was somewhat alarming." Since when is interdependence a bad thing? If one project connects synergistically with another then so much the better!

Rebuttal Comments for "Overall" - Tracers:

Response to Reviewer 81 – Reviewer claims that the quantifying of reversible sorption, resistance to thermal decay and contrasting diffusivity is slow. In response, these are the reactive tracer properties that we intend to demonstrate once we have proven the quantum dot tracers to be capable conservative tracers. We can‘t run before we can walk.

Response to Reviewer 38- Reviewer claims that ―this is a good project and is progressing appropriately.” I strongly agree.

Rebuttal Comments for "Strengths" - Tracers:

No Response Entered

Rebuttal Comments for "Weaknesses" - Tracers:

Response to Reviewer 50 - Reviewer claims that ―the experiments so far are on Ottawa sand, which is not realistic for the goal of estimating fracture surface area”. In response, the Ottawa sand experiments are absolutely relevant in establishing a baseline using a sorbent that is relatively inert. Our next step is to move to sorbents that have more highly reactive sites for adsorption.

Response to Reviewer 58- Reviewer claims that the investigator ―seemed unaware of colloid transport work”. In response, this PI is highly aware of colloid transport work. Again, we need more time to present our project if we are to have a chance of addressing every avenue of a project.

Rebuttal Comments for "Suggestions for Improvement" - Tracers:

Response to Reviewer 58- Reviewer suggests ―more collaboration with geoscientists”. In response, I collaborate almost entirely with geoscientists. Unfortunately, there was time to present only the material science aspects of this project.

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11202
Presentation Title: Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems
Investigator: Kennedy, Mack (Lawrence Berkeley National Laboratory)
Panel: Rebuttal - Tracers and Tracer Interpretation
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Tracers:

Response to Reviewer 81- We disagree with the reviewer.

During the period covered by this review, our major focus has been on model development and use of laboratory experiments to test our hypotheses and methodology; the project is in an exploratory phase. Eventually, we are going to apply the technique to field-scale applications.

Second, the reviewer implies that we intend to use laboratory experiments to characterize a real reservoir. This is not the case. We fully understand the complex relationship between a real reservoir and laboratory experiments associated with rock samples (e.g., heterogeneity and scaling). However, it is equally important to be aware that chemical reactions occur at small scale. Without a good understanding of the processes/reactions occurring on the small scale, it would be extremely difficult, if not impossible, to understand and model tracer transport processes in a reservoir. The actual motivation of the laboratory experiments is (1) to provide data sets to test our hypothesis (that reaction rate is related to reservoir attributes of interest, such as fracture surface area), (2) to evaluate our modeling methodology and approach, and (3) to provide reaction-related parametric values to be applied to a given reservoir where rock samples have been collected. There is no real scientific reason why the knowledge of this kind, gained from laboratory experiments, cannot be applied to a geothermal reservoir.

Response to Reviewer 71- We fully agree with this reviewer‘s comment. The project indeed represents the first systematic effort to use natural tracer to estimate the critical parameters for an EGS system, fracture surface area, between injection and production wells.

We fully understand the differences between BET surface areas and ―geologic" surface areas (or fracture-matrix interfacial surface areas associated with flow paths between injection and production wells). It is not our intention to use BET areas to represent ―geologic" surface area for a given reservoir. Instead, our laboratory measurements are used to establish how local reaction rates are related to rock surface area.

Response to Reviewers 50 and 58 - Fracture surface area is a key parameter for an EGS system and tracer interpretation is the only promising technique to estimate this parameter. We are aware of and understand the implication of the existence of numerous uncertainties. That is why this project explores the use of multiple tracers, associated with the same flow paths, to try to minimize these uncertainties.

Response to Reviewer 38 -During the period covered by this review, our major focus has been on model development and use of laboratory experiments to test our hypotheses and methodology; the project is still in an exploratory phase. Eventually, we are going to apply the technique to field-scale applications. One final product of the project will be a new tracer interpretation technique and we feel considerable progress has been made. We fully agree, isotopes are natural tracers that can be used to further constrain reaction paths/rates in geothermal systems.

Rebuttal Comments for Scientific/Technical Approach - Tracers:

Response to Reviewers 71 and 81 -

1. Both artificial and natural tracers are useful for characterizing EGS systems. In addition to artificial tracers, natural tracers (always staying in the reservoir) provide useful information on water flow paths and fracture-matrix interaction.

2. We fully understand the differences between BET surface areas and ―gologic" surface areas (or fracture-matrix interfacial surface areas associated with flow paths between injection and production wells). It is not our intention to use BET areas to represent ―gologic" surface area for a given reservoir. Instead, our laboratory measurements are used to establish how local reaction rate is related to rock surface area. Also, it should be noted that recognition of the importance of BET surface area in these systems has significant impact on the interpretation of artificial tracers.

3. We have experienced modelers and experimentalists on our team. We fully understand the usefulness and limitations of numerical models. They are useful only when they incorporate the right physics/chemistry, correct conceptual model, and reliable model inputs. That is why we have a closely related combination of modeling and experimental tasks. At the same time, it is useful to note that modeling is a necessary component for estimating reservoir parameters (such as fracture surface area) that cannot, otherwise, be directly observed or measured.

4. We totally agree with the reviewer on this. It is important to note that surface area estimated from single-well tests may not be representative of the true surface area associated with flow paths between injection and production wells.

Response to Reviewers 50 and 58 - Our team includes both geochemists and hydrogeolgists who have considerable experiences in tracer-related studies. The reliance on simple vs. complex models poses both a scientific and philosophical question for practical applications, largely because of the interplay between data availability and uncertainty. In our mineralogy models, some simplification is necessary to address the practical problems. Also note that our lab experimental results will be used to test the accuracy (and uncertainty) of the simplifications and our models. Nobody likes to use ―simple mineralogy models", but in the absence of detailed data, that's where you start.

Response to Reviewer 38 **-** We agree: the application of all tracers, natural or otherwise, will be reservoir dependent to some degree. But without projects, such as this and others, we have little data or understanding of the extent of reservoir dependence. The use of natural isotopes is a major component of the project.

Rebuttal Comments for Accomplishments, Results and Progress - Tracers:

Response to Reviewer 71-

1. We fully agree. Expansion to additional isotope systems will constrain the system even further.

2. To the best of our knowledge, we are probably the first group to show the existence of multiple time periods of [dis]equilibia. We also demonstrated that different surface areas correspond to different breakthrough curves (concentration as a function of time) during these time periods. In other words, the breakthrough curves (or observed tracer signals) are sensitive to the surface area and therefore can be used to estimate the area. This was expected because the surface area controls the mass transfer between fractures and surrounding rock matrix where the reactions occur.

Response to Reviewers 38, 50 and 58 - As indicated by the other reviewers and also in the project summary, we have made significant progress in both modeling and experimental tasks relative to the project schedule.

Rebuttal Comments for Project Management/Coordination - Tracers:

Response to reviewer 71 -Regarding the question of modeling obtaining area estimates, see our response to this reviewer‘s comment on Accomplishment, Results and Progress.

Regarding the question if BET surface area and geologic surface area can be resolved, see our response to this reviewer‘s comment on Relevance/Impact of Research.

Rebuttal Comments for "Overall" - Tracers:

Response to Reviewer 38 -Currently, this project is still in the early research stages. As the project moves forward, we will have more integration between the different tasks.

Rebuttal Comments for "Strengths" - Tracers:

No Response Entered

Rebuttal Comments for "Weaknesses" - Tracers:

Response to Reviewer 58 - Because of the limitation of time and space, we could not discuss all the details of our progress in the presentation and project summary. In fact, all the relevant dimensionless numbers are considered in our developed analytical solutions.

Also, we fully understand the differences between BET surface areas and ―geologic” surface areas (or fracture-matrix interfacial surface areas associated with flow paths between injection and production wells). It is not our intention to use BET areas to represent ―geologic” surface area for a given reservoir. Instead, our laboratory measurements are used to establish how local reaction rate is related to rock surface area.

Finally, we would like to mention that we fully understand the existence of uncertainty. That is why this project uses multiple tracers associated with the same flow paths to reduce the uncertainty.

Rebuttal Comments for "Suggestions for Improvement" - Tracers:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11203
Presentation Title: Tracer Methods for Characterizing Fracture Stimulation in Engineered
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Panel: Rebuttal - Tracers and Tracer Interpretation
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Tracers:

Response to Reviewer 5 – Reviewer wrote: ―Modeling only; purely theoretical research". This comment was probably misplaced because most of my reporting was on laboratory and field experiments, with just a bit of modeling.

Response to Reviewer 4 - Reviewer 4 was concerned about detection limits of the tracers to be used in the downhole tool. Detection limits are not an issue. The dilution factors of tracers in wellbores are orders of magnitude less than in reservoirs.

Rebuttal Comments for Scientific/Technical Approach - Tracers:

Response to Reviewer 3 - Reviewer 3 wrote: ―Injection-backflow is of questionable use in fracture-dominated systems, as this is so different from the flow and composition paths to be experienced in an EGS development." I disagree. The near-wellbore fracture network is exactly the same pathway whereby stimulation and circulation fluids will enter the reservoir via an injection well. Therefore, a method such as ours that calculates the surface area of the near-wellbore fracture network is very relevant.

Rebuttal Comments for Accomplishments, Results and Progress - Tracers:

Response to Reviewer 5 -Reviewer 5 wrote: ―Sorption/desorption needs to be considered in future modeling efforts." The Reviewer must have missed this part of the discussion as most of our modeling is on sorption/desorption. Karsten's work is not, but ours is.

Resposne to Reviewer 4 - Reviewer 4 noted that ―R should be around 1.2". I agree, but we think that a smaller retardation factor will still be useful—at least for demonstrating the concept. Research continues, however, on identifying compounds with higher values of R.

Rebuttal Comments for Project Management/Coordination - Tracers:

No Response Entered

Rebuttal Comments for "Overall" - Tracers:

Response - Reviewer 1 asked: ―Why not use fractures or surrogate fractures in the laboratory experiments? The use of sand is questionable with respect to application to modeling." We intend to use surrogate fractures in future experiments, but sand provides a conservative and well characterized baseline material. In other words, sand is probably the least porous and least sorbing sorbent that we could choose. If the tracers sorb on sand then they will likely sorb more on more realistic sorbents.

