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

2010 Geothermal Technology Program Peer Review Report

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Staffed and Supported by:
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New West Technologies, Inc.
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Cover photos: Calpine's Sonoma Geothermal Plant at The Geysers field in Northern California

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1.0 Introduction and Overview

On May 18-20, 2010, the Geothermal Technologies Program (GTP) conducted a peer review of selected research and demonstration projects funded by the Program. The peer review followed guidance developed by the DOE Energy Efficiency and Renewable Energy Program based on best practices for peer review in government and academic research. The peer review process benefits the Program by providing external, objective and informed evaluations on the relevance of funded projects to the Program's goals and objectives, the effectiveness of project management, and the progress made toward the funded project's objectives. Principal investigators (PIs) benefit from the peer review through expert feedback on project execution and suggestions on how to resolve problems or enhance the value of their research. In addition, through the peer review process, PI's receive validation and encouragement for significant work and progress. Peer review advances geothermal science and technology by improving individual research and by challenging and enhancing the focus of GTP-sponsored research on objectives that are important for geothermal development.

The full agenda for the Peer Review meeting, including a list of projects that received full reviews and those that were presented as overviews, is available in Section 6.3. Information on a total of 203 projects was presented at the meeting (for presentations see the GTP website: www1.eere.energy.gov/geothermal/peer_review_2010.html). Of these, 35 projects in 6 technical tracks received full formal peer reviews. These were projects that had been underway long enough to have achieved significant results. The detailed reviews for these 35 projects are collected in Section 4.0 below. The remaining 168 projects were only recently funded and were presented in overviews that detailed project objectives, plans, schedules, and general approach. A full review of these projects will be conducted at a later date, when sufficient progress has been made to warrant such a review. Summaries of the overview sessions are presented below in Section 3.0.

A minimum of three peer reviewers was assigned to each technical track. Reviewers were selected for their recognized geothermal and/or geoscience expertise, years of experience, and objectivity. Candidate reviewers were screened for potential problems with conflict of interest during the selection process. None of the selected peer reviewers were funded by the GTP for work in the tracks they reviewed, nor were they involved in any of the reviewed projects. Peer reviewers and their assigned technical tracks are shown in Table 1.

Table 1: Tracks, Projects, Principal Investigators, and Peer Reviewer Assignments

Track	Project	PI	Peer Reviewer	Peer Reviewer	Peer Reviewer	Peer Reviewer	Peer Reviewer
Enhanced Geothermal Systems	Brady's Hot Springs	Krieger	Douglas Blankenship	Phillip Wright	John Ziagos		
	Raft River	Moore					
	Desert Peak	Zemach					
	EGS Hydraulic and Thermal Stimulation	Rose					
	EGS at NW Geysers	Walters					
Low-temperature Demonstrations	Gred Award Chena Hot Springs	Karl	Richard Campbell	Pablo Gutierrez	Colin Harvey	Paul Kasameyer	
	Electric Power from Co-produced Water CHSR	Karl					
	Klamath and Lake Counties Industrial Park	Riley					
	Geothermal Testing Facilities at RMOTC	Johnson					
Analysis, Data Systems and Education	GETEM Development	Mines	Duncan Foley	Gerald Nix	Phillip Wright		
	National Geothermal Student Competition	Visser					
	Geo-heat Center	Lund					
	Systems Engineering	Lowry					
	LCA of Geothermal Technologies	Wang					
High-temperature Tools and Drilling	Detecting Fractures Using Technology at High Temperatures and Depths - Geothermal Ultrasonic Fracture Imager GUFI	Patterson	George Cooper	Daniel Hand	David Lombard		
	The Development and Demonstration of an Electric Submersible Pump at High Temperatures - High-temperature Motor Windings for Down-hole Pumps Used in Geothermal Energy Production	Hooker					
	Development of Tools for Measuring Temperature, Flow, Pressure, and Seismicity of EGS Reservoirs - 300 °C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems	Tilak					
	High Temperature Pump Monitoring - High-temperature ESP Monitoring	Dhruva					
	Extending the Temperature Range of Electric Submersible Pumps to 338 °C - Hotline IV - High-temperature ESP	Dhruva					
	Fielding of HT Seismic Tools and Evaluation of HT FPGA Module - Development of a HT-seismic Tool	Henfling					
Seismicity and Seismic	Microearthquake Technology for EGS Fracture Characterization	Foulger	Yuri Fialko	Jonathan Lees	Wayne Pennington	John Ziagos	
	Seismic Fracture Characterization Methods For Enhanced Geothermal Systems	Queen					
	Microseismic Study with LBNL - Monitoring the Effect of Injection of Fluids from the Lake County Pipeline on Seismicity at The Geysers, California Geothermal Field	Majer					
	Development of an Updated Induced Seismicity Protocol for the Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems	Majer					
	Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir	Fehler					
	Well Monitoring Systems for EGS	Normann					
	Analysis of Geothermal Reservoir Stimulation using Geomechanics-based Stochastic Analysis of Injection-induced Seismicity	Ghassemi					
Reservoir Characterization	Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs	Ghassemi	Edward Bolton	Blaise Bourdin	Barbara Dutrow	John Rudnicki	Ben Sternberg
	Joint Inversion of Electrical and Seismic Data for Fracture Characterization and Imaging of Fluid Flow in Geothermal Systems	Revil					
	Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems	Tokosz					
	Fracture Characterization in Enhanced Geothermal Systems by Wellbore and Reservoir Analysis	Horne					
	The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs	Moore					
	Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems	Rose					
	Tracer Methods for Characterizing Fracture Stimulation in Enhanced Geothermal Systems (EGS)	Pruess					
	Chemical Signatures of and Precursors to Fractures Using Fluid Inclusion Stratigraphy	Dilley					

The PI for each project was required to submit a written project summary and a PowerPoint presentation that addressed the review evaluation criteria as detailed in guidance prepared by DOE. A researcher representing the project was also asked to attend the Peer Review meeting to present the project and answer questions. Investigators were allowed to submit additional materials including publications and resumes of key team members. Oak Ridge Associated Universities/Oak Ridge Institute for Science and Education (ORAU/ORISE) provided a secure on-line method for investigators to submit their project materials and for peer reviewers to read the materials and submit evaluation forms. Each project was subject to the same peer-review criteria and scoring system reproduced in the Appendices, Section 6.0. The peer reviewers were provided with documents that outlined Program goals and objectives. They also heard Program staff discuss each of GTP's subprograms at the plenary session at the start of the Peer Review meeting on May 18th, 2010. This provided the reviewers with an understanding of the Program's goals, structure and resources.

Each fully reviewed project received a score for the following evaluation criteria: Relevance and Impact of the Research; Scientific/Technical Approach; Accomplishments, Expected Outcomes and Progress; Project Management Coordination; and Overall general rating. Reviewers were asked to score each project by assigning one of four numbers to each criterion: 4 = Outstanding, 3 = Good, 2 = Fair, 1 = Poor.

This Peer Review was not designed to assess the Geothermal Technologies Program as a whole or involve the peer reviewers in directly comparing projects across the Program. Therefore, the reviewers' ratings and comments focused specifically on issues with individual projects.

The Average Overall Score for each project is shown in Figure 1 on the following page. This score was derived from the reviewer's individual scores by a method discussed in Section 4.0, below, and represents a single-number metric by which the projects can be characterized. Figure 1 shows that 17 projects were rated in the Good to Outstanding range, 4 were rated Good, 12 were rated in the Fair to Good range, 1 was rated Fair, and 1 was in the Poor to Fair range. A lower-rated project indicates that one or more reviewers found that the project did not successfully meet all criteria. Geothermal sub-program managers will use these ratings to strengthen all projects, especially those rated at the low end. Some of the issues identified by the reviewers are associated with project management. For example, projects that are behind schedule scored lower and raised reviewer concerns; similarly, projects without robust, realistic milestones, schedules and resource plans also attracted reviewer attention. Analysis of the reviewer scores indicate, however, that project management is not a widespread problem throughout the Geothermal Technologies Program portfolio, as the majority of projects received good ratings in this area. Figure 2 provides a detailed summary of the numerical average scores for each project by evaluation criteria, grouped by project technical track.

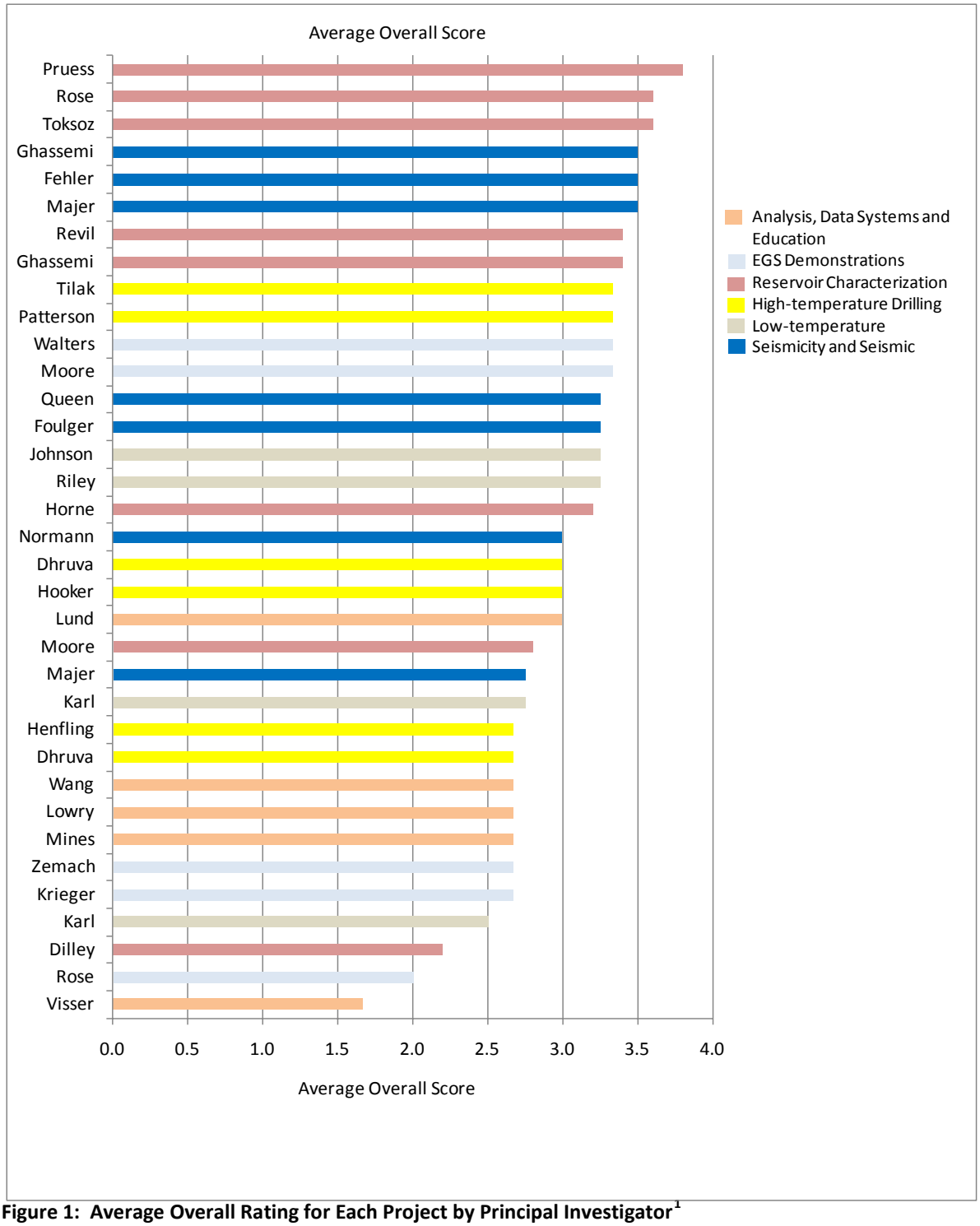


Figure 1: Average Overall Rating for Each Project by Principal Investigator[1]

[1] Please note: the score of the Horne Reservoir Characterization project may have been affected by the reviewers not receiving his project summary report. GTP would like to note the PI's summary report was received by the Program, but due to an oversight the report was inadvertently not transmitted to the PeerNet system for the panel's peer reviewers to view.

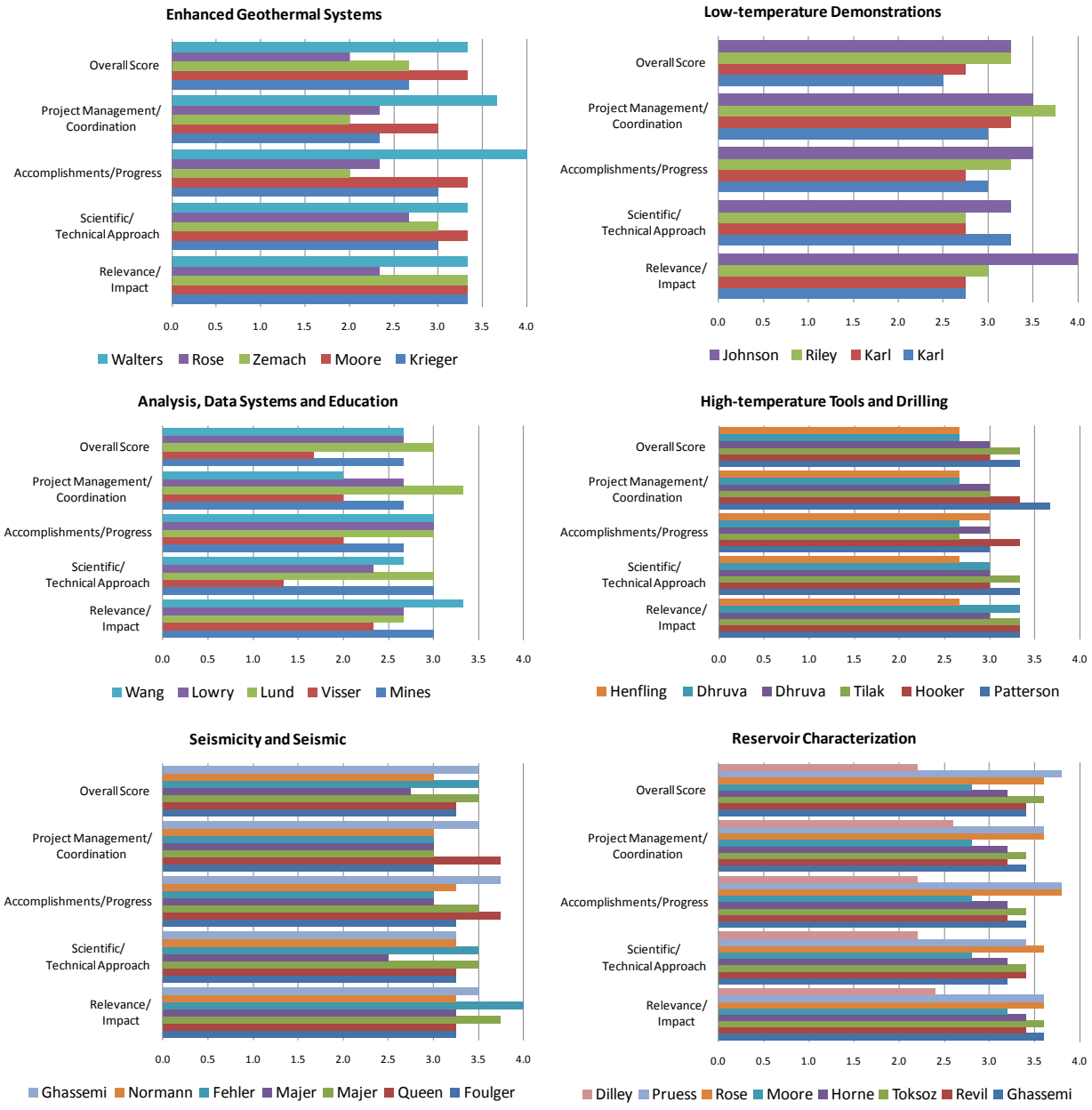


Figure 2: Average Scores by Track, Project and Review Criterion

Table 2: Summary of Scores for Projects Receiving Full Peer Review

	Relevance and Impact	Scientific, Technical Approach	Accomplishments Outcomes and Progress	Project Management and Coordination	Overall Score
	Avg.	Avg.	Avg.	Avg.	Avg.
Enhanced Geothermal Systems, (5 projects)	3.1	3.1	2.9	2.7	2.8
Low Temperature (4 projects)	3.1	3.0	3.1	3.4	2.9
Analysis, Data Systems and Education (5 projects)	2.8	2.5	2.7	2.5	2.5
HT Tools and Drilling (6 projects)	3.2	3.1	2.9	3.1	3.0
Seismicity and Seismic (7 projects)	3.4	3.1	3.3	3.2	3.2
Reservoir Characterization (8 projects)	3.4	3.2	3.2	3.2	3.3

Numerical averages of the reviewers' scores for each criterion evaluated and for all projects in a track are shown in Table 2. Considering only the Overall Score (rightmost column) projects in Seismicity and Seismic, High-temperature Tools and Drilling, and Reservoir Characterization average in the Good to Outstanding range. Projects in Low-temperature Demonstrations; Enhanced Geothermal Systems; and Analysis, Data Systems and Education tracks were in the Fair to Good range for Overall Score.

Average scores for Relevance and Impact across the technical tracks were slightly higher than the averages for other criteria. The high/low spread was also slightly smaller than for other categories. These scores, in conjunction with supporting reviewer comments, indicate that GTP generally selects and supports projects that the peer reviewers believe are effectively addressing the Program's goals and objectives. There were no clear strengths or weaknesses in other criteria, with variations in the averages that appear to be driven more by individual project issues than any systematic problem with Scientific/Technical Approach, Accomplishments, or Project Management and Coordination. EGS had average scores in the Good range for Relevance/Impact and Scientific/Technical Approach, but averages in the Fair to Good range for the other criteria. The Analysis, Data System and Education sub-program averages were in the Fair to Good range across all criteria. These averages should be interpreted in context; average scores in the Low-temperature Demonstrations and Analysis, Data Systems and Education tracks are based on a small number of projects, only four and five respectively. Therefore, one low-scoring project has more weight in these tracks and affects the average more significantly than in the Reservoir Characterization track, which had eight projects. The lowest score in the Analysis, Data Systems and Education track was 1 (poor) in 4 of the 5 criteria which shows a project that did not successfully meet the established criteria was a major influence on the lower averages in this technical track. Comparing scores across technical tracks, Seismicity and Seismic, Reservoir Characterization and Low-temperature Demonstrations had average scores in the Good to Excellent range across all the criteria.

A much more detailed presentation of results from the 35 peer-reviewed projects is given below in Section 4.0. That section comprises the majority of this report and includes all peer reviewer scores and comments for each individual project

The PI for each peer reviewed project has received feedback as a result of this Peer Review, including reactions and comments from the responsible DOE sub-program manager. Projects where the reviewers had specific recommendations to improve the project have already received direction from Program staff to adjust project plans and address reviewer recommendations. PIs were also given the opportunity to respond to reviewer comments; where they chose to respond, a summary of their comments is included at the end of each individual project evaluation in Section 4.0.

2.0 Summary of Plenary Sessions and Luncheon Presentations

The Peer Review meeting began with presentations from the Geothermal Technologies Program staff designed to acquaint the participants with the organization and management of DOE's Geothermal Program, its budget, and its key goals and objectives. Steve Chalk, DOE EERE's Chief Operating Officer and Deputy Assistant Secretary for Renewable Energy (Acting) opened the session with a discussion of how the Geothermal Program has gone from a proposed budget of zero and slated for closeout to one of the largest and most promising research program areas in EERE by making the technical and economic case for geothermal energy as a major resource for the future. He explained why EERE has such high expectations for geothermal energy, and the importance of effectively managing research and of sound peer review in the Program. He noted that GTP now has the broadest technology portfolio since the 1970s and that this meeting represents approximately $500 million in federally funded work. He outlined the advances made by the geothermal industry and the contributions made by DOE and the National Laboratories. His remarks also underscored the new challenges for GTP in developing Enhanced Geothermal Systems as a viable base-load energy source. He added that the Program has faced challenges before and has a strong tradition of excelling in multi-purpose technology development.

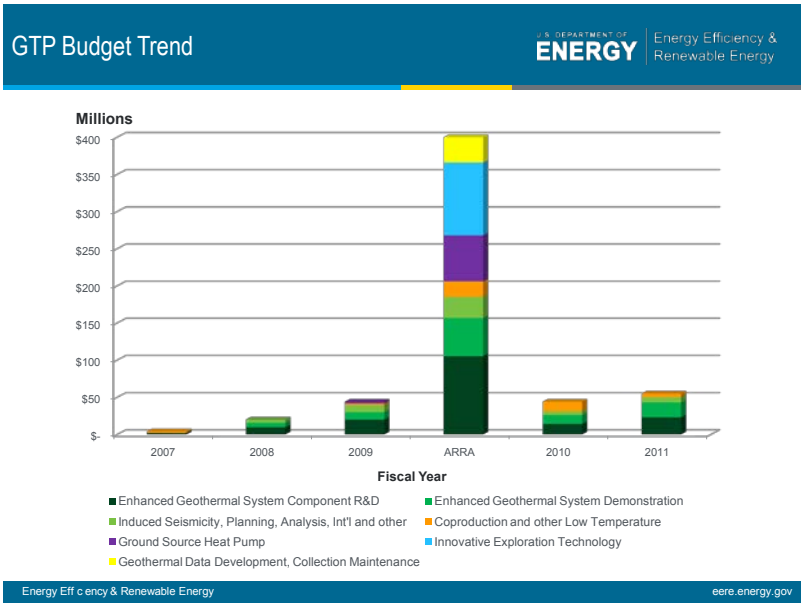


Figure 3: GTP Budget Trend

Jay Nathwani, GTP Acting Program Manager, presented an overview of the GTP Program budget, organization and major goals and objectives. Figure 3 shows the unusual opportunity, and challenge, presented by the budget surge from the American Recovery and Reinvestment Act of 2009 (ARRA.) His presentation was followed by presentations on each of the key sub-program areas: Strategic Planning; Analysis and Geothermal Informatics; Enhanced Geothermal Systems; Low-temperature/Co-produced/Geopressured geothermal energy; Innovative Exploration Technologies; and Ground-source Heat Pumps. The full presentations, which include multi-year research plans, objectives and milestones, budget breakdowns and highlights of key research, are available on the GTP website along with all project presentations and additional material from the Peer Review meeting.

The luncheon speaker on the first day of the meeting was Dr. Walt Snyder of Boise State University, who made a technical presentation on the National Geothermal Data System (NGDS), an ARRA funded initiative that Boise State University leads. The goal of this ambitious project is to develop an internet-based distributed network of databases containing a broad spectrum of geothermal-related data. This system will link to a broad spectrum of catalogued geothermal data made available to the public, including geothermal developers, utilities, funding agencies, regulatory agencies and others in the geothermal community through a map-based interface. The NGDS will use and adapt existing technology as well as emerging informatics standards and protocols. There are plans to partner with other data sources to maximize data availability for users and minimize duplication. The NGDS will be able to handle the full range of geoscience and engineering data pertinent to geothermal resources as well as to incorporate data from the full suite of geothermal resource types. It will handle data on geothermal site attributes, power plants, environmental factors, policies and procedures, and institutional barriers. It will provide resource classification and financial risk assessment tools to help encourage the development of more geothermal resources by industry. The NGDS will be easy to use and will meet the needs of the professional and the public for information on geothermal resources. As the data are digitized and standardized, it will help researchers in both the private and public sectors make much more effective use of the information for understanding geothermal resources and potential, and create a platform for continuing to gather and disseminate new data as they are created.

The luncheon speaker for the second day of the meeting was Dr. Henry Kelly, Principal Deputy Assistant for EERE. He discussed EERE's research portfolio and specifically how geothermal energy has been revisited and given a much greater priority within DOE based on its great resource potential and the potential for new research and technology development to enable utilization of a much larger portion of the resource base to be used for base-load electrical power generation and for direct uses. Geothermal energy is now recognized at the highest levels of the Department as a key technology because of its ability to provide a counter-balance to the intermittent renewable energy technologies, while still delivering energy with near-zero carbon emissions. With a clearer understanding of the advances made in enhanced geothermal systems and low-temperature technology, and their potential to serve much larger areas of the country than traditional hydrothermal resources have been able to do, DOE has developed ambitious plans for widespread utilization of geothermal energy well beyond its current range.

3.0 Summary of Overview Presentations

Newly funded projects – those that made insufficient progress to warrant a full peer review – were presented in overview fashion by the individual researchers (usually, but not always, the PI). There were 168 projects in this category. Each presentation was allowed a 15-minute time slot in addition to a 15-minute question and answer (Q&A) period, shared with two to three other projects, during which the audience could engage the presenter. Monitors in each session introduced the speakers, kept time and performed other organizational duties. The overview sessions were grouped by technical track with three or four projects per session, and, to accommodate the large number of presentations, parallel tracks were scheduled (see the meeting agenda in Section 6.3 and the tables below).

For the researchers, these sessions served as an opportunity to present and discuss their projects with colleagues prior to a full peer review planned for next year, and to receive feedback during question and answer sessions following each presentation. These sessions also created an important opportunity for researchers to meet GTP managers from headquarters and the Golden Field Office and to develop a working relationship going forward.

An important facet of the meeting was the opportunity for broad discussion and information sharing among researchers and other meeting participants during and after the sessions. Track moderators noted that the audience shared technical advice, made suggestions, and exchanged contact information during the question and answer sessions and breaks. There was broad support and enthusiasm for this Peer Review meeting. Participants commented that it was a good opportunity for a broad cross-section of the geothermal community to come together and share information, and they found it very useful. Some participants observed that meetings like this one are also useful to identify redundancy in some research areas.

The major issues with the overview sessions were associated with their popularity; attendees requested longer time slots for presentations and Q&As as well as fewer parallel tracks. Because of the number of projects and the compressed schedule, there were many cases where it was necessary for participants to choose between sessions in competing tracks, leaving some presenters with small audiences. There were also suggestions for grouping projects more effectively by topic, streamlining elements of the presentation template, and providing more time for preparation. Despite these concerns, PIs complied with presentation and summary instructions and adhered very effectively to the compressed presentation schedule[2].