Rebuttal Comments for "Strengths" - Tracers:

No Response Entered

Rebuttal Comments for "Weaknesses" - Tracers:

Response to Reviewer 3 - Reviewer 3 said: ―perhaps need more expertise in mineralogy and interwell-scale heterogeneity to improve program". We have extensive experience within our group that we are calling upon to characterize alteration mineralogy and interwell heterogeneity. I regret that there was insufficient time in the presentation to describe this aspect of our project.

Rebuttal Comments for "Suggestions for Improvement" - Tracers:

No Response Entered

Review: 2011 Geothermal Technologies Program Peer Review
Presentation Number: 11205
Presentation Title: Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO_2 and Water-based Geothermal Reservoirs
Investigator: Plummer, Mitchell (Idaho National Laboratory)
Panel: Rebuttal - Tracers and Tracer Interpretation
Proposal Mean: N/A

Rebuttal Comments for Relevance/Impact - Tracers:

Response: Most comments were favorable identifying areas of the project with positive impact to resource development. The field test and analytical toolbox were identified as valuable results of the project. *Reviewer 58 indicated that the encapsulated materials were not proved feasible*. The testing conducted with the encapsulated materials was a very small part of the project and was not sufficient to prove the technique. However, we feel that the encapsulation technique showed promise rather than being a failure. Soluble materials were successfully isolated from water so that a much broader range of tracers could be used in geothermal settings. Significantly more work is needed in the area of encapsulation, particularly in selecting the encapsulation materials so that they are tailored to the specific setting for use. We also emphasize that our interest in encapsulated materials is essentially to delay reaction of soluble reactants, which does not require recovery of the encapsulated colloids. We recognize that recovery of particle tracers may be extremely difficult, but that is not an impediment to success in this application. Thus, while we have not developed the method to the stage necessary to demonstrate success, we did not find that encapsulation will not work.

Rebuttal Comments for Scientific/Technical Approach - Tracers:

Response: Most comments were favorable indicating that the software toolbox would be useful to industry. The blend of modeling, lab, and field activities was lauded. *Reviewer 58 commented that there were no new analyses, methods, or materials*. While much of this project is an extension of work that was begun for the Hot Dry Rock project, there were no actual field demonstrations of the reactive tracer concept conducted in that project. To our knowledge, this is the first actual attempt at deployment of thermally reactive tracers in a geothermal reservoir. We observed the thermally reactive tracers in the production wells at Raft River at concentrations relative to the conservative tracers that showed thermal degradation at a rate consistent with other measurements of reservoir temperature. This experiment demonstrates the feasibility of using thermally reactive tracers in a geothermal reservoir, and demonstrates that the tracers do carry information about thermal history. We admit that significantly more work is needed to demonstrate accurate thermal monitoring using the technique. Some of the algorithms included in the tracer analysis toolbox are existing technology. Our contribution was to utilize a simplified reservoir model approach that considers the primary controls on thermal evolution and uses combined conservative and reactive tracer data to infer parameters of that reservoir model, such as fracture aperture and spacing. While the encapsulation part of the project was fairly small, we believe that this technique shows the potential for development of significant new methods of tracer testing. We disagree with this reviewer and feel that we made significant progress on advancing reactive tracers for measuring thermal evolution.

Rebuttal Comments for Accomplishments, Results and Progress - Tracers:

Response: All comments were positive indicating good results and progress.

Rebuttal Comments for Project Management/Coordination - Tracers:

Response: Reviewers complemented the collaboration with U. S. Geothermal for the field testing. *One observation (from reviewer 58) was that there was not a clear go-no go decision gate established.* We concur with this observation. This project ends this fiscal year, so no action is needed. However, in future projects, we will identify decision points and decision criteria to support go no-go decisions.

Rebuttal Comments for "Overall" - Tracers:

Response: These comments were very positive indicating that the project had made more progress than other projects and the results were interesting and directly addressed the primary geothermal resource issue of temperature. *Reviewer 81 found the results to be 'somewhat ambiguous', but also indicated that further work may be promising*. *Another reviewer (71) indicated that add-on funding should be considered*. We concur that the work to date has not resolved all the uncertainties associated with interpretation of thermally reactive tracer tests. However, our work has demonstrated the feasibility of these tests in hydrothermal systems. We also concur that follow-on funding would be a good idea.

Rebuttal Comments for "Strengths" - Tracers:

Response: The reviewers identified the value of getting field data and collaborating with U. S. Geothermal on the field test.

Rebuttal Comments for "Weaknesses" - Tracers:

Response: *Reviewer 81 suggested that there was too much emphasis on modeling as a means of constraining model inputs, and insufficient analysis of reservoir data, particularly borehole fracture characterization*. We concur that the more reservoir data used to develop the conceptual model the better. As our objective was evaluating the feasibility of the reactive tracers, we did not spend a lot of effort on refining the Raft River conceptual model as we would have liked to do. Such an activity would be included in an actual deployment of the reactive tracer technique. Reviewer 50 commented that reactive tracers should be combined with conservative tracers. This is exactly what we did in the Raft River field test, so we apparently did not communicate this adequately in the presentation. We absolutely agree that both conservative and reactive tracers must be used together.

Reviewer 58 commented that porting existing solutions into MATLAB is not an impressive research project. We concur that if this was the objective of the project, it would not have been an impressive project. However, the objective of the project was to demonstrate the feasibility of using thermally reactive tracers to measure thermal drawdown during reinjection of spent geothermal fluids. To that end, you must be able to analyze and interpret the results of the tracer test. You also must be able to design the tracer test, particularly to select tracers with the appropriate decay constants for the temperature and residence time in the reservoir. Therefore, a set of analytical tools is needed to support the reactive tracer technology. We developed a program that provides a quantitative interpretation of combined conservative and reactive tracer data in terms of reservoir characteristics that control cooling of a fractured rock reservoir. In the course of doing that, we found it convenient to include other commonly used tracer methods and constructed an graphical user interface to facilitate their use. Having decided to do that, we felt that the industry could benefit from this toolbox, and so sought to make it readily available.

Rebuttal Comments for "Suggestions for Improvement" - Tracers:

Response: None of the reviewers made any suggestions for improvement.

Appendix C: General Project Evaluation Form via PeerNet

Evaluation Criteria

Panel: Data Systems

Relevance/Impact of Research - Weight = 15%

Assess the project based on the importance of achieving the project's objectives relative to the broader geothermal program mission and goals. Evaluate on the extent to which the project addresses known, anticipated, and significant technical knowledge gaps or market barriers. Assess the project on the impact the activities and results have on costs, performance, applications, markets, and other factors in geothermal energy development.

4 – Outstanding

The project has made substantial progress and impact on the DOE's Geothermal Technologies missions and goals. Project has demonstrated outstanding advancement in addressing knowledge gaps and barriers. The project has exceptional impact on factors in geothermal energy development.

3 – Good

The project has made notable progress and impact on the DOE's Geothermal Technologies missions and goals. Project has demonstrated significant advancement in addressing knowledge gaps and barriers. The project has considerable impact on factors in geothermal energy development.

2 – Fair

The project has made modest progress and impact on the DOE's Geothermal Technologies missions and goals. Project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate impact on factors in geothermal energy development.

1 – Poor

The project has made little or no progress and impact on the DOE's Geothermal Technologies missions and goals. Project has demonstrated little to no advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has marginal impact on factors in geothermal energy development.

- ◯ Outstanding
- ◯ Good
- ◯ Fair
- ◯ Poor

Comments Regarding Relevance/Impact of Research

Paste from Word

Scientific/Technical Approach - Weight = 30%

Assess the project based on the quality of the technical approach, rated for the rigor and appropriateness of the employed technical approach (work elements, procedures and methods, instrumentation, equipment, staffing, etc.) to achieving the project's objectives with the available resources. This criterion covers both the design of the scientific/technical approach and how well the approach has been executed in the project tasks.

4 – Outstanding

The approach is sharply focused, excellent in design and centered on one or more key technical barriers to achieving the project's objectives. The execution of the approach is outstanding and has little to no room for improvement.

3 – Good

The approach is well thought out and effective in achieving the project's objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has minor room for improvement.

2 – Fair

Some aspects of the project may lead to progress in achieving project objective and overcoming barriers/knowledge gaps but the approach has significant weaknesses and noteworthy areas for improvement.

1 – Poor

The approach is unlikely to make significant contributions to the objectives and barriers/knowledge gaps. Significant flaws in the approach are identifiable with major areas of improvement.

- Outstanding
- Good
- Fair
- Poor

Comments Regarding Scientific/Technical Approach

Paste from Word

Accomplishments, Results and Progress - Weight = 30%

Assess the project based on the technical accomplishments, results, and progress of the tasks. Scores should reflect the significance of these results in relation to project objectives and their technical targets/goals. Factors within this criterion will center around two areas:

1. Quality – the quality of accomplishments, results, and progress made towards technical goals/targets and project objectives.

2. Productivity – the level of productivity in work underway considering accomplishments and the value of the accomplishments compared to the costs. This includes achievements against planned goals and objectives, technical targets, awards, or other success measures presented.

4 – Outstanding

The accomplishments, results, and outcomes have been outstanding in relation to the resources expended and progress towards project objectives and technical targets/goals.

3 – Good

The accomplishments, results, and outcomes have been good in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for slight improvement.

2 – Fair

The accomplishments, results, and outcomes have been adequate in relation to the resources expended and progress towards project objectives and technical targets/goals. There is room for improvement.

1 – Poor

The accomplishments, results, and outcomes have been marginal in relation to the resources expended and progress towards project objectives and technical targets/goals. There is significant room for improvement.

- ◯ Outstanding
- ◯ Good
- ◯ Fair
- ◯ Poor

Comments Regarding Accomplishments, Results and Progress

Paste from Word

Project Management/Coordination - Weight = 25%

Assess the project based on how well technical, policy, schedule, business and staffing plans, and spend plan are carried out and prospective future plans. Assessments are to be made based on the inclusion of appropriate and logically placed decision points that effect the future direction of the work. Coordination of activities with collaborators, stakeholders, and other entities (e.g. permitting officials) should be included in the assessment of the project.

4 – Outstanding

Management of this project has been exceptionally effective and/or plans for future management are well-structured and include all the appropriate and logically placed management checks and controls. Any variance from original plans/schedule were corrected early and resulted in little to no impact on the overall project.

3 – Good

Management of this project has been very effective and/or plans for future management are well-structured and include all the appropriate and logically placed management checks and controls, however minor improvements are desirable. Any variance from original plans/schedule were corrected early and resulted in minor impact on the overall project.

2 – Fair

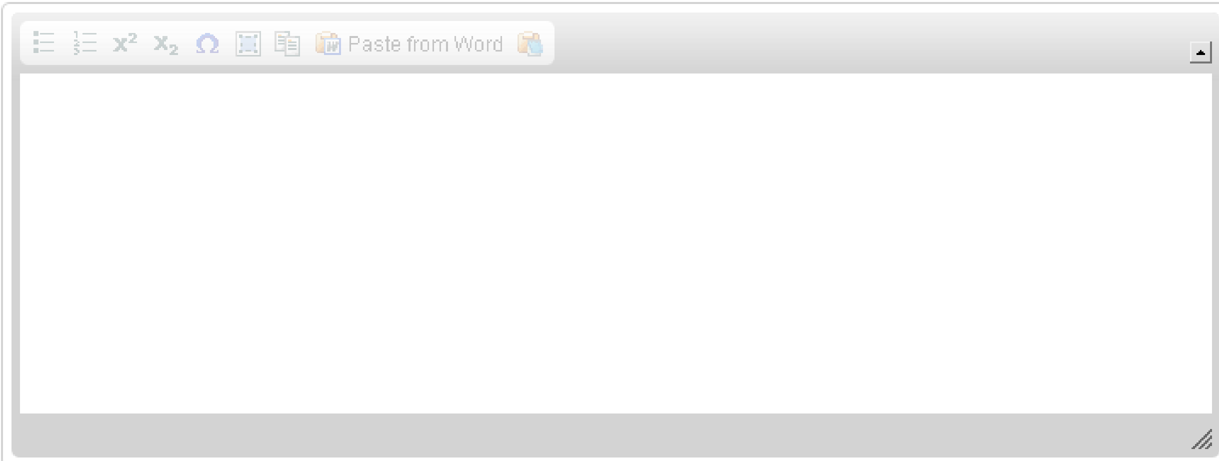
Management of this project has been weak and/or plans for future management are not well-structured and lack the appropriate and logically placed management checks and controls, numerous improvements are required. Any variance from original plans/schedule were delayed in correction and resulted in moderate impact on the overall project.

1 – Poor

Management of this project has been ineffective and has impaired the success of the project and/or future plans are poorly structured and missing the appropriate and logically placed management checks and controls; significant improvements are essential. Any variance from original plans/schedule were delayed in correction or not addressed and resulted in significant impact on the overall project.

- ○ Outstanding
- ○ Good
- ○ Fair
- ○ Poor

Comments Regarding Project Management/Coordination



Overall

In addition to the above 4 criterion, you are asked to provide an overall assessment of the project in a written narrative. Please comment on each project's overall strengths and weaknesses—this may include suggestions for improvement.

Comments Regarding Strengths

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Comments Regarding Weaknesses

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Suggestions for Improvement

Appendix D: 2011 Peer Review Meeting Detailed Agenda

2011 Geothermal Technologies Program Peer Review Meeting

Track 1 - Systems Analysis, Resources Assessment, Data System Development & Population; Power Conversion Technology; Stimulation/Fracture Prediction Modeling

Monday, June 6, 2011 — General Sessions — Salon F - H

8:00 – 9:15 am	Continental Breakfast and Registration
9:30 – 10:40 am	Open Plenary Session
10:40 – 11:00 am	**Break**
11:00 – 11:45am	Opening Plenary Session continuation
11:45 – 1:00 pm	**Lunch**

Systems Analysis, Resource Assessment, Data System Development & Population Brookside A&B

1:00 – 1:30 pm	System Engineering and Analysis	Thomas Lowry	Sandia National Laboratories
1:30 – 2:00 pm	Energy Returned On Investment of Engineered Geothermal Systems	Arthur Mansure	Arthur Mansure
2:00 – 2:30 pm	Analysis of Low-Temperature Utilization of Geothermal Resources	Brian Anderson	West Virginia University
2:30 – 3:00 pm	**Break**		
3:00 – 3:30 pm	Coproduction Risk Assessment	Chad Augustine	National Renewable Energy Laboratory
3:30 – 4:00 pm	Market & Policy Analysis	Chad Augustine	National Renewable Energy Laboratory
4:00 – 4:30 pm	Decision Analysis for Enhanced Geothermal Systems	Herbert Einstein	Massachusetts Institute of Technology
4:30 – 5:00 pm			
5:00 – 7:00 pm	Networking Event		

Tuesday, June 7, 2011 — Systems Analysis, Resource Assessment, Continued — Brookside A&B

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Geothermal Supply Curves Development	Chad Augustine	National Renewable Energy Laboratory
9:30 – 10:00 am	Geothermal Resource Assessment and Classification	Colin Williams	U.S. Geological Survey
10:00 – 10:30 am	National Geothermal Data System Architecture Design, Testing and Maintenance	Walter Snyder	Boise State University
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	State Geological Survey Contributions to National Geothermal Data System Data Development, Collection and Maintenance	Lee Allison	Arizona State Geological Survey

11:15 – 11:45 am	DOE Geothermal Data Repository	Walter Snyder	Boise State University
11:45 – 12:15 pm	Heat Flow Database Expansion for National Geothermal Data System Data Development, Collection and Maintenance	David Blackwell	Southern Methodist University
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	GETEM Development	Greg Mines	Idaho National Laboratory
2:00 – 2:30 pm	Life-cycle Analysis for Geothermal Power Systems	Michael Wang / Corrie Clark	Argonne National Laboratory
2:30 – 3:00 pm	Water Resource Requirements for Geothermal Energy Production	Michael Wang / Corrie Clark	Argonne National Laboratory
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems	Uday Turaga	ADI Analytics, LLC
3:45 – 4:15 pm	Baseline System Costs for 50.0 MW Enhanced Geothermal System	Paul Dunn	GEECO
4:15 – 4:45 pm	Economic Impact Analysis for EGS (EGI)	Varun Gowda	University of Utah
4:45 – 5:30 pm			
5:00 – 7:00 pm	Congressionally Directed Project POSTER SESSION		

Wednesday, June 8, 2011 Systems Analysis, Resource Assessment, Continued; Power Conversion Salon F

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment And The Potential Employment, Energy, and Environmental Impacts of Direct Use Applications	Elizabeth Battocletti	Bob Lawrence & Associates, Inc.
9:30 – 10:00 am	National Geothermal Student Competition	Jesse Geiger	National Renewable Energy Laboratory
10:00 – 10:30 am	National Geothermal Academy	Wendy Calvin	University of Nevada Reno
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am			
11:15 – 11:45 am			
11:45 – 12:15 pm			
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	High Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	Helge Klockow	GE Global Research
2:00 – 2:30 pm	Tailored Working Fluids for Enhanced Binary Geothermal Power Plants	Ahmad Mahmoud	United Technologies Research Center
2:30 – 3:00 pm	Working Fluids and their Effect on Geothermal Turbines	Adrian Sabau	Oak Ridge National Laboratory
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems	Peter McGrail	Pacific Northwest National Laboratory
3:45 – 4:15 pm	Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Bassam Jody	Argonne National Laboratory

4:15 – 4:45 pm	Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources	Lance Hayes	Energent Corporation
4:45 – 5:30 pm			
5:00 – 7:00 pm			

Thursday, June 9, 2011 Power Conversion; Stimulation/Fracture Prediction Modeling Salon H

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Optimization of hybrid-water/air-cooled condenser in an enhanced turbine geothermal ORC system	Hailing Wu	United Technologies Research Center
9:30 – 10:00 am	Hybrid and Advanced Air Cooling	Desikan Bharathan	National Renewable Energy Laboratory
10:00 – 10:30 am	Air-Cooled Condensers in Next-Generation Conversion Systems	Greg Mines	Idaho National Laboratory
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am			
11:15 – 11:45 am			
11:45 – 12:15 pm			
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs	Charles Carrigan	Lawrence Livermore National Laboratory
2:00 – 2:30 pm	Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity	Ahmad Ghassemi	Texas A&M University
2:30 – 3:00 pm	FRAC-STIM: A Physics-Based Fracture Stimulation, Reservoir Flow and Heat Transport Simulator	Robert Prodgorney	Idaho National Laboratory
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.	John Pritchett	Science Applications International Corporation
3:45 – 4:15 pm	Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs	Ahmad Ghassemi	Texas A&M University
4:15 – 4:45 pm	Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems	Marte Gutierrez	Colorado School of Mines
4:45 – 5:30 pm			
5:00 – 7:00 pm			

Friday, June 10, 2011 Working Group Meeting Salon H

8:00 – 9:00 am	Continental Breakfast and Registration
9:00 – 11:00 am	DOE Working Group Session

2011 Geothermal Technologies Program Peer Review Meeting

Track 2 – Enhanced Geothermal Systems Demonstrations; Seismicity & Reservoir Fracture Characterization; Specialized Materials & Geopolymer Sealing Materials

Monday, June 6, 2011 — General Sessions — Salon F - H

8:00 – 9:15 am	Continental Breakfast and Registration
9:30 – 10:40 am	Open Plenary Session
10:40 – 11:00 am	**Break**
11:00 – 11:45am	Opening Plenary Session continuation
11:45 – 1:00 pm	**Lunch**

Enhanced Geothermal Systems (EGS) Demonstrations — Amphitheater

1:00 – 1:30 pm	Feasibility of EGS demonstration at Brady's Hot Spring	Peter Drakos	ORMAT – **NOT PRESENTING**
1:30 – 2:00 pm	Enhanced Geothermal Systems – Concept Testing and Development at the Raft River Geothermal Field	Joseph Moore	University of Utah
2:00 – 2:30 pm	Implementation of a Demonstration EGS Project at Naknek, Alaska	Donna Vukich	Naknek Electric Association
2:30 – 3:00 pm	**Break**		
3:00 – 3:30 pm	Newberry Volcano EGS Demonstration	Susan Petty	AltaRock Energy, Inc.
3:30 – 4:00 pm	New York Canyon Stimulation	Bernard Raemy	TGP Development Company LLC
4:00 – 4:30 pm	Desert Peak East EGS Project	Ezra Zemach	ORMAT – **NOT PRESENTING**
4:30 – 5:00 pm			
5:00 – 7:00 pm	Networking Event		