3.1 Enhanced Geothermal Systems

The Enhanced Geothermal Systems (EGS) technical track of overview presentations consisted of three demonstration projects. The EGS projects aim to: (1) demonstrate EGS reservoir creation technology in

[2] Of those overview projects shown in the schedule, four projects were not presented at the meeting. The projects that were not presented are identified with a double asterisk in the project table in the corresponding overview session summaries.

various geologic environments and geographic regions; (2) quantitatively demonstrate and validate stimulation techniques that sustain fluid flow and heat extraction rates; and (3) show that EGS can be scaled up to produce power economically. The Newberry project is located in central Oregon, on the flanks of a volcanic system with a known high-temperature heat source. The objective of this demonstration project is to develop an EGS reservoir via stimulation of multiple zones of a low permeability, high temperature rock. The Southwest Alaska Regional Geothermal Energy Project is located in King Salmon, Alaska. This demonstration project provides an opportunity to demonstrate EGS technology in an environment with higher energy costs than most regions in the United States, and has normal temperature gradients. The New York Canyon project is located in western Nevada. The goal of this project is to demonstrate the application of EGS technology at the NYC site in a way that minimizes cost and maximizes opportunities for repeat applications elsewhere. Considered together with the EGS projects that received full reviews, this portfolio of projects represents a concerted effort to resolve key issues in advancing EGS technology and reducing economic risk associated with EGS development. Table 3 lists each EGS overview project and the project's presenter.

Table 3: Enhanced Geothermal Systems Overview Projects

Project	Presenter
Newberry Volcano EGS Demonstration	Petty, AltaRock Energy, Inc.
Southwest Alaska Regional Geothermal Energy Project - Implementation of a Demonstration EGS Project in Naknek, AK	Vukich, Naknek Electric Association
New York Canyon Stimulation	Raemy, TGP Development Company, LLC

3.2 Low-temperature/Co-produced/Geopressured

The Low-temperature/Co-produced/Geopressured technical track of overview presentations comprised 12 projects. The projects in this technical track presented energy production opportunities in a variety of geographic regions that seek to take advantage of low- to moderate-temperature fluids, water expelled from oil and gas production wells, and resources occurring in deep basins where the fluid and gas are under very high pressure.

The low-temperature demonstration projects in this technology track include, among others, a project in Klamath Falls, Oregon, that seeks to construct a low-temperature power plant which will be integrated into an existing district heating system. Another project, operated by a rural electric cooperative in Surprise Valley, Oregon, plans to construct a binary power plant and utilize the low-temperature fluids to support a local aquaculture facility.

The co-produced demonstration projects that presented an overview are located in Texas and North Dakota and are in the process of constructing low-temperature binary units, which will operate utilizing co-produced fluid from existing oil and gas wells. The geopressured demonstration project in this

technical track will build a geopressured-geothermal plant in Cameron Parish, Louisiana, and will utilize kinetic, thermal, and chemical energy to produce electricity.

The Low-temperature/Coproduced/Geopressured portfolio of projects will help to achieve wider adoption of under-utilized, low-temperature energy resources through surface and down-hole technology advances. Table 4 lists each Low-temperature/Co-produced/Geopressured overview project and the project's presenter.

Table 4: Low-temperature/Co-produced/Geopressured Overview Projects

Project	Presenter
Purchase and Installation of a Geothermal Power Plant to Generate Electricity Using Geothermal Water Resources	Brown, City of Klamath Falls
Beowawe Binary Bottoming Cycle	McDonald, Beowawe Power, LLC
Demonstration of a Variable Phase Turbine Power System for Low-temperature Geothermal Resources	Hays, Energent Corporation
Novel Energy Conversion Equipment for Low-temperature Geothermal Resources	Kohler, Johnson Controls, Inc.
Demonstrating the Commercial Feasibility of Geopressured-geothermal Power Development at the Sweet Lake Field, Cameron Parish, LA	Jordan, Louisiana Tank, Inc.
Develop NREL Center for Low-temperature Research/Project Data Collection	Williams, NREL
Osmotic Heat Engine for Energy Production from Low-temperature Geothermal Resources	McGinnis, Oasys Water
Rural Electric Cooperative Geothermal Development	Silveria, Surprise Valley Electrification Corporation
Dixie Valley Bottoming Binary Project	McDonald, Terra-Gen Sierra Holdings, LLC
Technical Demonstration and Economic Validation of Geothermally-produced Electricity from Co-produced Water at Existing Oil/Gas Wells in TX	Alcorn, Universal GeoPower LLC
Electric Power Generation from Co-produced Fluids from Oil and Gas Wells	Gosnold, University of North Dakota
Electric Power Generation from Low- to Intermediate-temperature Resources	Gosnold, University of North Dakota

3.3 Analysis, Data Systems and Education

The Analysis, Data Systems and Education technical track comprised 18 projects. These projects included the following areas: the National Geothermal Data System (NGDS), analysis, and education and workforce development.

The NGDS initiative entails a three-part strategy of system design, development and testing; data development, collection and maintenance; and national resource assessment and classification. As a part of this initiative, the Boise State University NGDS Architecture Design, Testing and Maintenance project is leading the effort to create a web-based network of databases and data sites that will allow public access to geothermal and related data along with their effort to support the acquisition of new and legacy data through their NGDS Data Acquisition and Access project. Several other projects in this technical track contribute complementary efforts to the above work through data aggregation and the preparation of data sets from state geologic surveys. In addition, a project led by the U.S. Geological Survey (USGS) will assist with the NGDS by expanding the USGS geothermal resource assessment efforts (note that by Congressional mandate, the USGS is responsible for geothermal resource assessment in the United States).

The scope of the analysis projects included, among other topics, a range of subject areas consisting of the following: transmission planning analysis for utility-scale deployment of geothermal energy generation technologies; the economic benefits of EGS deployment; life-cycle costs of baseline EGS; estimating the capacity and cost of geothermal resources; and, decision-analysis tools to assess uncertainties associated with the exploration, development, and operation of EGS. Of the workforce development projects, one set a goal to establish a national geothermal training institute to provide instructional programs to educate and train the next generation of geothermal energy professionals and another aims to develop models to estimate jobs and economic impacts from geothermal project development.

As a whole, the portfolio of projects in this track represents a broad effort to expand and improve available geothermal resource and technology information; develop new ways to apply this information to geothermal development using improved economic, geographic and geologic analysis tools; and enhance geothermal education so more people are aware of geothermal energy's potential, with more students and professionals becoming interested in geothermal careers. Table 5 lists each Analysis, Data Systems and Education overview project and the project's presenter.

Table 5: Analysis, Data Systems and Education Overview Projects

Project	Presenter
Geothermal Resources and Transmission Planning	Hurlbut, NREL
Economic Impact Analysis for EGS	Gowda & Levy, University of Utah
National Geothermal Data System Architecture Design, Testing and Maintenance	Snyder, Boise State University
National Geothermal Data Systems Data Acquisition and Access	Snyder, Boise State University
Geothermal Data Aggregation: Submission of Information into the National Geothermal Data System	Blackwell, Southern Methodist University
State Geological Survey Contributions to the National Geothermal Data System	Allison, Arizona State Geological Survey
Estimation & Analysis of Life-cycle Costs of Baseline Enhanced Geothermal Systems	Turaga, ADI Analytics, LLC
National Geothermal Resource Assessment and Classification	Williams, U.S. Geologic Survey
2009 Geothermal, Co-production, and GSHP Supply Curve	Augustine, NREL
Baseline System Costs for 50 MW Enhanced Geothermal System -- A Function of: Working Fluid, Technology, and Location, Location, Location	Dunn, Gas Equipment Engineering Corporation
Decision Analysis for Enhanced Geothermal Systems	Einstein, Massachusetts Institute of Technology
Energy Returned on Investment of Engineered Geothermal Systems	Mansure, Art Mansure
Analysis of Low-temperature Utilization of Geothermal Resources	Anderson, West Virginia University Research Corporation
Expanding Geothermal Resource Utilization in Nevada Through Directed Research and Public Outreach	Faulds/Calvin, University of Nevada at Reno
Geothermal Workforce Education Development and Retention	Anderson, W VA University/Calvin, University of Nevada, Reno (UNR)
Geothermal Policymakers' Guidebook, State-by-State Developers' Checklist, and Geothermal Developers' Financing Handbook	Young, NREL
Exploration: Best Practices and Success Rates	Young, NREL
Jobs and Economic Development Modeling	Young, NREL

3.4 Ground-source Heat Pump Demonstrations

The Ground-source Heat Pump (GSHP) Demonstration technical track of overview presentations comprised 38 projects. Many projects involved the design, construction, and implementation of operating geothermal heat-pump systems in practical commercial or educational applications. For example, one application in poultry farming was aimed at reducing mortality during hot summer months. Several projects were aimed primarily at gathering data on costs and benefits for the purpose of supporting designers and marketers of GSHP systems.

Several projects of a research nature were aimed at modeling geothermal well systems in order to size them properly, to maximize their functionality, and to minimize construction and operating costs. Finally, one project was aimed at developing the basis of a national certification system for GSHP designers and installers that may promote the development of the trained professionals necessary for accelerated national GSHP implementation.

There were projects to develop expanded classes for using geothermal heat-pump technologies, including hot climate applications and a variety of institutions including jails, a union headquarters complex, a National Guard headquarters, and a university housing complex. Innovative features of these approaches included two projects using water in former mines as a heat source/sink to reduce the cost below those of conventional well drilling, and immersion of the heat exchanger in the surface waters of a river.

This technology track also covered a variety of design/construction/operation projects in a museum, a multi-story residential condominium complex, an historic building (Colorado State Capitol building), a civic ice arena, and a number of schools. Included were conventional vertical well fields, surface water units, and standing column wells. A few projects focused on developing improved design tools, modeling of system performance, including in one case the surface ice on a lake and stratification of thermal layers in that lake serving as a source/sink.

These presentations encompassed a number of practical implementations of ground-source heat pump programs, over a range of sizes up to quite large systems. One very large project encompasses an entire university campus. If successful, this could allow similar projects to develop in a university setting. Projects also included two performing arts centers that are renovations of old or historic buildings, an innovative hybrid system employing not only GSHP but also a desiccant-based dehumidifier, and a number of college physical plants to be upgraded and modernized. Table 6 lists each Ground-source Heat Pump Demonstration overview project and the project's presenter.

Table 6: Ground-source Heat Pump Demonstration Overview Projects

Project	Presenter
Two-175 Ton (350 Tons total) Chiller Geothermal Heat Pumps for Recently Commissioned LEED Platinum Building	Hoffman, Johnson Controls, Inc.
National Certification Standard for the Geothermal Heat Pump Industry	Kelly, Geothermal Heat Pump Consortium
Measuring the Costs & Economic, Social & Environmental Benefits of Nationwide Geothermal Heat Pump Deployment & the Potential Employment, Energy & Environmental Impacts of Direct Use Applications	Battocletti, Bob Lawrence & Associates, Inc.
Geothermal Academy: Focus Center for Data Collection, Analysis and Dissemination	Nakagawa, Colorado School of Mines
Finite Volume Based Computer Program for Ground Source Heat Pump Systems	Menart, Wright State University
Development of a Software Design Tool for Hybrid Solar-geothermal Heat Pump Systems in Heating- and Cooling-dominated Buildings	Yavuzturk, University of Hartford
Development of Design and Simulation Tool for Hybrid Geothermal Heat Pump System	Ellis, Climatemaster & Liu, ORNL
Hybrid Geothermal Heat Pump Systems Research	Hackel, Energy Center of Wisconsin
Cedarville School District Retrofit of Heating and Cooling Systems with Geothermal Heat Pumps and Ground Source Water Loops	Ferguson, Cedarville School District 44
Large Scale GSHP as Alternative Energy for American Farmers: Technical Demonstration & Business Approach	Xu, The Curators of the University of Missouri
Analysis of Energy, Environmental and Life Cycle Cost Reduction Potential of Ground Source Heat Pump in Hot and Humid Climate	Tao, Florida International University Board of Trustees
Analysis and Tools to Spur Increased Deployment of "Waste Heat" Rejection/Recycling Hybrid GHP Systems in Hot, Arid or Semiarid Climates Like Texas	Masada, The University of Texas at Austin
Geothermal Retrofit of Illinois National Guard State Headquarters Building	Lee, Department of Military Affairs
A Demonstration System for Capturing Geothermal Energy from Mine Waters beneath Butte, MT	Gilmore, Montana Tech of The University of Montana
RiverHeath, Appleton, WI	Geall, RiverHeath LLC
District Energy SW 40th Street Thermal Plant	Amancherla, District Energy Corporation
Optimal Ground Source Heat Pump System Design	Ozbek, Environ International Corporation

Table 6 (continued): Ground-source Heat Pump Demonstration Overview Projects

Project	Presenter
Flathead Electric Cooperative Facility Geothermal Heat Pump System Upgrade	Talley, Flathead Electric Cooperative
Forest County Geothermal Energy Project	Elliott & Farnham, Forrest County
Retrofit of the Local 150 of International Operating Engineers Headquarters Campus	Cheiftez, Indie Energy Systems Company, LLC
Education and Collection Facility Ground Source Heat Pump Demonstration Project	Noel, Denver Museum of Nature & Science
Wilders Grove Solid Waste Service Center	Battle, City of Raleigh
Oak Ridge City Center Technology Demonstration Project	Thrash, Oak Ridge City Center, LLC
Lake Elizabeth Micro-utility	Isaac, SKYCHASER ENERGY, INC.
Colorado State Capitol Building Geothermal Program	Shephard, Colorado Department of Personnel and Administration
City of Eagan - Civic Ice Arena Renovation	Lutz, City of Eagan
District Wide Geothermal Heating Conversion	Chatterton, Blaine County School District #61
Tennessee Energy Efficient Schools Initiative Ground Source Heat Pump Program	Graham, Tennessee Department of Education
Improved Design Tools for Surface Water and Standing Column Well Heat Pump Systems	Spitler, Oklahoma State University
CNCC Craig Campus Geothermal Project	Boyd, Colorado Northwestern Community College
1010 Avenue of the Arts - New School & Performing Arts Theater	Colman, 1001 South 15th Street Associates LLC
**Middlesex Community College's Geothermal Project (MA)	**Klein, Middlesex Com. College
North Village Ground Source Heat Pumps	Redderson, Furman University
Pioneering Heat Pump Project	Aschliman, Indiana Institute of Technology
Human Health Science Building Geothermal Heat Pump Systems	Leidel, Oakland University
Geothermal Heat Pump System for the New 500-bed 200,000 SF Apartment-style Student Housing Project at the University at Albany's Main Campus	Lnu, University of Albany
BSU GHP District Heating and Cooling System (Phase I)	Lowe, Ball State University
Heat Pump Feasibility Study	Beiswanger, Deamen College

3.5 Validation of Innovative Exploration Technologies

The Validation of Innovative Exploration Technologies (IET) technical track of overview presentations comprised 25 projects. The IET projects are focused on lowering the up-front risk and cost associated with geothermal projects; developing new, innovative exploration methods; and, confirming new geothermal capacity. These projects examine a number of advanced exploration technologies, including remote sensing, geochemistry, advanced seismic methods, shallow-temperature surveys, stress/strain measurements, drilling, and the combination of several methods.