Tuesday, June 7, 2011 — EGS Demonstrations; Seismicity & Reservoir Fracture — Forest Glen

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Mark Walters	Calpine - Geysers Power Company LLC
9:30 – 10:00 am			
10:00 – 10:30 am			
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems	Nafi Toksoz	Massachusetts Institute of Technology
11:15 – 11:45 am	Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir	Michael Fehler	Massachusetts Institute of Technology
11:45 – 12:15 pm	Joint Inversion of Electrical and Seismic Data for Fracture Characterization and Imaging of Fluid Flow in Geothermal	Michael Batzle	Colorado School of Mines

	Systems		
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks	Bob Hardage	The University of Texas at Austin
2:00 – 2:30 pm	Characterizing Fractures in Geysers Geothermal Field from Microseismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	Fred Aminzadeh	University of Southern California
2:30 – 3:00 pm	Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments (GEYSERS)	Ahmad Ghassemi	Texas Engineering Experiment Station
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions With Microearthquake Data for 3D Velocity Structure, Earthquake Locations, and Moment Tensors in Geothermal Reservoirs	Daniel O'Connell	William Lettis & Associates, Inc.
3:45 – 4:15 pm	Towards the understanding of induced seismicity in enhanced geothermal systems	Roland Gritto	Array Information Technology
4:15 – 4:45 pm	Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Dennise Templeton	Lawrence Livermore National Laboratory
4:45 – 5:30 pm			
5:00 – 7:00 pm	Congressionally Directed Project POSTER SESSION		

Wednesday, June 8, 2011 Seismicity & Reservoir Fracture Characterization Salon H

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in EGS Reservoirs	Lianjie Huang	Los Alamos National Laboratory / National Energy Technology Laboratory
9:30 – 10:00 am	Joint Seismic-EM Inversion	Gregory Newman	Lawrence Berkeley National Laboratory
10:00 – 10:30 am	Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced	E. L. Majer	Lawrence Berkeley National Laboratory
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Distributed Thermal Pertubation Sensing	Barry Freifeld	Lawrence Berkeley National Laboratory
11:15 – 11:45 am			
11:45 – 12:15 pm			
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm			
2:00 – 2:30 pm			
2:30 – 3:00 pm			
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm			

3:45 – 4:15 pm			
4:15 – 4:45 pm			
4:45 – 5:30 pm			

Thursday, June 9, 2011 Specialized Materials & Geopolymer Sealing Materials Salon C

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Geopolymer Sealing Materials	Thomas Butcher / Toshi Sugama	Brookhaven National Laboratory
9:30 – 10:00 am	High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells	Paul Fabian	Composite Technology Development, Inc.
10:00 – 10:30 am	Temporary Bridging Agents for use in drilling and completion of Engineered Geothermal Systems	Larry Watters	CSI Technologies, LLC
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Development Of An Improved Cement For Geothermal Wells	George Trabits	Trabits Group, LLC
11:15 – 11:45 am	Evaluation of Thermal Spray Coatings as Pressure Seals	Joe Henfling	Sandia National Laboratories
11:45 – 12:15 pm	Technologies for extracting valuable metals and compounds from geothermal fluids	Stephen Harrison	Simbol Mining Corp.
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm			
2:00 – 2:30 pm			
2:30 – 3:00 pm			
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm			
3:45 – 4:15 pm			
4:15 – 4:45 pm			
4:45 – 5:30 pm			

Friday, June 10, 2011 Working Group Meeting Salon C

8:00 – 9:00 am	Continental Breakfast and Registration
9:00 – 11:00 am	DOE Working Group Session

2011 Geothermal Technologies Program Peer Review Meeting

Track 3 – High Temp Tools, Sensors, Systems, Drilling Systems

Monday, June 6, 2011 General Sessions Salon F - H

8:00 – 9:15 am	Continental Breakfast and Registration
9:30 – 10:40 am	Open Plenary Session
10:40 – 11:00 am	**Break**
11:00 – 11:45am	Opening Plenary Session continuation
11:45 – 1:00 pm	**Lunch**

High Temp Tools, Sensors, Systems, Drilling Systems

1:00 – 1:30 pm	
1:30 – 2:00 pm	
2:00 – 2:30 pm	
2:30 – 3:00 pm	**Break**
3:00 – 3:30 pm	
3:30 – 4:00 pm	
4:00 – 4:30 pm	
4:30 – 5:00 pm	
5:00 – 7:00 pm	Networking Event

Tuesday, June 7, 2011 High Temp Tools, Sensors, Systems, Drilling Systems Salon G

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	High Temperature 300C Directional Drilling System, including drill bit, steerable motor, and drilling fluid, for Enhanced Geothermal Systems	Aaron Dick	Baker Hughes Oilfield Operations Incorporated
9:30 – 10:00 am	Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Kenneth Oglesby	Impact Technologies, LLC
10:00 – 10:30 am	Roller cone and rotary drag drill bits with a novel cutting insert and a centralized jack/hammer are proposed for three fold increase in overall EGS drilling.	David Hall	Novatek, Inc.
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Development of a Hydrothermal Spallation Drilling System for EGS	Jared Potter	Potter Drilling, Inc.
11:15 – 11:45 am	Technology Development and Field Trials of EGS Drilling Systems	David Raymond	Sandia National Laboratories
11:45 – 12:15 pm	Enhance And Deliver A High Temperature Directional Drilling Instrument For Geothermal MWD Tools	Eric Anderson	Honeywell International Inc.
12:15 – 1:30 pm	**Lunch**		

1:30 – 2:00 pm	Pressure sensor and Telemetry methods for measurement while drilling in geothermal wells	Alexey Vert	GE Global Research
2:00 – 2:30 pm	Resistant NanoComposite Stainless Steel Coatings and Bits for Geothermal Drilling	William Peter	Oak Ridge National Laboratory
2:30 – 3:00 pm	High Temperature Perforating System for Enhanced Geothermal Applications	Peter Howard	Schlumberger Technology Corp.
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	High-Temperature High-Volume Lifting for Enhanced Geothermal Systems	Norman Turnquist	GE Global Research
3:45 – 4:15 pm	Gas generator development and testing for controlled rapid pressurization using liquid propellants for EGS well stimulation	Mark Grubelich	Sandia National Laboratories
4:15 – 4:45 pm	Feasibility and Design Studies for a High Temperature Downhole Tool	Hatice Akkurt	Oak Ridge National Laboratory
4:45 – 5:30 pm			
5:00 – 7:00 pm	Congressionally Directed Project POSTER SESSION		

Wednesday, June 8, 2011 High Temp Tools, Sensors, Systems, Drilling Systems Salon G

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	300 °C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems	Alexey Vert	GE Global Research
9:30 – 10:00 am	Harsh Environment Silicon Carbide Sensor Technology for Geothermal Instrumentation	Albert Pisano	The Regents of the Univ of California
10:00 – 10:30 am	Development of a High Temperature Fiber Optic Transmission System	Joe Henfling	Sandia National Laboratories
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Well Monitoring Systems for EGS	Randy Normann	Perma Works
11:15 – 11:45 am	High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Matthew Hooker	Composite Technology Development Inc. Production
11:45 – 12:15 pm	Base Technologies and Tools for Supercritical Reservoirs	Joe Henfling	Sandia National Laboratories
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Waveguide-Based Ultrasonic and Far-Field Electromagnetic Sensors for Downhole Reservoir Characterization	Shuh-Haw Sheen	Argonne National Laboratory
2:00 – 2:30 pm	Acoustic Sensor for Downhole Fluid	Christian Pantea	Los Alamos National Laboratory
2:30 – 3:00 pm	Geothermal Ultrasonic Fracture Imager	Doug Patterson / Jim Legget	Baker Hughes Oilfield Operations Incorporated
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Mark Lowell	Draka Cableteq USA, Inc.
3:45 – 4:15 pm	Multiparameter Fiber Optic Sensing System for Monitoring	William Challener	General Electric Company

	Enhanced Geothermal Systems		
4:15 – 4:45 pm	High-Temperature Motor Windings for Downhole Pumps Used in Geothermal Energy Production	Matthew Hooker	Composite Technology Development Inc.
4:45 – 5:30 pm			

Thursday, June 9, 2011High Temp Tools, Sensors, Systems, Drilling Systems

8:00 – 9:00 am	Continental Breakfast
9:00 – 9:30 am	
9:30 – 10:00 am	
10:00 – 10:30 am	
10:30 – 10:45 am	**Break**
10:45 – 11:15 am	
11:15 – 11:45 am	
11:45 – 12:15 pm	
12:15 – 1:30 pm	**Lunch**
1:30 – 2:00 pm	
2:00 – 2:30 pm	
2:30 – 3:00 pm	
3:00 – 3:15 pm	**Break**
3:15 – 3:45 pm	
3:45 – 4:15 pm	
4:15 – 4:45 pm	
4:45 – 5:30 pm	

Friday, June 10, 2011 Working Group Meeting Salon G

8:00 – 9:00 am	Continental Breakfast and Registration
9:00 – 11:00 am	DOE Working Group Session

2011 Geothermal Technologies Program Peer Review Meeting

Track 4 – Low - Temperature, Co-Production, Geopressured Demonstration; Reservoir Exploration, Characterization & Modeling; Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions

Monday, June 6, 2011 General Sessions Salon F - H

8:00 – 9:15 am	Continental Breakfast and Registration
9:30 – 10:40 am	Open Plenary Session
10:40 – 11:00 am	**Break**
11:00 – 11:45am	Opening Plenary Session continuation
11:45 – 1:00 pm	**Lunch**

Low - Temperature, Co-Production, Geopressured Demonstration Forest Glen

1:00 – 1:30 pm	Beowawe Bottoming Binary Project	Dale McDonald	Beowawe Power, LLC
1:30 – 2:00 pm	Dixie Valley Bottoming Binary Project	Dale McDonald	Terra-Gen Sierra Holdings, LLC
2:00 – 2:30 pm	Rural Cooperative Geothermal Development Electric and Agriculture	Daniel Silveria	Surprise Valley Electrification Corp
2:30 – 3:00 pm	**Break**		
3:00 – 3:30 pm	Low Temperature Geothermal at Klamath Falls	Brian Brown	City of Klamath Falls
3:30 – 4:00 pm	Novel Energy Conversion Equipment for Low Temperature Geothermal Resources	Eric Minor	Johnson Controls, Inc.
4:00 – 4:30 pm	Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas	Chris Luchini	Universal GeoPower LLC
4:30 – 5:00 pm			
5:00 – 7:00 pm	Networking Event		

Tuesday, June 7, 2011 Low - Temperature, Co-Production, Geopressured Demonstration Salon H

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Electric Power Generation from Co-Produced Fluids from Oil and Gas Wells	William Gosnold	University of North Dakota
9:30 – 10:00 am	Electric Power Generation from Low to Intermediate Temperature Resources	William Gosnold	University of North Dakota
10:00 – 10:30 am	Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources	Robert McGinnis	Oasys Water
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Demonstrating the Commercial Feasibility of Geopressured-Geothermal Power Development at the Sweet Lake Field, Cameron Parish, Louisiana	Steven Jordan	Louisiana Tank, Inc. – **NOT PRESENTING**
11:15 – 11:45 am			

11:45 – 12:15 pm			
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm			
2:00 – 2:30 pm			
2:30 – 3:00 pm			
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm			
3:45 – 4:15 pm			
4:15 – 4:45 pm			
4:45 – 5:30 pm			
5:00 – 7:00 pm	Congressionally Directed Project POSTER SESSION		

Wednesday, June 8, 2011 Reservoir Exploration, Characterization & Modeling Salon B

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling	Gregory Newman	Lawrence Berkeley National Laboratory
9:30 – 10:00 am	Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-Dimensional Electrical Resistivity Structure	Phillip Wannameker	University of Utah
10:00 – 10:30 am			
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	James Faulds	Board of Regents NSHE on behalf of the University of Nevada Reno
11:15 – 11:45 am	Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation.	Joe Iovenitti	AltaRock Energy, Inc.
11:45 – 12:15 pm	Integrated Chemical Geothermometry System for Geothermal Exploration	Nicolas Spycher	Lawrence Berkeley National Laboratory
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Coupled Thermal-Hydrological-Mechanical-Chemical Model and Experiments for Optimization of Enhanced Geothermal System Development and Production	Eric Sunnonthal	Lawrence Berkeley National Laboratory
2:00 – 2:30 pm	Development of Advanced Thermal-Hydrological- Mechanical-Chemical (THMC) Modeling Capabilities for Enhanced Geothermal Systems	Yu-Shu Wu	Colorado School of Mines
2:30 – 3:00 pm	THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity	Derek Elsworth	Pennsylvania State University
3:00 – 3:15 pm	**Break**		

3:15 – 3:45 pm	Modeling and Simulation of EGS Reservoir Thermal Performance	Darin Desilets	Sandia National Laboratories
3:45 – 4:15 pm	A New Analytic-Adaptive Model for EGS Assessment, Development and Management Support	George Danko	Board of Regents NSHE on behalf of the University of Nevada Reno

Thursday, June 9, 2011 Supercritical Carbon Dioxide /Reservoir Rock Chemical Interactions Salon F

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am			
9:30 – 10:00 am			
10:00 – 10:30 am			
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Development of Chemical Model to Predict the Interactions between Supercritical Carbon Dioxide and Reservoir Rock in EGS reservoirs	Chuan Lu	University of Utah
11:15 – 11:45 am	Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	Miroslav Petro	Symyx Technologies, Inc.
11:45 – 12:15 pm	An Integrated Experimental and Numerical Study: Developing a Reaction Transport Model that Couples Chemical Reactions of Mineral Dissolution/Precipitation with Spatial and Temporal Flow Variations in CO2/Brine/Rock Systems	Martin Saar	Regents of the University of Minnesota
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Laboratory and Field Experimental Studies of CO2 as Heat Transmission	Karsten Pruess	Lawrence Berkeley National Laboratory
2:00 – 2:30 pm	Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid	Karsten Pruess	Lawrence Berkeley National Laboratory
2:30 – 3:00 pm	Synchrotron X-Ray Studies of Supercritical Carbon Dioxide/Reservoir Rock Interfaces (ANL)	Hoydoo You	Argonne National Laboratory
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Carbonation Mechanisms of Reservoir Rock by Supercritical Carbon Dioxide	Thomas Butcher / Toshi Sugama	Brookhaven National Laboratory
3:45 – 4:15 pm	Chemical Impact of Elevated CO2 on Geothermal Energy Production	Susan Carroll	Lawrence Livermore National Laboratory
4:15 – 4:45 pm	Properties of CO2 Rich Pore Fluids and their Effect on Porosity Evolution in EGS Rocks	David Cole	Oak Ridge National Laboratory

Friday, June 10, 2011 Working Group Meeting Salon C

8:00 – 9:00 am	Continental Breakfast and Registration
9:00 – 11:00 am	DOE Working Group Session

2011 Geothermal Technologies Program Peer Review Meeting

Track 5 – Innovative Exploration Technology; Tracers and Tracer Interpretation

Monday, June 6, 2011 General Sessions Salon F - H

8:00 – 9:15 am	Continental Breakfast and Registration
9:30 – 10:40 am	Open Plenary Session
10:40 – 11:00 am	**Break**
11:00 – 11:45am	Opening Plenary Session continuation
11:45 – 1:00 pm	**Lunch**

Innovative Exploration Technology; Tracers and Tracer Interpretation

1:00 – 1:30 pm	
1:30 – 2:00 pm	
2:00 – 2:30 pm	
2:30 – 3:00 pm	**Break**
3:00 – 3:30 pm	
3:30 – 4:00 pm	
4:00 – 4:30 pm	
4:30 – 5:00 pm	
5:00 – 7:00 pm	Networking Event

Tuesday, June 7, 2011 Innovative Exploration Technology Salon F

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Black Warrior: Sub-soil Gas and Fluid Inclusion Exploration and Slim Well Drilling	John Casteel	Newberry Geothermal Holdings, LLC
9:30 – 10:00 am	Caldwell Ranch Exploration and Confirmation Project	Mark Walters	Geysers Power Company, LLC
10:00 – 10:30 am	Innovative exploration techniques for geothermal assessment at Jemez Pueblo, New Mexico	Greg Kaufman	Pueblo of Jemez
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Detachment faulting and Geothermal Resources - An Innovative Integrated Geological and Geophysical Investigation in Fish Lake Valley, Nevada	Daniel Stockli	Univ of Kansas Center for Research, Inc.
11:15 – 11:45 am	Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada	Rick Zehner	Geothermal Technical Partners, Inc.
11:45 – 12:15 pm	Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss	Jon lear	El Paso County

12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	New River Geothermal Research Project, Imperial County, CA	Stuart Johnson	Ram Power, Inc.
2:00 – 2:30 pm	Away from the Range Front: Intra-basin Geothermal Exploration	Karl Spinks	GeoGlobal Energy LLC
2:30 – 3:00 pm	Merging high resolution geophysical and geochemical surveys to reduce exploration risk at Glass Buttes, Oregon	Patrick Walsh	ORMAT Nevada Inc.
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	Alum Innovative Exploration Project	Stuart Johnson	Sierra Geothermal Power, Inc.
3:45 – 4:15 pm	Silver Peak Innovative Exploration Project	Stuart Johnson	Sierra Geothermal Power, Inc.
4:15 – 4:45 pm	Validation of Innovative Exploration Techniques Pilgrim Hot Springs, Alaska	Gwen Holdman	University of Alaska Fairbanks
4:45 – 5:30 pm			
5:00 – 7:00 pm	Congressionally Directed Project POSTER SESSION		

Wednesday, June 8, 2011 Innovative Exploration Technology Salon C

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Blind Geothermal System Exploration in Active Volcanic Environments; Multi-phase Geophysical and Geochemical Surveys in Overt and Subtle Volcanic Systems, Hawai‘i and Maui	Brigette Martini	ORMAT Nevada Inc.
9:30 – 10:00 am	Use Remote Sensing Data (selected visible and infrared spectrums) to locate high temp ground anomalies in Colorado. Confirm heat flow potential w/ on-site temp surveys to drill deep resource wells	F. Robinson	Flint Geothermal LLC
10:00 – 10:30 am	Finding Large Aperature Fractures in Geothermal Resource Areas Using a Three-Component Long-Offset Surface Seismic Survey, PSInSAR and Structural Kinematic Analysis	William Teplow	U.S. Geothermal, Inc.
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA	Skip Matlick	ORMAT Nevada Inc.
11:15 – 11:45 am	A 3D-3C Reflection Seismic Survey and Data Integration to Identify the Seismic Response of Fractures and Permeable Zones over a Known Geothermal Resource: Soda Lake, Churchill County, Nevada	Dick Benoit	Magma Energy Corp.
11:45 – 12:15 pm	Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System (An Alternative to Grid-Drilling for Geothermal Exploration): McCoy, Churchill County, Nevada	Dick Benoit	Magma Energy Corp.
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Advanced Seismic Data Analysis Program ('Hot Pot Project') - Alytical Techniques of Coherency First Arrival Data Processing and Full Waveform Inversion Velocity Model and Validation by	Shuman Moore	OSKI Energy LLC

	Drilling Wells		
2:00 – 2:30 pm	Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Donna Noel	Pyramid Lake Paiute Tribe
2:30 – 3:00 pm	Application of 2D VSP Imaging Technology to the Targeting of Exploration and Development Wells in a Basin and Range Geothermal System, Humboldt House-Rye Patch Geothermal Area, Pershing County, Nevada	Richard Ellis	Presco Energy, Inc.
3:00 – 3:15 pm	**Break**		
3:15 – 3:45 pm	The Snake River Geothermal Drilling Project: Innovative Approaches to Geothermal Exploration	John Shervais	Utah State University
3:45 – 4:15 pm	We propose to explore and commercially develop ―blind" (no surface evidence) convective hydrothermal systems associated with a young silicic pluton on the flanks of Newberry Volcano, Oregon.	Albert Waibel	Newberry Geothermal Holdings, LLC
4:15 – 4:45 pm	Crump Geyser: High Precision Geophysics & Detailed Structural Exploration and Slim Well Drilling	John Casteel	Newberry Geothermal Holdings, LLC
4:45 – 5:30 pm			