One project focuses on technology transfer and aims to integrate several rock-mechanics technologies that are more established in mining. Another tests the effectiveness of shallow-temperature surveys to identify deep drilling targets cost effectively. A project located in Oregon at Crump Geyser applies an innovative geophysical approach to improve well targeting. At the McGregor Range on the Fort Bliss Military Reservation in New Mexico, a project is in progress to assess the area's geothermal resource using proven techniques and new analysis tools. In all, eight states are represented in these projects.

Several IET projects test the applicability of three-dimensional/three-component (3D-3C) reflection seismic methods. Others combine high-resolution geophysical and geochemical techniques with remote sensing for analysis and modeling prior to siting and drilling. Several focus on blind geothermal systems in a variety of geological locations and could enable the identification of more blind geothermal resources. Given the variety of locations, technologies and participants involved, this group of projects is clearly expanding the range of technologies and approaches available for exploration, and demonstrating their application. Table 7 lists each IET overview project and the project's presenter.

Table 7: Validation of Innovative Exploration Technologies Overview Projects

Project	Presenter
Effectiveness of Shallow Temperature Surveys to Target a Geothermal Reservoir at Previously Explored Site at McGee Mountain, NV	Zehner, Geothermal Technical Partners, Inc.
**Unalaska Geothermal Energy (AK)	**Fulton, City of Unalaska
Away from the Range Front: Intra-basin Geothermal Exploration	Melosh, GeoGlobal Energy LLC
Crump Geyser: High Precision Geophysics and Detailed Structural Exploration and Slim Well Drilling	Casteel & Niggeman, Nevada Geothermal Power Company
El Paso County Geothermal Electric Generation Project Ft. Bliss	Lear, El Paso County
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, NV	Benoit, Magma Energy Corp.
Conducting a 3-D Converted Shear Wave Project to Reduce Exploration Risk at Wister, CA	Matlick, ORMAT Nevada,Inc.
Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System: A Viable Alternative to Grid-drilling for Geothermal Exploration: McCoy, Churchill County, NV	Benoit, Magma Energy Corp.

Table 7 (continued): Validation of Innovative Exploration Technologies Overview Projects

Project	Presenter
Black Warrior: Sub-soil Gas and Fluid Inclusion Exploration and Slim Well Drilling	Casteel, Nevada Geothermal Power Company
Use of Remote Sensing Data to Locate High Temperature Ground Anomalies in CO	Robinson, Flint Geothermal LLC
Validation of Innovative Exploration Technologies for Newberry Volcano	Waibel, Newberry Geothermal Holdings, LLC
Validation of Innovative Exploration Technologies at the Colado, NV, Geothermal Prospect	Combs, Vulcan Power Company
Merging High-resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, OR	Walsh, ORMAT Nevada, Inc.
Blind Geothermal System Exploration in Active Volcanic Environments; Multi-phase Geophysical and Geochemical Surveys in Overt and Subtle Volcanic Systems, Hawai'i and Maui	Martini, ORMAT Nevada, Inc.
Advanced Seismic data Analysis Program (The "Hot Pot Project")	Moore, OSKI Energy LLC
Application of 2-D VSP Imaging Technology to the Targeting of Exploration and Development Wells in a Basin and Range Geothermal System, Humboldt House-Rye Patch Geothermal Area	Ellis, Presco Energy, Inc.
Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, NM	Kaufman, Pueblo of Jemez
Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Jackson & Pohll, Pyramid Lake Paiute Tribe
Finding Large Aperture Fractures in Geothermal Resource Areas Using a Three-component Long-offset Surface Seismic Survey	Teplow, US Geothermal, Inc.
New River Geothermal Research Project, Imperial County, CA	Johnson, Ram Power, Inc.
Alum Innovative Exploration Project	Ronne, Sierra Geothermal Power, Inc.
Silver Peak Innovative Exploration Project	Ronne, Sierra Geothermal Power, Inc.
Pilgrim Hot Springs, Ak	Holdmann, University of Alaska Fairbanks
Detachment Faulting and Geothermal Resources - Pearly Hot Springs, NV	Stockli, University of Kansas Center for Research Inc.
Snake River Geothermal Drilling Project: Innovative Approaches to Geothermal Exploration	Shervais, Utah State University

3.6 High-temperature Tools and Sensors, Down-hole Pumps and Drilling

The High-temperature Tools and Sensors, Down-hole Pumps and Drilling technical track of overview presentations comprised 18 projects. These projects addressed component R&D for both EGS and conventional geothermal technologies. Challenges that these projects are working to overcome include developing and adapting tools for the high-temperature and high-pressure environments associated with geothermal reservoirs and advancing drilling technology for high-temperature, more rigid geological formations.

One project is working to develop a high-temperature, multi-parameter fiber-optic sensing system for EGS. Another project deals with high-temperature lifting system component technology for EGS. The development of telemetry electronics and pressure-sensor systems is the focus of another project. The drilling projects address: the design and production of a prototype geothermal directional drilling navigation tool; micro-hole arrays drilled with advanced abrasive slurry-jet technology; and, the development of drilling systems based on rock penetration technologies.

Several projects address: high-temperature logging tools; high-temperature instrumentation for borehole imaging; tools for characterizing and modeling the subsurface of EGS project sites; drilling tools and alternative drilling methods; and, well construction capability. The range of technologies and research issues addressed by these projects touches on key challenges facing geothermal development and operation in high-temperature environments. The variety of approaches also provides alternative pathways in some of the key research areas to reduce the risk of relying on a single research path. Table 8 lists each High-temperature Tools and Sensors, Down-hole Pumps and Drilling overview project and the project's presenter.

Table 8: High-temperature Tools and Sensors, Down-hole Pumps and Drilling Overview Projects

Project	Presenter
Multi-parameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems	Knobloch, GE Global Research
High-temperature, High-volume Lifting for Enhanced Geothermal Systems	Turnquist, GE Global Research
Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells	Tilak, GE Global Research
OM300: Geothermal MWD Tools Navigation Instrument	MacGugan & Ohme, Honeywell International Inc.
Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Oglesby, Impact Technologies LLC
Technology Development and Field Trials of EGS Drilling Systems	Bauer, SNL
Base Technologies and Tools for Supercritical Reservoirs	Henfling, SNL
Advanced Drilling Systems for EGS	Hall, Novatek, Inc
Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing	Freifield, LBNL
Feasibility and Design for a High-temperature Down-hole Tool	Akkurt, ORNL
Multi-purpose Acoustic Sensor for Down-hole Fluid Monitoring	Pantea, LANL
Wear-resistant Nano-composite Stainless Steel Coatings and Bits for Geothermal Drilling	Peter, ORNL
Harsh Environment Silicon Carbide Sensor Technology for Geothermal Instrumentation	Pisano, The Regents of the University of California
Complete Fiber/Copper Cable Solution for Long-term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Lowell, DRAKA CABLETEQ USA, INC.
Development of a Hydrothermal Spallation Drilling System for EGS	Potter, Potter Drilling, Inc.
High-temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Hooker, Composite Technology Development, Inc.
** High-temperature Perforating System for Enhanced Geothermal Applications	**Smart, Schlumberger Technology Corp
High-temperature 300 °C Directional Drilling System	Macpherson, Baker Hughes Oilfield Operations Incorporated

3.7 Seismicity and Reservoir Fracture Characterization

The Seismicity and Reservoir Fracture Characterization technical track of overview presentations comprised nine projects. Some of the barriers that these projects are working to overcome include: reducing the cost and improving the quality of site characterization; improving EGS reservoir productivity; improving fluid-flow modeling and validation capabilities; developing a prediction capability of reservoir response to stimulation; developing an imaging capability for fractures after stimulation; and, induced seismicity. To address these barriers, the projects presented in this technical track are working to: utilize EGS fracture and fluid-network imaging; understand induced seismicity in EGS; utilize new imaging methods using passive and time-lapse active seismic data; better detect and locate microearthquakes observed during EGS operations; and, characterize, map, and control fracture networks.

The results from these projects are important to all stages of geothermal development. They will yield better understanding in the development of geothermal reservoirs in the early stages after they have been identified, explored, and drilled. For mature geothermal fields, they will help ensure continued productivity and full development. For proposed developments, particularly for EGS, the results of these projects will help explain and mitigate public concern over induced seismicity. Table 9 lists each Seismicity and Reservoir Fracture Characterization overview project and the project's presenter.

Table 9: Seismicity and Reservoir Fracture Characterization Overview Projects

Project	Presenter
Fluid Imaging of Enhanced Geothermal Systems	Newman, LBNL
Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems	Gritto, Array Information Technology
Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems Reservoirs	Huang, LANL
Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Templeton, LLNL
Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments	Ghassemi, Texas A&M University
Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-dimensional Electrical Resistivity Structure	Wannamaker, University of Utah
Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-exposed, High-velocity Rocks	Hardage, University of Texas at Austin
Characterizing Fractures in Geysers Geothermal Field from Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	Aminzadeh, University of Southern California
Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions	O'Connell, William Lettis & Associates, Inc.

3.8 Reservoir Characterization

The Reservoir Characterization technical track of overview presentations consisted of one project. The focus of this project includes laboratory experiments and laboratory and field data from CO_2 injection at

a geothermal site, obtaining basic information on the performance of CO_2-based EGS, and enhancing and calibrating modeling capabilities for such systems. Considered together with Reservoir Characterization projects that received full reviews, this effort is broadly aimed at improving the application of reservoir characterization techniques and the analysis of reservoir information to improve geothermal development. Table 10 lists the Reservoir Characterization overview project and the project's presenter.

Table 10: Reservoir Characterization Overview Project

Project	Presenter
Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced Geothermal Systems	Pruess, LBL

3.9 Tracers and Exploration Technologies

The Tracers and Exploration Technologies technical track of overview presentations comprised 11 projects. Tracers are invaluable tools for detailed reservoir studies. In the effort to advance tracer-based methods, this technical track focuses on addressing some of the following barriers: inadequate tracers and/or tracer methodology to accurately define the subsurface system of fractures and map fluid flow; limited fracture detection capability; lack of high-temperature monitoring tools and sensors; limited flow-path identification capability; inter-well connectivity; and reservoir sustainability.

Innovative aspects of these projects include: the use of perfluorinated tracer compounds (PFTs) as a new type of geothermal tracer; the application of a suite of tracers for simultaneously measuring temperature changes and fracture surface-area changes in inter-well tracer tests; numerical optimization of multi-component chemical geothermometry at multiple locations; and the estimation of fracture surface area and spacing through the interpretation of signals of natural chemical and isotopic tracers. As a group these projects have the potential to greatly expand tracer tools and methods available for exploration and reservoir characterization, making the process of exploration and reservoir characterization more precise, easier to interpret, and easier to implement. Table 11 lists each Tracers and Exploration Technologies overview project and the project's presenter.

Table 11: Tracers and Exploration Technologies Overview Projects

Project	Presenter
Using Thermally-degrading, Partitioning and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Watson, BNL; Reimus; Vermeul, PNNL
Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-based Geothermal Reservoirs	Hull, INL
Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments	Becker, California State University, Long Beach Foundation
Integrated Chemical Geothermometry System for Geothermal Exploration	Spycher, LBNL
Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Kennedy, LBNL
Novel Multi-dimensional Tracers for Geothermal Inter-well Diagnostics	Tang, Power, Environmental and Energy Research Institute
Quantum Dot Tracers for Use in Enhanced Geothermal Systems	Rose, University of Utah
Characterizing Structural Controls of EGS-candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	Faulds, Board of Regents, NSHE, on behalf of UNR
Development of Exploration Methods for Enhanced Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation	Iovenitti, Altarock Energy, Inc.
Advanced 3-D Geophysical Imaging Technologies for Geothermal Resource Identification	Newman, LBNL & Fehler, MIT
Fracture Evolution Following Hydraulic Stimulation within an EGS Reservoir	Rose, University of Utah

3.10 Specialized Materials and Fluids and Power Plants

The Specialized Materials and Fluids and Power Plants technical track of overview presentations comprised 15 projects. These R&D projects seek to reduce the cost of key geothermal component technologies and develop new and innovative technologies that advance the utilization of geothermal energy. This technical track included a diverse group of projects that examine high-temperature, down-hole tool applications; geothermal mineral extraction; working fluids for binary power plants; sealing materials for drilling and fracturing in EGS wells; high-temperature, high-pressure zonal isolation devices; and high-temperature cements for geothermal wells.