Thursday, June 9, 2011 Tracers and Tracer Interpretation Salon G

8:00 – 9:00 am	Continental Breakfast		
9:00 – 9:30 am	Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics	Yongchun Tang	Power Environmental and Energy Research Institute
9:30 – 10:00 am	Quantum Dot Tracers for Use in Engineered Geothermal Systems	Peter Rose	University of Utah
10:00 – 10:30 am	Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Mack Kennedy	Lawrence Berkeley National Laboratory
10:30 – 10:45 am	**Break**		
10:45 – 11:15 am	Tracer Methods for Characterizing Fracture Stimulation in Engineered	Karsten Pruess	Lawrence Berkeley National Laboratory
11:15 – 11:45 am	Using Thermally-Degrading, Partitioning, and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Thomas Watson	Brookhaven National Laboratory, Pacific Northwest National Laboratory, and Los Alamos National Laboratory
11:45 – 12:15 pm	Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2 and Water-based Geothermal Reservoirs	Mitchell Plummer	Idaho National Laboratory
12:15 – 1:30 pm	**Lunch**		
1:30 – 2:00 pm	Tracers and Tracer Interpretation: Verification of Geothermal Tracer Methods in Highly Constrained	Matthew Becker	California State University, Long Beach Foundation
2:00 – 2:30 pm			

2:30 – 3:00 pm	
3:00 – 3:15 pm	**Break**
3:15 – 3:45 pm	
3:45 – 4:15 pm	
4:15 – 4:45 pm	
4:45 – 5:30 pm	

Friday, June 10, 2011 Working Group Meeting Salon C

8:00 – 9:00 am	Continental Breakfast and Registration
9:00 – 11:00 am	DOE Working Group Session

Appendix E: Program Review Attendees

First Name	Last Name	Organization
Hatice	Akkurt	Oak Ridge National Laboratory
Michael	Albrecht	TBA Power, Inc.
Lee	Allison	Arizona Geological Survey
Ellen	Allman	Terra-Gen Power
Fred	Aminzadeh	University of Southern California
Stephen	Anderson	Evergreen Energy
Brian	Anderson	West Virginia University
Arlene	Anderson	Geothermal Technologies Program
Tyler	Angers	Draka
Lawrence	Anovitz	Oak Ridge National Laboratory
Chad	Augustine	National Renewable Energy Laboratory
Aimee	Bailey	U.S. Department of Energy
Phillip	Bandy	Boise State University
Jacob	Barker	Composite Technology Development, Inc
Andy	Barnicoat	Geoscience Australia
Elizabeth	Battocletti	Bob Lawrence & Associates, Inc.
Stephen	Bauer	Sandia National Laboratories
Matthew	Becker	Cal State Long Beach
Anthony	Belvin	U.S. Department of Energy/Nuclear Energy
Carlon	Bennett	Ruby Mountain Inc.
Dick	Benoit	Magma Energy Corp (U.S.)
Travis	Berrier	Harris Corp.
Desikan	Bharathan	National Renewable Energy Laboratory
Rachel	Bilyk	SRA Int'l / Dept of Energy Geothermal Technologies Program
David	Blackwell	SMU Geothermal Laboratory
Douglas	Blankenship	Sandia National Laboratories
Leslie	Blodgett	GEA
Steve	Bohlen	Lawrence Livermore National Laboratory
Tonya "Toni"	Boyd	Geo-Heat Center
Lauren	Boyd	U.S. Department of Energy
Jame	Branch	Ram Power
Grant	Bromhal	NETL
Chris	Bromley	IEA-GIA
Lucien	Bronicki	Ormat Technologies Inc
Paul	Brophy	EGS Inc
Brian	Brown	Brian Brown Engineering
Carol	Bruton	Simbol Materials
Julie	Bunch	Oak Ridge Institute for Science and Education
Thomas	Butcher	Brookhaven National Laboratory
Wendy	Calvin	University of Nevada - Reno
Richard	Campbell	CH2M HILL
Louis	Capitanio	U.S. Department of Energy, Office of Fossil Energy
Kenneth	Carpenter	Heat Mining Company LLC

First Name	Last Name	Organization
Charles	Carrigan	Lawrence Livermore National Laboratory
Susan	Carroll	Lawrence Livermore National Laboratory
Christopher	Carusona	U.S. Department of Energy Golden Field Office
John	Casteel	Nevada Geothermal Power Co.
William	Challener	GE Global Research
Andrew	Chiasson	Geo-Heat Center
Charles	Christensen	Golden Field Office, GTP
Corrie	Clark	Argonne National Laboratory
Tom	Clark	ElectraTherm Inc
Ava	Coy	U.S. Department of Energy
Dustin	Crandall	URS @ NETL
Robert	Creed	consulting geologist
Angela	Crooks	U.S. Department of Energy
Greg	Cuprak	West Chester University
David	Cuyler	Sandia National Laboratories (Contractor to U.S. Department of Energy)
George	Danko	University of Nevada, Reno
Julie	Dement	ORAU
Ted	DeRocher	Oski Energy, LLC
Darin	Desilets	Sandia National Labs
Patrick	Dobson	Lawrence Berkeley National Laboratory
Daniel	Doctor	USGS
Richard	Doctor	Argonne National Laboratory
P.J.	Dougherty	SMI Inc.
Thomas	Driesner	ETH Zurich
Paul	Dunn	Gas Equipment Engineering Corp.
Ronald	Dykhuizen	Sandia National Laboratories
James	Echols	Magma Energy (U.S.) Corp
Herbert	Einstein	MIT
Richard	Ellis	Presco Energy, LLC
Derek	Elsworth	Pennsylvania State University
Ed	Eugeni	SRA International
Brandon	Evans	BCS, Inc.
Catherine	Fahey	SRA International / U.S. U.S. Department of Energy
Charles	Fairhurst	Itasca Consulting Group
James	Faulds	University of Nevada
Michael	Fehler	MIT
Stefan	Finsterle	Berkeley lab
Barry	Freifeld	Lawrence Berkeley National Laboratory
LaShawn	Foster	Department of Energy
Gary	Friedmann	Naknek Electric Association
Pengcheng	Fu	Lawrence Livermore National Laboratory
Ahmad	Ghassemi	Texas A&M University
William	Glassley	California Geothermal Energy Collabortive
Sara	Gonnion	CNJV
Will	Gosnold	University of North Dakota
Alison	Gotkin	United Technologies Research Center

First Name	Last Name	Organization
Varun	Gowda	Energy & Geoscience Institute
Roland	Gritto	Array Information Technology
Miroslaw	Gruszkiewicz	Oak Ridge National Laboratory
Hal	Gurgenci	The University of Queensland
Eric	Haas	U.S. U.S. Department of Energy
Nathan	Hancock	Oasys Water
Daniel	Hand	Sustainable Engineering
Bob	Hardage	Bureau of Economic Geology
Markus	Haring	Geothermal Explorers International Ltd
Stephen	Harrison	Simbol Materials
Christopher	Harto	Argonne National Laboratory
Lance	Hays	Energent
Joseph	Henfling	Sandia National Laboratories
Daniel	Hennessy	Argonne National Laboratory
Catherine	Hickson	Alterra Power Corp.
Michael	Hillesheim	National Renewable Energy Laboratory
Ryan	Hoesly	SRA, International
Michael	Hogue	Bureau of Economic and Business Research, University of Utah
Jamie	Holladay	PNNL
Alison	Holm	Geothermal Energy Association
Matthew	Hooker	Composite Technology Development
Roland	Horne	Stanford University
Lianjie	Huang	Los Alamos National Laboratory
Hans-Philipp	Hussels	Siemens Corporate Research
Lawrence	Hutchings	Lawrence Berkeley National Laboratory
Joseph	Iovenitti	AltaRock Energy Inc.
Todd	Jaffe	Davenport Newberry
Allan	Jelacic	U.S. Department of Energy (Retired)
Dan	Jennejohn	GEA
Bassam	Jody	Argonne National Laboratory
Gudni A	Johannesson	ORKU.S.TOFNUN The nat. Icelandic Energy uthority
Lyle	Johnson	U.S. Department of Energy/RMOTC
Phil Lamar	Jones	Ruby Mountain Inc.
Paul	Kasameyer	Lawrence Livermore National Lab
Greg	Kaufman	Pueblo of Jemez
Sharad	Kelkar	Los Alamos National Laboratory
B. Mack	Kennedy	Lawrence Berkeley National Laboratory
Kwang	Kim	University of Nevada, Reno
Thomas	King	Oak Ridge National Laboratory
Tom	Kiser	ORISE
Kerry	Klein	New West Technologies/Geothermal Technologies Program
Tim	Kneafsey	Lawrence Berkeley National Laboratory
Steven D	Knudsen	Sandia National Labs
Dennis	Kountz	DuPont Fluoropolymer Solutions
Alina	Kulikowski Tan	Terra-Gen Power
Dharmendra	Kumar	Colorado School of Mines
Michael	Lane	Oski Energy, LLC

First Name	Last Name	Organization
Adrian	Larking	Green Rock Energy Limited
Bob	Lawrence	Bob Lawrence & Associates, Inc.
Jon	Lear	Ruby Mountain Inc.
Jon	Lear	Ruby Mountain Inc
James	Leggett	Baker Hughes
Mark	Leidig	Weston Geophysical Corp.
Scott	Lindblom	Sandia National Laboratories
Grant	Logsdon	CNJV
Mark	Lowell	Draka Cableteq U.S.A
Thomas	Lowry	Sandia National Labs
Chris	Luchini	Universal GeoPower
Margaret	Lyday	Oak Ridge Institute for Science and Education
Douglas	MacGugan	Honeywell Aerospace
John	Macpherson	Baker Hughes Inc.
Ahmad	Mahmoud	United Technologies Research Center
Ernest	Majer	Lawrence Berkeley National Laboratory
Frank	Maldonado	Sandia National Laboratories
Michael	Mann	University of North Dakota
Arthur	Mansure	Geothermal Consultant
Alethia	Marble	U.S. Department of Energy
Brigette	Martini	Ormat Nevada Inc.
Glenn	Masada	University of Texas at Austin
Raphael	Matarazzo	Harris Corporation
Joseph	Matlick	Ormat Nevada Inc.
Lesley	McConnell	NZ Ministry of Science & Innovation, New Zealand Embassy
Mark	McCready	University of Notre Dame
Peter	McGrail	Pacific Northwest National Laboratory
Elisabet	Metcalfe	U.S. Department of Energy- Geothermal Technologies Program (SRA)
JoAnn	Milliken	U.S. Department of Energy
Greg	Mines	Idaho National Laboratory
Camella	Mitchell	ORISE
Adrian	Miura	Sandia National Labs
Lawrence	Molloy	Foundation for Geothermal Innovation
Michael	Mongillo	IEA-Geothermal Implementing Agreement
Joseph	Moore	Energy & Geoscience Institute, Univ. of Utah
Gregory	Nash	Ram Power, Corp.
Jay	Nathwani	U.S. Department of Energy
Gregory	Newman	Lawrence Berkeley National Laboratory
James	Nichols	Truckee Meadows Community College
Angel	Nieto	CNJV
David	Nieva	I.I.E.
John	Niple	Applied Physics Systems
Randy	Normann	Perma Works LLC
Daniel	OConnell	Fugro Consultants, William Lettis & Associates Division
Kenneth	Oglesby	Impact Technologies LLC
Patricia	Oglesby	Impact Technologies LLC