The power plant projects in this technical track were focused on the efficiency, output, and costs associated with the generation of electrical power from air-cooled and ORC geothermal power plants.

At a geothermal power plant in California, a project is underway to demonstrate generation technology for extracting lithium from geothermal brines. If successful, this effort may demonstrate the potential for improving the economics of EGS projects by creating new revenue streams for geothermal projects.

Also in this technical track, an innovative heat storage and transport approach is under development that could hold the potential to double the power output of EGS power generation plants. These and many more projects in this technical track are forging a path to advances in specialized geothermal materials and fluids and are identifying and analyzing approaches to developing geothermal power-plant efficiencies. Table 12 lists each Specialized Materials and Fluids and Power Plants overview projects and the project's presenter.

Table 12: Specialized Materials and Fluids and Power Plants Overview Projects

Project	Presenter
Evaluate Thermal Spray Coatings as a Pressure Seal	Henfling, SNL
Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids	Harrison, Simbol Mining Corp.
Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Jody, ANL
Geopolymer Sealing Materials	Butcher, BNL
High-temperature, High-pressure Devices for Zonal Isolation in Geothermal Wells	Fabian, Composite Technology Development, Inc.
High-potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	Klockow, GE Global Research
Temporary Bridging Agents for Use in Drilling and Completion of EGS	Watters, CSI Technologies, LLC
Development Of An Improved Cement For Geothermal Wells	Trabits, Trabits Group, LLC
Air-cooled Condensers in Next-generation Conversion Systems	Mines, INL
Geothermal Working Fluids	Brennecke, Notre Dame University
Hybrid and Advanced Air Cooling	Kutscher & Bharathan, NREL
Working Fluids and Their Effect on Geothermal Turbines	Sabau, ORNL
Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems	McGrail, PNNL
Optimization of Hybrid-water/Air-cooled condenser in an Enhanced Turbine Geothermal ORC system	Wu, United Technologies Research Center
Metal Organic Heat Carriers for Enhanced Geothermal Systems	Mahmoud, United Technologies Research Center

3.11 Chemistry, Reservoir and Integrated Models

The Chemistry, Reservoir and Integrated Models technical track of overview presentations comprised 18 projects. Utilizing a combination of laboratory, theoretical, modeling, and field studies, these projects are working to enhance the ability to characterize EGS systems and provide practical approaches to EGS long-term performance, design, operation strategies, and commercial feasibility.

Under development in this technology track are a stimulation prediction model, a 3-dimensional numerical simulator, thermal-hydrological-mechanical-chemical modeling (THMC) tools, and other modeling tools. Several projects address a number of research aspects related to supercritical CO_2 and EGS reservoir rocks by harnessing the effective characteristics of CO_2 for heat transmission.

The focus of another project is the development of waveguide-based ultrasonic and far-reaching electromagnetic sensors to measure key EGS reservoir parameters. This technical track also included a project that will investigate the use of non-toxic or low environmental-impact liquid propellants for the stimulation of fracturing in geothermal fields. Table 13 lists each Chemistry, Reservoir and Integrated Models overview project and the project's presenter.

Table 13: Chemistry, Reservoir and Integrated Models Overview Projects

Project	Presenter
Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems	Gutierrez, Colorado School of Mines
Development of Advanced THMC Modeling Capabilities for Enhanced Geothermal Systems	Wu, Colorado School of Mines
Enhanced Geothermal Systems with CO2 as Heat Transmission Fluid	Pruess, LBNL
Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.	Pritchett, Science Applications International Corporation
Coupled THMC Model and Experiments for Optimization of Enhanced Geothermal System Development and Production	Sonnenthal, LBNL
Chemical Impact of Elevated CO2 on Geothermal Energy Production	Carroll, LLNL
THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity	Ellsworth, Pennsylvania State University
Carbonation Mechanism of Reservoir Rock by Supercritical Carbon Dioxide	Butcher, BNL
**Experiment-based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	**Petro, Symyx Technologies, Inc.
A New Analytic-adaptive Model for EGS Assessment, Development and Management Support	Danko, Board of Regents, NSHE, on behalf of UNR
Development of Chemical Model to Predict the Interactions between Supercritical Carbon Dioxide and Reservoir Rock in EGS Reservoirs	Lu, University of Utah

Table 13 (continued): Chemistry, Reservoir and Integrated Models Overview Projects

Project	Presenter
Waveguide-based Ultrasonic and Far-field Electromagnetic Sensors for Down-hole Reservoir Characterization	Sheen, ANL
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	Saar, Regents of the University of Minnesota
Properties of CO2-rich Pore Fluids and Their Effect on Porosity Evolution in EGS Rocks	Cole, ORNL
FRACSTIM/I: An Integrated Fracture Stimulation and Reservoir Flow and Transport Simulator	Podgorney, INL
Predicting Stimulation-response Relationships for Enhanced Geothermal Reservoirs	Carrigan, LLNL
Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation	Grubelich, SNL
Synchrotron X-ray Studies of Supercritical Carbon Dioxide/ Reservoir Rock Interfaces	You, ANL

4.0 Detailed Findings for Peer-reviewed Projects

As discussed previously in this report, 35 projects received full peer review at the May meeting. The following sections present the ratings and comments of each peer reviewer for each project. The presentations and reviews were organized by technical track and project during the meeting, and are documented in the same way below. Each reviewer's comments and ratings are independent from those of other reviewers, and each is given equal weighting in this evaluation. There was no requirement for or attempt by the peer reviewers to reach a consensus on ratings or comments. Peer reviewers were allowed to discuss the materials and presentations among themselves and to ask each other questions, but only for the purposes of preparing their own independent assessments. Each peer reviewer used the same peer review forms and criteria (see Section 6.1), and reviewed the same project summary and presentation materials.

The scoring system used for each project allowed the reviewers to choose from only the following numbers to signify how well the project adhered to the established criterion: 4 = Outstanding, 3 = Good, 2 = Fair, 1 = Poor. Thus, a word of caution is in order: we must guard against over interpretation of the scores and averages given in this report. Small differences of a few tenths of a point may not be significant. However, from the range of scores reported, it is apparent which projects the reviewers rated highly and which they did not.

The tables below show an Overall Score for each reviewer in the rightmost column. This Overall Score was assigned by the reviewers, and represents their best synthesis of the scores for the individual criteria *combined with their overall impression of the project*. In particular, the Overall Score is *not* the numerical average of the scores for the individual criteria. In order to develop a single-number metric for each project, the numerical average of the reviewers' individual Overall Scores has been adopted in this report. This number is shown in the rightmost column (in the orange-shaded cell) as the Average Overall Score and again in the introductory material for each project.

4.1 Enhanced Geothermal Systems

The five projects in the EGS technical track illustrate efforts to demonstrate the technical feasibility of EGS technologies in different geologic conditions, to validate stimulation techniques, including the techniques to form and sustain EGS reservoirs, and EGS reservoir development in the periphery of an operating hydrothermal system. Figure 4 summarizes EGS review scores by evaluation criteria for each PI's project and Table 14 presents detailed scores by reviewer.

Figure 4: Enhanced Geothermal Systems Review Scores by Project PI and Evaluation Criteria

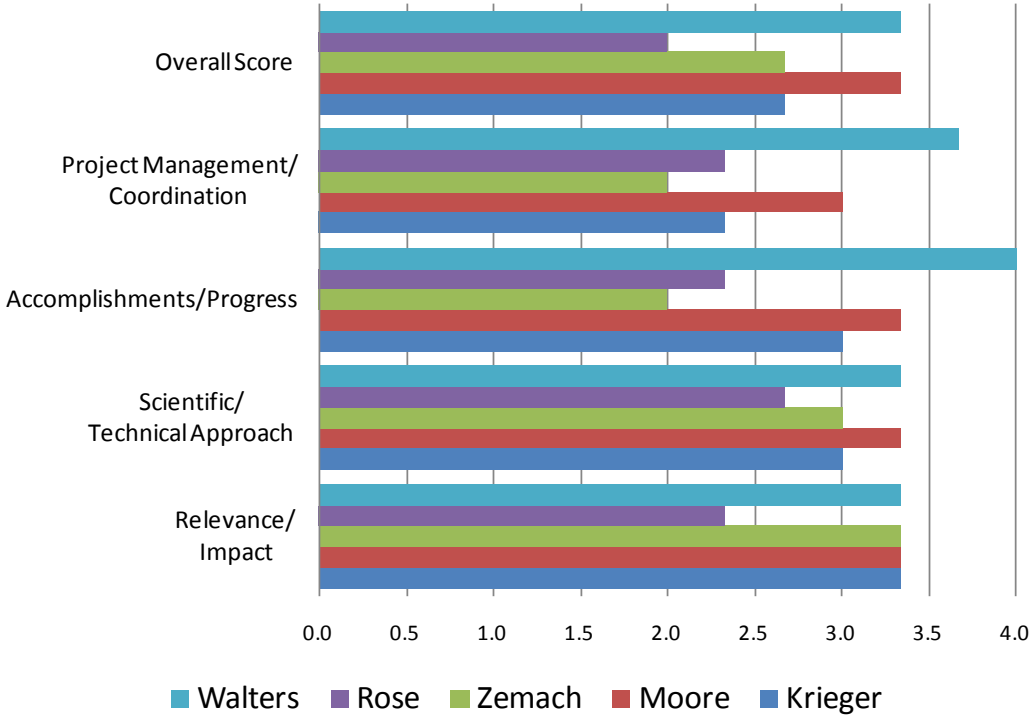


Table 14: Enhanced Geothermal Systems Project Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Brady's Hot Springs	Krieger	1	3.0	4.0	3.0	3.0	3.0
		2	4.0	3.0	3.0	3.0	3.0
		3	3.0	2.0	3.0	1.0	2.0
		Average	3.3	3.0	3.0	2.3	2.7
Raft River	Moore	1	3.0	4.0	4.0	4.0	4.0
		2	4.0	3.0	3.0	3.0	3.0
		3	3.0	3.0	3.0	2.0	3.0
		Average	3.3	3.3	3.3	3.0	3.3
Desert Peak	Zemach	1	3.0	3.0	2.0	2.0	2.0
		2	4.0	3.0	2.0	2.0	3.0
		3	3.0	3.0	2.0	2.0	3.0
		Average	3.3	3.0	2.0	2.0	2.7
EGS through Hydraulic and Thermal	Rose	1	1.0	3.0	2.0	2.0	1.0
		2	4.0	3.0	3.0	3.0	3.0
		3	2.0	2.0	2.0	2.0	2.0
		Average	2.3	2.7	2.3	2.3	2.0
EGS at NW Geysers	Walters	1	3.0	3.0	4.0	4.0	3.0
		2	4.0	4.0	4.0	4.0	4.0
		3	3.0	3.0	4.0	3.0	3.0
		Average	3.3	3.3	4.0	3.7	3.3

4.1.1 Feasibility of EGS Development at Brady's Hot Springs, Nevada

Presentation Number: 006
Investigator: Krieger, Zvi (ORMAT Nevada, Inc.)
Objectives: To stimulate permeability in tight well 15-12 and improve connection to the rest of the field; improve overall productivity or injectivity.
Average Overall Score: 2.7/4.0

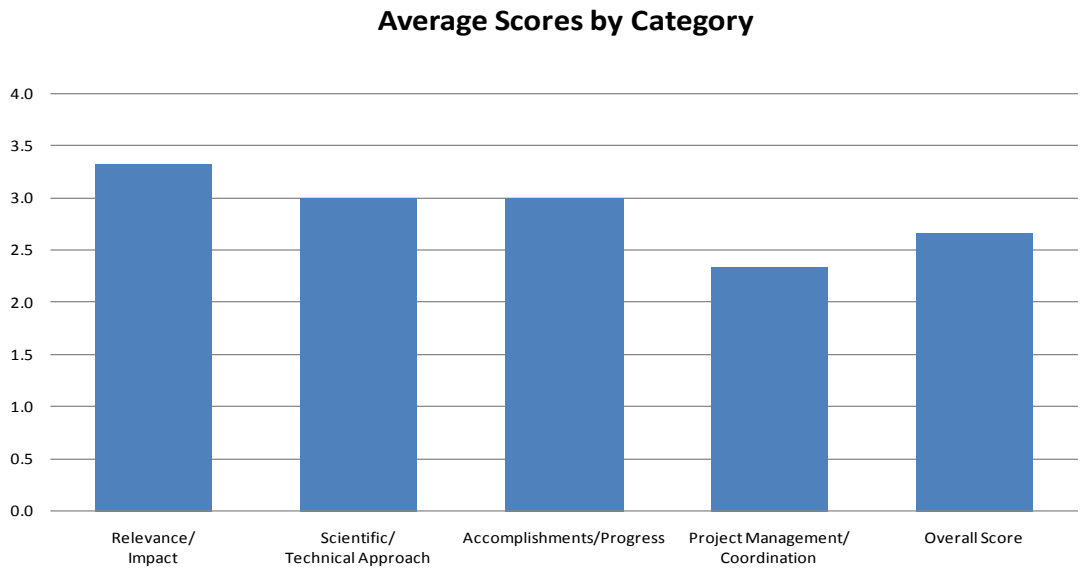


Figure 5: Feasibility of EGS Development at Brady's Hot Springs, Nevada

4.1.1.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- The project is only 10% complete, however the objectives of the project seem in line with the Program's need to demonstrate the ability to develop EGS projects as well as improve the needed scientific base.

- This important project, if successful, would develop and demonstrate EGS technology to create permeability in tight rocks in the vicinity of an operating hydrothermal system.

- The Brady's EGS demonstration project's goal is to enhance permeability in 15-12 ST1 to increase generation at the Brady's Power plant by 2-3 MW. If successful, this project will make an important contribution to the Geothermal Program mission. The project activities could solve known technical barriers such as stimulating permeability in tight wells and improving connectivity and overall productivity or injectivity. If this project is successfully completed, this reviewer is confident that

the EGS program will benefit greatly and that the results will surely add to the EGS technology knowledge base and toolbox.

4.1.1.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Fair (2)

Supporting comments:

- Well laid out project that, if executed, addresses numerous scientific issues.
- The technical approach appears to be sound and was designed by a team having extensive geothermal energy experience.
- The overall technical approach is uninspired. This work is not state-of-the-art R&D but rather applied technology, which is appropriate for a demonstration project. There are adequate resources but insufficient information was presented to assess the scientific rigor of the work elements, procedures and methods. It is not clear to this reviewer that the project will achieve the objectives. The design of the project is straightforward but the technical approach is inadequately described and not clearly laid-out in the tasks provided and project timeline. It is recommended that a task timeline be developed that will assist in managing the schedule and costs.

4.1.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Very strong team of researchers, but being only 10% complete the project needs to be focused to make sure it is completed by June 2012.
- The project started in June of 2009, and a year later is 10% complete. In view of the overall project, this is probably adequate progress. The team assembled for the project is very capable.
- The overall quality of the research team, equipment and facilities is good. The reviewer does not know the PI but some of the researchers on this team are known to this reviewer and are of the highest caliber. Relevant experience and the balance of appropriate skills of the research team are of excellent quality. However, the project is behind schedule with schedule variance at roughly -24% based on a supplied 10% scope complete in 34% of the total project time. Project cost variance was not calculated since current costing was not supplied.

4.1.1.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Good (3), Good (3) , Fair (1)

Supporting comments:

- The ability to effectively manage and coordinate the project participants is a concern given the schedule slips associated with the Desert Peak project that has a similar project team.

- No decision points are called out, and the project has not proceeded far enough to judge the quality of the management accurately.

- The technical, policy, business, and spend plans for the project were not presented and therefore this reviewer was not able to assess them adequately. In addition, there are no decisions points presented in the schedule.

4.1.1.5 Overall

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- Like all of the demonstration projects, there is the possibility of good science and understanding that will come from it. However, it is necessary that the project stay focused on the need to demonstrate EGS development. Why was a written summary not submitted?

- Overall, this project can be expected to generate a great deal of useful information on EGS technology.

- Overall, this is a fair project and this reviewer recommends that the project be put on hold until more detailed review can be made. The project is seriously behind schedule, which should be further investigated by the Program Manager and the information presented was not sufficient in order to assess project schedule and cost variance or evaluate the project plans. It is recommended that Program Manager request the PI to submit a detailed project plan with tasks and fully-loaded with costs.

4.1.1.6 PI Response

No response.

4.1.2 Concept Testing and Development at the Raft River Geothermal Field, Idaho

Presentation Number: 007
Investigator: Moore, Joseph (University of Utah)
Objectives: Develop and demonstrate the techniques required to form and sustain EGS reservoirs including combined thermal and hydraulic stimulation and numerical modeling. Improve the performance and output of the Raft River geothermal field by increasing production or injectivity.
Average Overall Score: 3.3/4.0

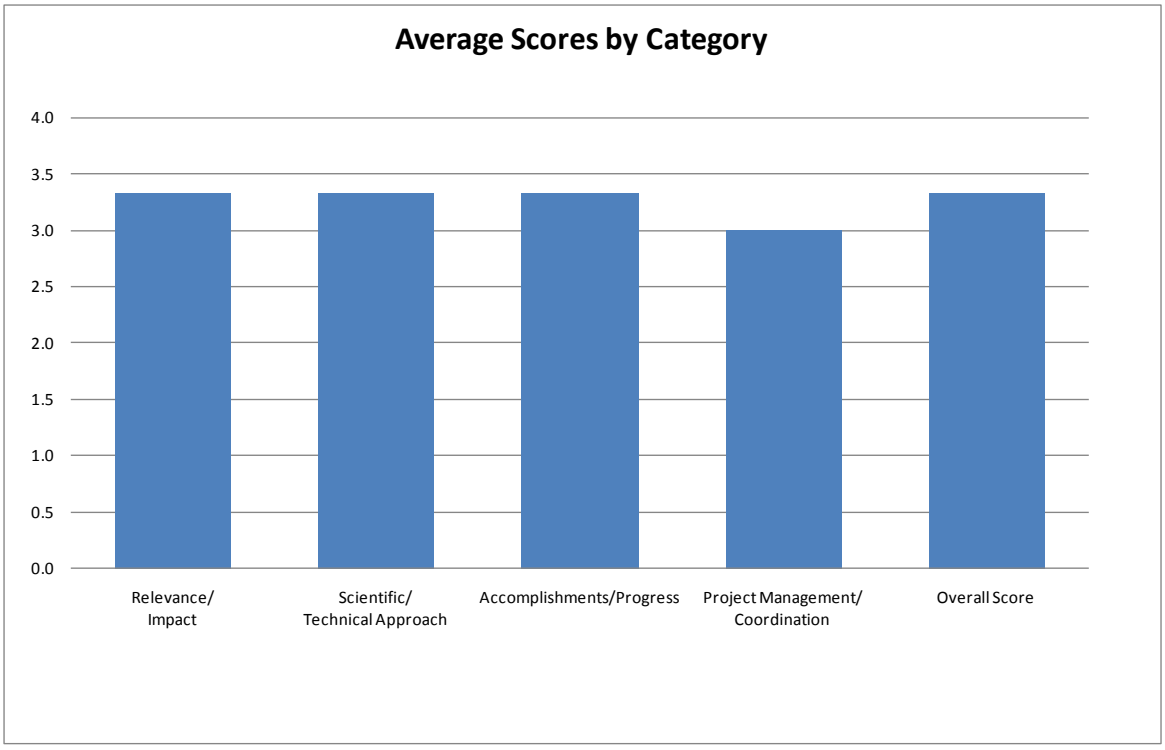


Figure 6: Concept Testing and Development at the Raft River Geothermal Field, Idaho

4.1.2.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- A well focused demonstration project that combines good science and engineering with stimulation approaches that if successful will benefit the DOE Geothermal Program
- This project is directly relevant to development of EGS systems in geothermal areas having relatively lower temperatures (~300 °F) and relatively shallow depth (~5,000 ft). Resources having these characteristics have not been extensively developed in the US and comprise a worthy resource base.
- This Raft River EGS demonstration project, if successfully completed, will make an important contribution to the Geothermal Program mission. The project activities will impact, not

necessarily solve, known technical barriers such as how to increase permeability. If this project is successfully completed this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.1.2.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Project appears focused and has sound science and engineering needed to make the demonstration successful.

- The technical approach appears to be sound, although no reasoning is given for the novel stimulation approach and for the other techniques applied. Does modeling or data from other areas suggest that thermal stimulation followed by hydraulic stimulation is a superior method?

- The overall technical approach is good. Applied technology like this is perfectly suited for a demonstration project and does not involve any state-of-the-art R&D. There are adequate resources and more than sufficient rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline.

4.1.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Like other projects, this project is only 10% complete due (at least to some degree) by the time it has taken to get through contractual issues. Given the delay the progress is good. An excellent team has been assembled and the path seems well defined.

- The project is only 10% complete – receipt of funding from DOE was delayed somewhat. The team appears to be well prepared to move forward when all permits have been obtained.

- The overall quality of the research team, equipment and facilities is good. Some of the researchers are known to this reviewer and are of high caliber. That being said, relevant experience and the balance of appropriate skills of the research team are unknown given this researcher's knowledge of the majority of the team members. There are several accomplishments to date but the project is, according to my rough calculations, behind schedule (report says 10% scope done in 7 months out of 15 total or 46% schedule = behind schedule by 36%). Was not able to ascertain the accomplishments as compared to costs to date since current costing was not given. Clearly, the bulk of the important activities remain and I could imagine that costs reflect this also. However, according to their schedule they are on schedule.

4.1.2.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Fair (2)

Supporting comments:

- The project manager appears to have been very effective at moving the project forward. In general, more decision points would be advisable but this reviewer believes the path and plan is adequate.

- Appropriate decision points are part of the project plan. The path forward is well planned.

- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically on track and project decisions points are appropriately placed.

4.1.2.5 Overall

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Well managed, focused project. The use of thermal and hydraulic stimulation will be interesting. Since proppant appeared to be successful in the past, the project should consider its use during the hydraulic stimulation. One concern is the pipeline construction. Continued focus needed to make sure the project stays on schedule.

- This project, if successful, will be an important demonstration of EGS reservoir development in lower-temperature igneous rocks.

- Overall, this reviewer recommends that the project proceed. It is recommended that the PI accelerate the tasks to catch-up on schedule variance.

4.1.2.6 PI Response

No response.

4.1.3 Desert Peak East EGS Project

Presentation Number: 008
Investigator: Zemach, Ezra (ORMAT Nevada, Inc.)
Objectives: Stimulate permeability in tight well 27-15 and improve connection to rest of the field; improve overall productivity and injectivity.
Average Overall Score: 2.7/4.0

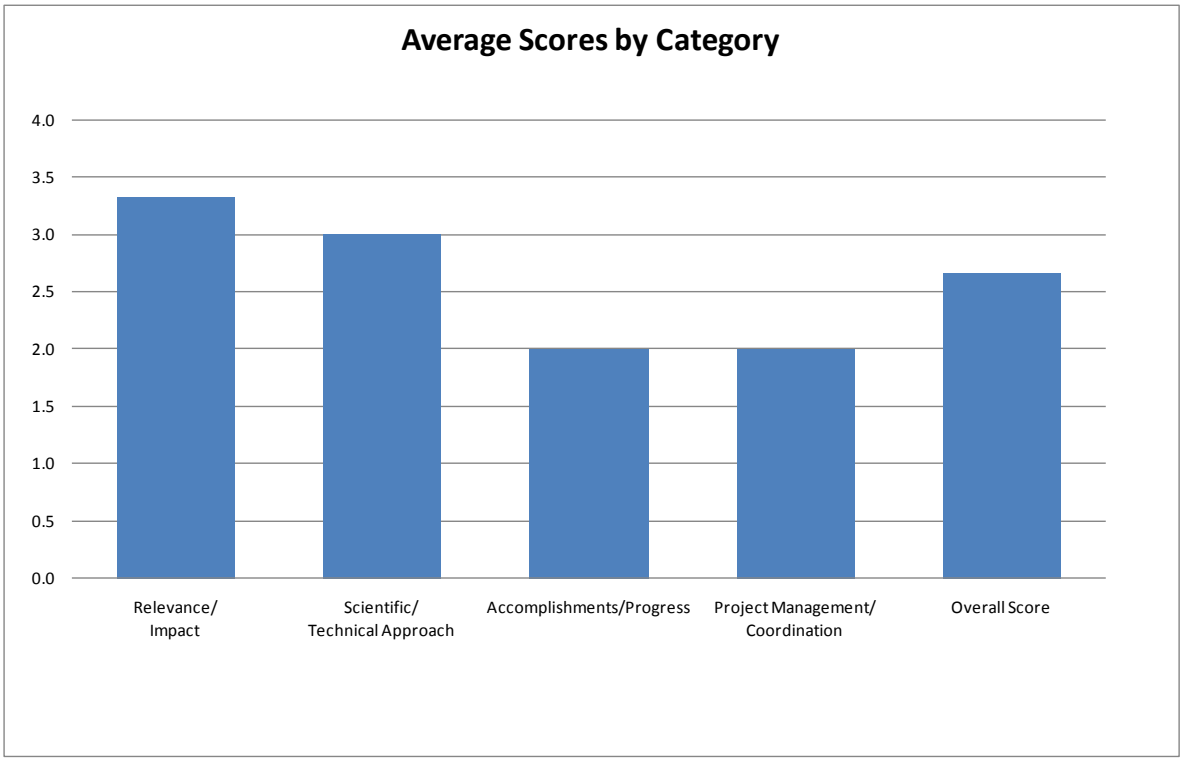


Figure 7: Desert Peak East EGS Project

4.1.3.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- Good science and engineering have come out of this project but the project setbacks have had a significant impact on the Program. The location for stimulation appears to have been a compromise in a well that was also a compromise. Again, the team has done an admirable job but the outcome of the project was compromised by events in the field.

- This project is important for developing EGS technology and demonstrating EGS development in rocks peripheral to a known hydrothermal resource. It has developed, and will continue to develop, information pertinent to EGS projects.

- This Desert Peak EGS demonstration project, if successful, will make an important contribution to the Geothermal Program mission. The project activities will illuminate (not necessarily solve)

known technical barriers such as stimulating permeability in tight wells and improving connectivity. If this project is successfully completed, this reviewer is confident that the EGS program will benefit greatly and that the results will surely add to the EGS technology knowledge base and toolbox.

4.1.3.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The approach is well thought out and deliberate with real world applications to the development of EGS. While the science is sound, this is a demonstration project and to some level the project seems to have lost focus on that fact.