First Name	Last Name	Organization
Bruce	Ohme	Honeywell Aerospace
Stephen	O'Rourke	Heat Mining Company LLC
Will	Osborn	AltaRock Energy, Inc.
Cristian	Pantea	Los Alamos National Laboratory
Mark	Paster	Consultant
Shirish	Patil	University of Alaska Fairbanks
Kimberly	Patten	Arizona Geological Survey
Doug	Patterson	Baker Hughes
Douglas	Perry	Davenport Newberry
tawatchai	petchsingto	Argonne National Laboratory
William	Peter	Oak Ridge National Labortory
Miroslav	Petro	PARC
Maria	Petrucci-Samija	DuPont
William	Pettitt	Itasca Consulting Group, Inc.
Susan	Petty	AltaRock Energy, Inc.
Benjamin	Phillips	National Science Foundation
Albert	Pisano	University of California, Berkeley
Mitchell	Plummer	Idaho National Laboratory
Robert	Podgorney	Idaho National Laboratory
Greg	Pohll	DRI
Yarom	Polsky	Oak Ridge National Laboratory
Jared	Potter	potter drilling, inc.
Anupma	Prakash	University of Alaska Fairbanks, Geophysical Institute
Loretta	Prencipe	New West (contractor)
John	Pritchett	SAIC
Xuele	Qi	GE Global Research
Bernard	Raemy	Terra-Gen Power
Jimmy	Randolph	University of Minnesota
David	Raymond	Sandia National Laboratories
Nolan	Read	Dupont
Timothy	Reinhardt	U.S. Department of Energy/BLM
Joel	Renner	consultant
Andre	Revil	Colorado School of Mines
Stephen	Richard	Arizona Geological Survey
Jeff	Roberts	Lawrence Livermore National Laboratory
Steve	Roberts	Oak Ridge Institute for Science and Education
F. Lee	Robinson	Flint Geothermal LLC
Jean-Claude	Roegiers	U.of Oklahoma
Peter	Rose	EGI/Univ. of Utah
Charlotte	Rowe	Los Alamos National Laboratory
Martin	Saar	University of Minnesota
Adrian	Sabau	Oak Ridge National Laboratory
Hossein	Salehfar	University of North Dakota
Carol	Schutte	U.S. Department of Energy
Brittany	Segneri	Department of Energy - contractor
John	Sharp	Sharp Informatics

First Name	Last Name	Organization
Shuh-Haw	Sheen	Argonne National laboratory
Vishakha	Shembekar	ADI Analytics LLC
John	Shervais	Utah State University
Gunter	Siddiqi	Swiss Federal Office of Energy
Moises Enrique	Smart	Schlumberger Technology Corp.
Walter	Snyder	Boise State University
Marina	Sofos	AAAS/U.S. Department of Energy
Eric	Sonnenthal	Lawrence Berkeley National Lab
Paul	Sonnier	CSI Technologies
Karl	Spinks	GeoGlobal Energy LLC
Jeff	Spray	Geothermal Expandables, LLC
Robert	Stacey	GeothermalEx Inc.
Greg	Stillman	U.S. Department of Energy
Daniel	Stockli	University of Kansas
Casey	Strickland	U.S. Department of Energy-Golden
Blake	Sturtevant	Los Alamos National Laboratory
Gene	Suemnicht	EGS Inc.
Toshifumi	Sugama	Brookhaven National Laboratory
John	Sullivan	Argonne National Laboratory
Lee-Ann	Talley	Oak Ridge Institute for Science and Education
YONGCHUN	TANG	PEER Institute
Yongchun	Tang	Power Environmental Energy Research Institute
Steven	Taylor	Rocky Mountain Geophysics
Robert	Taylor	CTD
Dennise	Templeton	Lawrence Livermore Lab
William	Teplow	U.S. Geothermal, Inc
Ella	Thodal	SRA Intl in Support of U.S. Department of Energy Geothermal Technologies Program
Hildigunnur	Thorsteinsson	U.S. Department of Energy
George	Trabits	Trabits Group, LLC
Uday	Turaga	ADI Analytics LLC
Robert	Turner	ORISE
Norman	Turnquist	GE Global Research
William	Vandermeer	U.S. Department of Energy - Golden Field Office
Alexey	Vert	GE Global Research
Charles	Visser	National Renewable Energy Lab
Donna	Vukich	Naknek Electric Association
Al	Waibel	Columbia Geoscience
Patrick	Walsh	Ormat Nevada Inc.
Mark	Walters	Calpine Corporation
Michael	Wang	Argonne National Laboratory
Philip E	Wannamaker	University of Utah/EGI
Thomas	Watson	Brookhaven National Laboratory
Phillip (Phil)	Welch	Energent Corp.
Daniel	Wendt	Idaho National Laboratory
Christopher	White	Louisiana State University

First Name	Last Name	Organization
Thomas	Wideman	Potter Drilling
Tom	Williams	National Renewable Energy Laboratory
Colin	Williams	U.S. Geological Survey
Bruce	Wilson	West Chester University
Thomas	Wood	Idaho National Laboratory
Nick	Woodward	U.S. Department of Energy Science
William	Worek	Brookhaven National Laboratory/University of Illinois at Chicago
Phillip M.	Wright	Consultant
Yu-Shu	Wu	Colorado School of Mines
Tianfu	Xu	Lawrence Berkeley National Laboratory
Karen	Yamamoto	Lawrence Berkeley National Laboratory
Hoydoo	You	Argonne National Laboratory
Richard	Zehner	Geothermal Technical Partners, Inc.
Ezra	Zemach	Ormat
Haijiang	Zhang	Massachusetts Institute of Technology
Jeff	Zhao	W.L. Gore & Associates, Inc.
Jalal	Zia	GE Global Research
John P	Ziagos	Lawrence Livermore National Laboratory/U.S. Department of Energy
Mark	Ziegenbein	U.S. Department of Energy Golden

Appendix F: List of Peer Reviewers

First Name	Last Name	Organization
Brian	Anderson	West Virginia University
Chad	Augustine	National Renewable Energy Laboratory
Aimee	Bailey	U.S. Department of Energy
Andy	Barnicoat	Geoscience Australia
Stephen	Bauer	Sandia National Laboratories
Anthony	Belvin	U.S. Department of Energy/Nuclear Energy
Douglas	Blankenship	Sandia National Laboratories
Tonya "Toni"	Boyd	Geo-Heat Center
Grant	Bromhal	NETL
Chris	Bromley	IEA-GIA
Lucien	Bronicki	Ormat Technologies Inc
Paul	Brophy	EGS Inc
Wendy	Calvin	University of Nevada - Reno
Richard	Campbell	CH2M HILL
Louis	Capitanio	U.S. Department of Energy, Office of Fossil Energy
Charles	Carrigan	Lawrence Livermore National Laboratory
Steven	Chuslo	Hannon Armstrong
Corrie	Clark	Argonne National Laboratory
George	Cooper	University of California, Berkeley
Dustin	Crandall	URS @ NETL
Robert	Creed	consulting geologist
David	Cuyler	Sandia National Laboratories (Contractor to U.S. Department of Energy)
George	Danko	University of Nevada, Reno
Daniel	Doctor	USGS
Richard	Doctor	Argonne National Laboratory
Ronald	Dykhuizen	Sandia National Laboratories
Derek	Elsworth	Pennsylvania State University
James	Faulds	University of Nevada
Varun	Gowda	Energy & Geoscience Institute
Mark	Grubelich	University of Utah
Hal	Gurgenci	The University of Queensland
Pablo	Gutierrez	California Energy Commission
Daniel	Hand	Sustainable Engineering
Joseph	Henfling	Sandia National Laboratories
Wendolyn	Holland	U.S. Department of Energy/Energy Efficiency and Renewable Energy
Matthew	Hooker	Composite Technology Development
Roland	Horne	Stanford University
Gudni A	Johannesson	ORKU.S.TOFNUN The nat. Icelandic Energy uthority
Lyle	Johnson	U.S. Department of Energy/RMOTC
Paul	Kasameyer	Lawrence Livermore National Lab
Jonas	Ketilsson	National Energy Authority of Iceland
Dennis	Kountz	DuPont Fluoropolymer Solutions
Adrian	Larking	Green Rock Energy Limited
Mark	Leidig	Weston Geophysical Corp.