- The technical approach to this project is sound, designed by a well qualified team. The PI notes the challenge of coordinating the efforts of diverse people from diverse organizations, but this has been done well.

- There has been a lot of work done at Desert Peak and the overall technical approach looks good but was not clearly presented. This work is not state-of-the-art R&D but rather applied technology, which is appropriate for a demonstration project. There are adequate resources and more than sufficient rigor of the work elements, procedures and methods that, if followed, should achieve the project objectives. The design of the project was not presented directly but was inferred from the list of accomplishments. The inferred plan was deemed reasonable. The technical approach was not clearly described nor clearly laid-out. Tasks yet to be done were not provided nor was a project timeline presented. Also, there was no discussion about why it took almost 7 years to do the stimulation.

4.1.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Fair (2), Fair (2), Fair (2)

Supporting comments:

- The quality of the people and resources involved are outstanding but the overall productivity and execution of the project is poor. This project needs to be completed.

- Progress seems to have lagged since the project was initiated in 2002, has an end date in July 2010, and is only 65% complete. The PI did not present the project schedule versus the original plans. It is evident that during the impending stimulation of well 27-15, the rate of expenditure will increase dramatically. The project team includes people with worldwide geothermal energy experience – it is an impressive team.

- The overall quality of the research team, equipment and facilities is good. The reviewer does not know the PI but some of the researchers on this team are known to this reviewer and are of the highest caliber. Relevant experience and the balance of appropriate skills of the research team are of excellent quality. I was not able to ascertain the cost or schedule variance to date since

current costing and original schedule were not supplied. Clearly, the most important task in this 7+ year project, the stimulation, has not been done yet for some reason.

4.1.3.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Fair (2), Fair (2)

Supporting comments:

- The project has suffered from numerous setbacks, but that alone does not explain the slow progress. The cause(s) of delays are not completely obvious to the reviewer but it appears from the noted challenges that coordination of resources was an issue.

- No chart of project schedule or specification of decision points was presented. From the work done so far on the project, well 27-15 still appears to be a viable candidate for stimulation.

- The technical, policy, business, and spend plans for the project were not presented and therefore this reviewer was not able to provide an assessment. In addition, there are no decisions points presented in the schedule.

4.1.3.5 Overall

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- The project has a strong team, producing good science but the execution has been lacking. The team should focus on completing this project without further delays.

- This is an important project for developing technology and demonstrating EGS reservoir development in the near-field of an operating hydrothermal system developed in indurated shale and mudstones.

- Overall, this seems like a good project but it is behind schedule. However, this reviewer recommends that the project proceed. The report was not made available to the reviewer, only the presentation. Critical project schedule and costs information was not provided in the presentation, information needed in order to assess schedule and cost variance. It is recommended that the Program Manager request the PI to develop a fully resource loaded Gantt chart for this project before proceeding and demand an explanation as to schedule variances.

4.1.3.6 PI Response

No response.

4.1.4 Creation of an Enhanced Geothermal System through Hydraulic and Thermal Stimulation

Presentation Number: 009
Investigator: Rose, Peter (University of Utah)
Objectives: To create an Enhanced Geothermal System on the margin of the Coso field through the hydraulic, thermal, and/or chemical stimulation of one or more tight injection wells; to increase the productivity of the Coso field by 10 MWe; and to develop and calibrate geomechanical, geochemical, and fluid flow models in order to extend the Coso/EGS concepts to wherever appropriate tectonic and thermal conditions apply.
Average Overall Score: 2.0/4.0

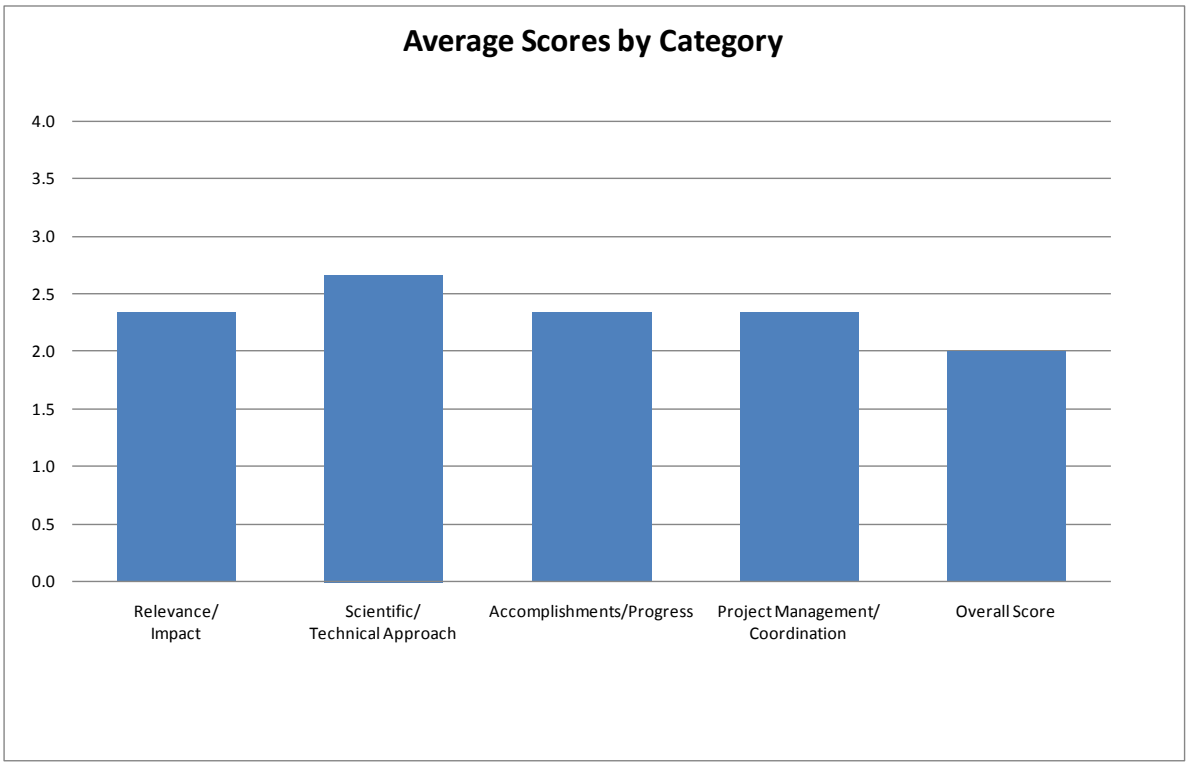


Figure 8: Creation of an Enhanced Geothermal System through Hydraulic and Thermal Stimulation

4.1.4.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Poor (1), Outstanding (4), Fair (2)

Supporting comments:

- Increased understanding of the Coso geothermal field was developed but the project is complete and did not result in a demonstration of EGS concepts and did not result in increased production. An increased understanding of the geomechanical setting and fluid flow were developed but at an unjustified price of about $11 million.

- The project, now essentially finished, was of primary importance to EGS development on the periphery of known hydrothermal systems, and was well funded. It was only partly successful as an EGS demonstration due to the drill encountering high permeability fractures in 34-9RD2, obviating the need for a stimulation experiment. Low pressure stimulation of 34-9A produced a good injector. An EGS reservoir was never produced. A great deal of new information was obtained from this project, so while it might have failed as an EGS demonstration, it was a success at developing information and experience valuable elsewhere.

- This Coso EGS demonstration project, if successful, might make a contribution to the Geothermal Program mission. The project activities could illuminate, not necessarily solve, known technical barriers, such as stimulating permeability in tight wells and improving connectivity? If this project is successfully completed, this reviewer believes that the EGS program will benefit somehow and that the results will surely add to the EGS technology knowledge base and toolbox. This program is the oldest EGS project in the portfolio and encountered severe drilling problems. It is not clear from the presentation if project goals have been met at all. It is not clear from vast amount of studies if anything tangible was produced.

4.1.4.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- The quality of the technical/scientific approach of this project is sound, however the primary objectives of the project were not met.

- The technical approach was good.

- The overall technical approach is reasonable, however, the details are not clearly presented. This work is not state-of-the-art R&D but rather applied technology, which is appropriate for a demonstration project. There are adequate resources and more than sufficient rigor of the work elements, procedures and methods but it doesn't look like the project objectives will be met. The overall design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline but it is not clearly spelled-out in the presentation as to why it took almost 8 years to do a proper stimulation. That being said, many studies have been accomplished in that time period.

4.1.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Fair (2)

Supporting comments:

- While an increased understanding of the Coso field was developed and the personnel involved were outstanding, the project was plagued with problems and did not meet the primary objectives. Were it not for the quality science associated with this project, poor would have been the score.

- The project team was well qualified for this project, and included university, government and industry scientists and engineers.

- The overall quality of the research team, equipment and facilities is adequate. The reviewer does not know the PI but some of the researchers on this team are known to this reviewer and are high caliber. Relevant experience and the balance of appropriate skills on the research team are good. Was not able to ascertain the cost or schedule variance to date since current costing and original schedule were not supplied. Clearly, the most important task in this 8+ year project, the stimulation, has not been successfully done yet for some reason.

4.1.4.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Fair (2)

Supporting comments:

- The material provided made it difficult to assess the quality of project management - however the results of the project biased this reviewer to a fair rating.

- Project management was good.

- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically, on track. There are no decisions points presented in the schedule, though a decision point was mentioned in the text.

4.1.4.5 Overall

Ratings of Three-member Peer Review Panel: Poor (1), Good (3), Fair (2)

Supporting comments:

- As noted previously, good science was achieved for this project, but the project was a failure. The reviewer is not pointing fingers here but this was a project to demonstrate EGS viability. The program needs to ensure that demonstration projects result in demonstration activities. Is it possible for some science to be postponed in demonstration projects until the viability of demonstration efforts are established?

- The results of this project have been well publicized in the literature during the last half dozen years. Although the project was well conceived, it largely failed as an EGS demonstration. However, the base of knowledge and experience gained makes this an interesting and informative case study.

- Overall, this is a very fair project and this reviewer recommends that the project be re-evaluated before proceeding. The report was not made available to the reviewer, only the presentation. Information was not made available in the presentation in order to assess project schedule and cost variance nor assess project success. Also, it was not explained as to why the project has continued so long.

4.1.4.6 PI Response

No response.

4.1.5 Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California

Presentation Number: 010
Investigator: Walters, Mark (Geysers Power Company, LLC)
Objectives: Create an Enhanced Geothermal System (EGS) by directly and systematically injecting low volumes of cold water into Northwest Geysers high-temperature zone (HTZ); investigate how cold-water injection mechanically and chemically affects fractured high-temperature rock systems; demonstrate the technology to monitor and validate stimulation and sustainability of such an EGS; develop an EGS research field laboratory that can be used for testing EGS stimulation and monitoring technologies including new high-temperature tools developed by others.
Average Overall Score: 3.3/4.0

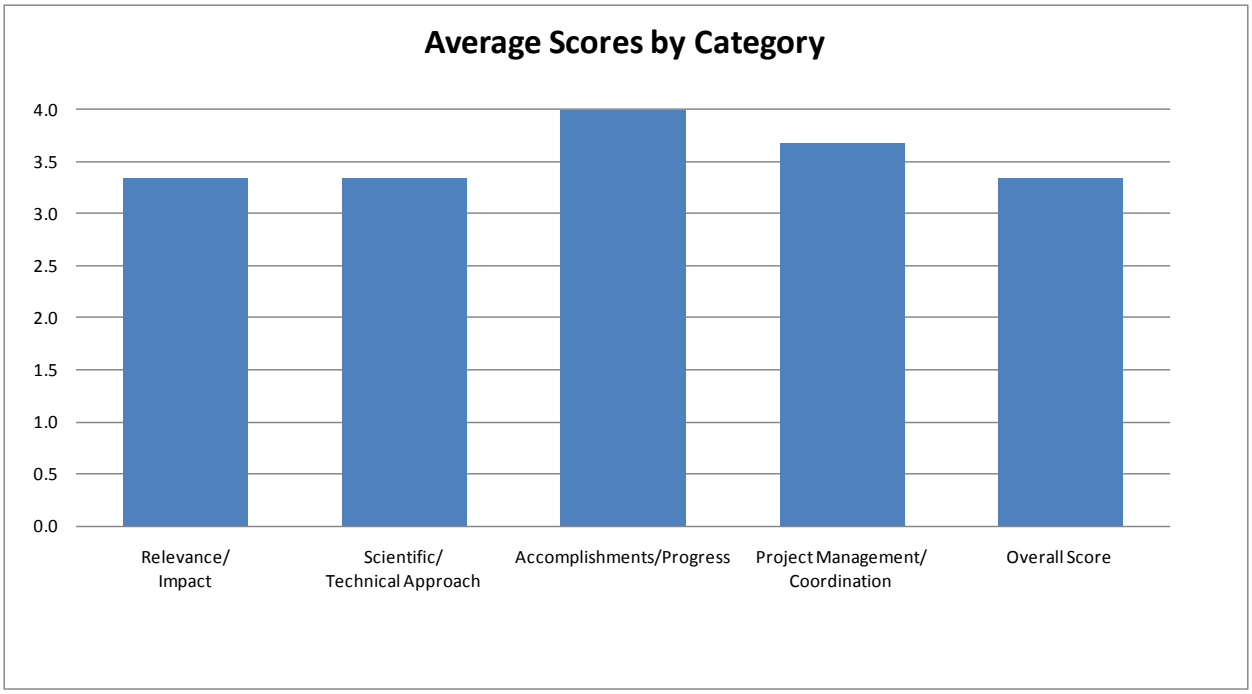


Figure 9: Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California

4.1.5.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- While the project has not moved to demonstration stage, the support work to date is appropriate for a demonstration project. This is a well documented project that should provide objective evidence regarding the efficacy of thermal stimulation efforts. Would consideration of possible hydraulic stimulation (albeit requiring high injection rates) be reasonable for this project?