First Name	Last Name	Organization
Scott	Lindblom	Sandia National Laboratories
Bill	Livesay	Consultant
Chip	Mansure	Consultant
Daniel	Matuszak	U.S. Department of Energy
Peter	McGrail	Pacific Northwest National Laboratory
Robert	Mellors	Lawrence Livermore National Laboratory
Adrian	Miura	Sandia National Labs
Michael	Mongillo	IEA-Geothermal Implementing Agreement
David	Nieva	I.I.E.
Randy	Normann	Perma Works LLC
Cristian	Pantea	Los Alamos National Laboratory
Mark	Paster	Consultant
Shirish	Patil	University of Alaska Fairbanks
William	Peter	Oak Ridge National Labortory
Maria	Petrucci-Samija	DuPont
Benjamin	Phillips	National Science Foundation
Albert	Pisano	University of California, Berkeley
Robert	Podgorney	Idaho National Laboratory
Yarom	Polsky	Oak Ridge National Laboratory
John	Pritchett	SAIC
Xuele	Qi	GE Global Research
Jean-Claude	Roegiers	Universityof Oklahoma
Charlotte	Rowe	Los Alamos National Laboratory
Karma	Sawyer	U.S. Department of Energy
Carol	Schutte	U.S. Department of Energy
Monisha	Shah	U.S. Department of Energy/Energy Efficiency and Renewable Energy
John	Sharp	Sharp Informatics
Shuh-Haw	Sheen	Argonne National laboratory
Mike	Shook	Chevron
Gunter	Siddiqi	Swiss Federal Office of Energy
Marina	Sofos	AAAS/U.S. Department of Energy
Daniel	Stockli	University of Kansas
Gene	Suemnicht	EGS Inc.
Mark	Taylor	Bloomberg
Steven	Taylor	Rocky Mountain Geophysics
Ileana	Tibuleac	University of Nevada, Reno
Alexey	Vert	GE Global Research
Herb	Wang	University of Wisconsin
Christopher	White	Louisiana State University
Colin	Williams	U.S. Geological Survey
Tom	Williams	National Renewable Energy Laboratory
Thomas	Wood	Idaho National Laboratory
Phillip M.	Wright	Consultant
John P	Ziagos	Lawrence Livermore National Laboratory/U.S. Department of Energy

Appendix G: Logistical Lessons Learned from the 2011 Peer Review Meeting

The 2011 Geothermal Technologies Program Peer Review Meeting took place on June 6-10, 2011 at the Bethesda North Marriott Hotel and Conference Center located in Bethesda, MD. A total of 146 projects were reviewed at the meeting and approximately 100 subject-matter experts participated as review panel members.

The 2011Peer Review Meeting was organized into five tracks or sessions and focused on the following areas geothermal technology areas:

- Systems Analysis, Resources Assessment, Data System Development and Population, Power Conversion Technology, and Stimulation/Fracture Prediction Modeling
- Enhanced Geothermal Systems Demonstrations, Seismicity and Reservoir Fracture Characterization, Specialized Materials and Geopolymer Sealing Materials
- High Temperature Tools, Sensors, Systems, and Drilling Systems
- Low-Temperature, Co-Production, Geopressured Demonstration, Reservoir Exploration, Characterization and Modeling, Supercritical Carbon Dioxide /Reservoir Rock Chemical Interaction
- Innovative Exploration Technology, and Tracers and Tracer Interpretation.

The following is a list of comments and actionable recommendations made by reviewers and review attendees, aimed at improving the process for future Geothermal Technologies Program peer review meetings.

- General comments regarding *logistics*:
  - Reviewers need to be confirmed earlier in the peer review process.
  - The room block should be adjusted for next year, based off this year‘s final pickup numbers, to coincide with the meeting format. Reviewer rooms need to be held before housing even opens, in a separate sub-block, to ensure all reviewers get hotel rooms at the conference hotel.
  - Hotel was very hard to work with prior to the meeting, but once onsite, they were attentive and provided great service.
  - Agendas could be condensed into one version for next year, so attendees don‘t receive five different ones upon registration. ―At a Glance” agendas would be helpful, like those we kept at registration for people to see. Quite a few people commented that the website agenda was very hard to read. A different format should be considered for next year.
  - Several complaints were received regarding room switching. If possible, find a way to keep the technology sessions in the same room(s) throughout the meeting.
- General comments regarding *hotel accommodations*:
  - The food was excellent.
  - The hotel was very nice.
  - The hotel was located too far from D.C.
  - Audio/Visual (A/V) equipment:
    - None of the equipment failed during the review.
    - The projectors were reliable but did not have great color. Resolution was fair/average.
    - The microphones and speakers were great.
    - All AV equipment was ready to go each day.
    - A/V equipment was high-quality. An early checklist detailing the must-haves and those responsible should be vetted by every team member.
    - Remote reviewers were a bit of a new concept, but thanks to good A/V technicians it went reasonably well.

    - A/V ran smoothly (speaking of audio visual equipment like microphones, projectors, etc. – not Internet).
    - Next year, laptops for each breakout room and laser pointers should be built into the budget.
  - A/V Techs
    - A/V staff was responsive and helpful. The Director of AV, left the hotel halfway through the conference, but his staff picked up right where he left off and did a great job.
    - The A/V technicians were very responsive and helpful. Each morning they would check to see if the moderators required any assistance in setting up the laptops and connecting them to the projectors.
- General comments regarding Internet service:
  - The Internet service did go down on Thursday which presented major problems for Reviewers trying to access PeerNet to score the projects.
  - Many hotels have a time of day/week when service is interrupted. Not sure if that‘s what occurred when it went down this time, but that could be a good venue question early, so that it can be scheduled around.
  - Internet for the most part worked well, except for the glitch on Thursday morning. Recommend avoiding hotels utilizing this Internet service provider.
- General comments regarding Review Format:
  - The review could have had more poster presenters. Have the smaller projects (budget) present in poster form and give the larger projects more time to present.
  - Need more opportunities for technical exchange at Peer Review.
  - Time is insufficient; need more discussion time.
  - Reviewers had interesting comments but had no time to go in depth.
  - Principal Investigators should be required to provide but not present on the project management aspect of their work, e.g. detailed budget, number of new employees, etc.
  - Principal Investigators should use a timeline to illustrate milestones and track progress.
  - Principal Investigators should have a minimum font size for their PowerPoint presentations.
  - Should consider wider ranging point scale for evaluating projects. Scoring 1 to 4 doesn't allow for nuance. Possibly a scale of 1 to 8 would be more effective.
  - Reviewers asked to see project SOPOs as additional background material.
  - Late presentation submissions were a problem for Reviewers. Reviewers need to have more time for larger projects.
- Positive feedback was received from the Reviewers regarding the PeerNet system.
- General comments regarding effectiveness of the moderators:
  - Moderators and note takers were well organized. Everyone knew where they needed to be and when.
  - For the most part, sessions ended on time and moderators kept the review on schedule.
  - Moderator guidance may want to include announcing that the meetings between reviewers and program staff should be closed-door and start a predetermined time after the last presentation (approximately five minutes or so).
  - Suggest not having any remote reviewers again. Although it worked pretty well, it could be disruptive at times and remote reviewers seemed inconvenienced.
- Major Complaints from Attendees:
  - It seems that many Principal Investigators were not fully prepared to have to present on their work. Is the language clear in their contract, or is this an area where this requirement could be more prominent in initial awarding of Principal Investigators?
  - Many attendees wanted wireless Internet and were frustrated/annoyed when told them it wasn‘t available (except for complimentary access in the hotel lobby). This is a very large expense and not crucial for the meeting, and therefore it is not advised to offer this service at future meetings.
  - Attendees praised the food – everyone seemed very happy with the meals and breaks. Great variety that pleased everyone.

- Areas for Improvement:
    - A review checklist should be generated and followed to capture and track all key elements/responsibilities.
    - Items could be added to the reviewer role definition, specifically layout any inappropriate topics of discussion for Principal Investigator questions.
    - Reviewers need to be confirmed much earlier in the process. Received some feedback from reviewers who were disgruntled that they weren‘t getting the answers they needed (no confirmation/updates) and then from those who were booked so late who were inconvenienced.
    - Develop a more accurate room block based on the current year‘s schedule/program.
    - Ensure all Department of Energy staff and presenters are registered for the meeting.

General comments regarding process improvements:

- For future Funding Opportunity Announcements (FOAs) or direct funding, the Program should consider requiring projects to at least have a project advisor from industry.
- The criteria or wording of the relevance/impact of research metrics should be revised. Current wording causes difficulty for reviewers to distinguish a score in the case of a multiple year project which may have high relevance to the Program but little to no progress in its first year.

Pre meeting preparation suggestions:

- Principal Investigators need to submit their required materials (presentations, two-page summary document) in a timelier manner in order to allow for adequate time to be reviewed by panel experts prior to the review meeting.
- The Program, rather than a contractor, should contact Principal Investigators who miss the submission deadline.
- The peer review process should be initiated sooner.
- Publishing the date that presentations are received and tracking when the presentations are posted in PeerNet would be useful.
- Some reviewers were surprised that high-temp cement projects were not included in the topic area.
- It is difficult to evaluate projects with proprietary materials and or information.
- Principal Investigators should be required to provide more technical content (e.g. data, graphs, structures, diagrams), and it should be included in the front of their presentations.
- Reviewers being able to see the proposals would be helpful in evaluating the project‘s success.
- The format of the peer review process was good. It was nice to have the presentations ahead of time.
- One or two presentations were not available to reviewers prior to the meeting. This is unacceptable.
- Project Management slides should be towards the end of the presentation.
- Still need to look at funding levels to see the value in what is being done.
- Thirteen is too many projects for one reviewer to evaluate. Eight to ten is a fairly standard workload for peer reviewers.
- Definitely want to be given more notice to be a reviewer.
- Given the general technical nature of the talks, twenty minutes is not enough to really make a realistic evaluation. Some of the required (non-technical) slides could have gone to the end.
- For many of the projects, supplemental information is needed. Summaries were very brief. To do this right, reviewers need to look up references.
- Required formats for all of presentations should not be one-size fits all.
- It would be helpful to have modelers review each other, but there is also danger in this.
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- For many of the projects, supplemental information is needed. Summaries were very brief. To do this right, reviewers need to look up references.
- Many acronyms were used: Transport Of Unsaturated Groundwater and Heat (TOUGH2), Finite Element Heat and Mass Transfer Code (FEHM), etc., which are not meaningful to others
- Suggestion: required presentation formats for all of these projects should not be one-size fits all.
- Each project is looking at different problems here. Many of these could be used to solve different problems. Problem was due to a lack of communication, none of them knew what other group was doing.
- Get everyone together a month prior. Cross-compare projects with similar problems.
- There was not much information in the presentations about how the projects' methods, innovations, etc., can be transferred to other sites. DOE should directly ask for this type of analysis in the future.
- The layout/template for the presentations limited the amount of time spent on technical detail. One of the reviewers' favorite presentations was the one that did not use the DOE GTP template. DOE should consider changing, or allowing more flexibility in the template next year.
- Many project presentations really lacked technical details.
  - Many diagrams were not large enough to read.
  - Suggestion: include more slides of technical data and diagrams; don't even need to talk about all of them, just have supplementary slides for the reviewers.
- Add a slide about proposed project tasks, progress made in accomplishing those objectives and changes to project scope.
- It was great seeing the presentations ahead of time. The summaries seemed a bit redundant.
- The project management stuff is tedious.
- Introductions of reviewers would be nice. This seemed a bit awkward.
- For the review questionnaire, asking about all the qualifications, awards, etc. are not relevant.

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