- This important project directly addresses an EGS reservoir creation technique under a particular set of conditions (low-pressure cold water injection) at The Geysers, a vapor-dominated field. It is rated highly even though the project is temporarily stalled until completion of the NEPA process by DOE.

- This Northwest Geysers EGS demonstration project, if successful, will make a significant contribution to the Geothermal Program mission. The project activities will address, not necessarily solve, known technical barriers, such as how are MEQs created in cold-water injections into steam-dominated reservoirs. If this project is successfully completed, this reviewer is confident that the EGS program will benefit greatly and that the results will surely add to the knowledge base.

4.1.5.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- See comment in Criteria 1.

- The approach is well thought out and comprehensive, by a well experienced team.

- The overall technical approach is good to outstanding. This work is not state-of-the-art R&D but rather applied technology, which is appropriate for a demonstration project. There are adequate resources and more than sufficient rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline.

4.1.5.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- Similar to all EGS demonstration projects reviewed, these personnel and facilities are outstanding and the primary recipient appears dedicated to this effort. While NEPA issues have delayed some project activities, supporting efforts have been completed.

- The project team is very well qualified to do this project, and their productivity has been good. They have great support from all of the facilities and information at The Geysers field.

- The overall quality of the research team, equipment and facilities is excellent. The PI has been working at The Geysers as a geologist for decades and is very knowledgeable, experienced and highly regarded. Several other of the researchers on this team are known to this reviewer and are of the highest caliber. Relevant experience and the balance of appropriate skills of the research team are known and are of excellent quality. Schedule variance is about 10% with some accomplishments to date but the project is behind schedule by about 3 months (reviewer's estimate from schedule table presented in report). Was not able to ascertain cost

variance to date since current costing was not given. Clearly, the bulk of the important activities remain and it is possible that costs reflect this also.

4.1.5.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- To date the project is well managed with responsibilities and coordination appropriately defined.

- The project is well staged and managed. Project participants have a history of successfully working together. A decision point occurs with the assessment of Prati 31 as an injection well.

- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically, on track. There are no decisions points presented in the schedule, though a decision point was mentioned in the text.

4.1.5.5 Overall

Ratings of Three-member Peer Review Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- Thermal stimulation efforts are a viable EGS option but it is moderately disappointing that other methods are not considered; particularly since thermal stimulation is believe to be effective in The Geysers field today. However, the project aims to document the effectiveness of thermal techniques and that is to be applauded.

- This is an important project that, if successful, will demonstrate methods for developing the northwest area of The Geysers, particularly the so-called “high-temperature zone” which results from an intrusion younger in age than that underlying much of The Geysers field. The temperature pulse resulting from this intrusion and now moving upward through the field represents a great target for substantially extending the life of The Geysers field. The project team is well qualified to carry out this project.

- Overall, this is a very good project and this reviewer recommends that the project proceed. Two modifications are suggested: 1) accelerate the tasks to catch-up on schedule variance and 2) add “go-no go” decision points to the schedule.

4.1.5.6 PI Response

No response.

4.2 Low-temperature Demonstrations

The following four projects are demonstrations of geothermal energy production from low-temperature resources. These demonstration projects include characterizing the resource potential of geothermal systems in remote locations, incorporating geothermal co-production in oil field environments, and utilizing direct use applications. Figure 10 summarizes Low-temperature Demonstrations review scores by evaluation criteria for each PI's project and Table 15 presents detailed scores by reviewer.

Figure 10: Low-temperature Demonstrations Review Scores by Project PI and Evaluation Criteria

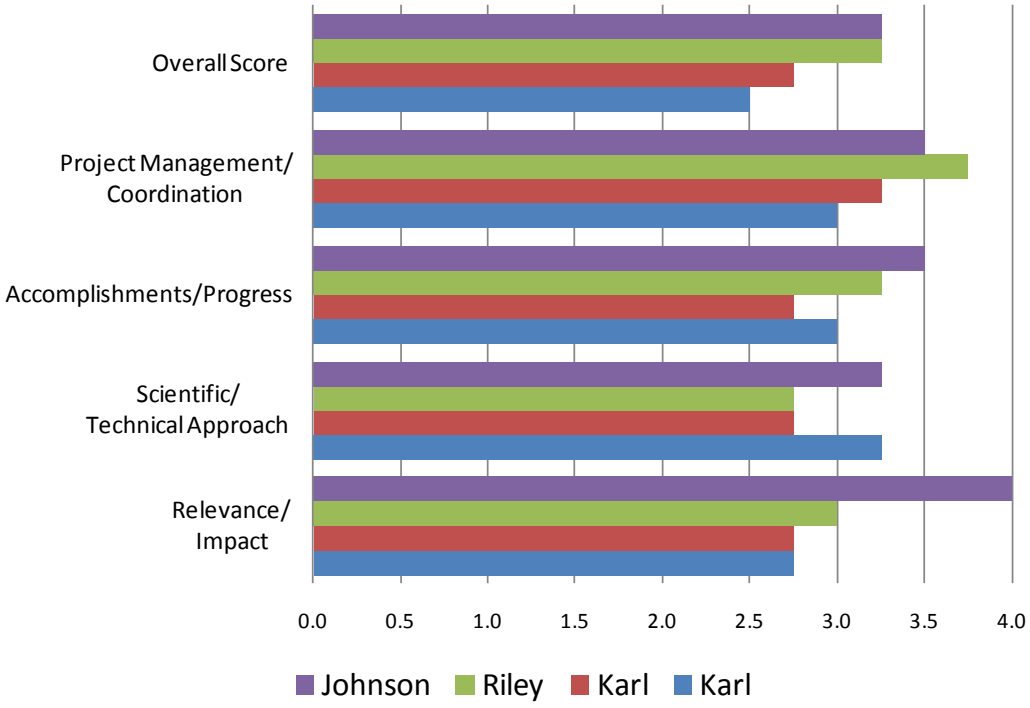


Table 15: Low-temperature Demonstrations Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
GRED Award Chena Hot Springs	Karl (GREDIII)	1	3.0	4.0	3.0	3.0	3.0
		2	3.0	4.0	3.0	4.0	2.0
		3	3.0	3.0	3.0	2.0	3.0
		4	2.0	2.0	3.0	3.0	2.0
		Average	2.8	3.3	3.0	3.0	2.5
Electric Power from Co-Produced Chena Hot Springs	Karl (CHSR)	1	3.0	3.0	3.0	4.0	3.0
		2	3.0	3.0	3.0	3.0	3.0
		3	2.0	2.0	2.0	3.0	2.0
		4	3.0	3.0	3.0	3.0	3.0
		Average	2.8	2.8	2.8	3.3	2.8
Klamath and Lake Counties Ind. Park	Riley	1	4.0	3.0	3.0	4.0	3.0
		2	2.0	2.0	3.0	3.0	4.0
		3	3.0	3.0	3.0	4.0	3.0
		4	3.0	3.0	4.0	4.0	3.0
		Average	3.0	2.8	3.3	3.8	3.3
Geothermal Testing Facilities RMOTC	Johnson	1	4.0	3.0	4.0	4.0	3.0
		2	4.0	4.0	4.0	3.0	4.0
		3	4.0	3.0	3.0	3.0	3.0
		4	4.0	3.0	3.0	4.0	3.0
		Average	4.0	3.3	3.5	3.5	3.3

4.2.1 GRED Drilling Award – GRED III Phase II

Presentation Number: 011
Investigator: Karl, Bernie (Chena Hot Springs Resort)
Objectives: To gain a better understanding of the geothermal reservoir at Chena Hot Springs Resort in Alaska; to test and document the reliability of previous predictions as to the nature of the reservoir; and to find a hotter resource to scale up power production at Chena Hot Springs for use at Eielson Air Force Base.
Average Overall Score: 2.5/4.0

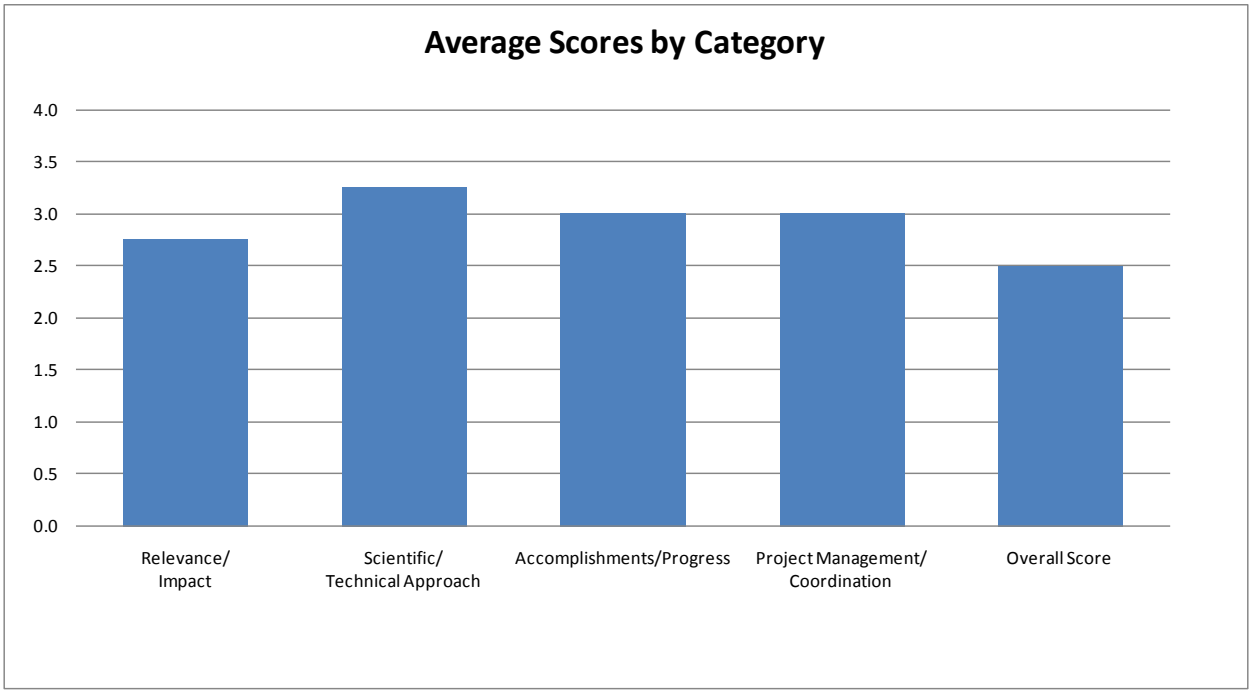


Figure 11: GRED Drilling Award – GRED III Phase ll

4.2.1.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Fair (2)

Supporting comments:

- Good information was obtained that could be valuable for other resources.
- The primary objective of this project was to develop a greater depth of knowledge about the Chena Hot Springs (CHS) reservoir. The importance of achieving the project's objectives is significant to the economic sustainability of the Chena Hot Springs Resort (CHSR) and future expansion plans to provide electricity to Eielson Air Force Base.

  Currently, CHSR has three organic Rankine cycle (ORC) geothermal power plants to meet the electrical needs. CHSR has been operating the 400 kW power plant from two production wells, Well Nos. 7 and Well TG-8, with 159 °F water. CHSR averages approximately 500 kW of electrical load. It is hoped that by drilling a deeper exploration well the CHSR will be able to find

hotter temperatures and more water flow to provide all the electrical supply to the CHSR. Well water temperature data collected over the last three years from Wells Nos. 7 and TG-8 indicate a temperature loss of about 6 °F, from 165 to 159 °F, which has reduced the electrical production of the geothermal power plant.

In response to the diminishing temperature at the CHSR, the awardees proposed to locate hotter temperature fractures and to get a better understanding of the geothermal field by drilling a new well - Well TG-12, located approx 300ft from Wells Nos. 7 and TG-8 with shallow depths of 600 and 1,020 ft, respectively.

This project did provide important project advances and adds to the knowledge base. The TG-12 well was logged to identify any permeable intervals and characterize productivity and injectivity of the well. Short-term interference testing was conducted between TG-12 and T-7 and TG-8. This project field will require further reservoir exploration and tracer testing is needed to confirm long-term well temperature and the reservoir behavior.

The project proposed to drill an exploration hole (TG-12) to a depth of 2,500-3,500 ft but due to a reversal of water temperatures around 2,700 ft, the drilling was rightly terminated. TG-12 achieved an average temperature of around 176 °F. A lot of interesting field dynamics was learned from this project regarding the resource. For example, during drilling operations it was observed that as water was pumped into TG-12, the temperature of Well TG-8 increased from 168 to 172 °F, and has been logged at a temperature as high as 176 °F.

The project also proposes to maximize field resource potential by eliminating the need for diesel and potentially supply electricity to Eielson Air Force Base, which is located 40 miles away. Which is not the best idea. It may be cheaper and better, strategically speaking, to conduct a resource assessment under the Air Base and develop the geothermal resource under the Air Base. Why develop a 40-mile transmission line? Who is going to pay for it? What about the environmental impacts it will have?

- The development at Chena is a world first and it is important that we learn a lot more about the power potential of these fracture dominated systems. Even though such systems may only be capable of providing limited power generation, they are still very relevant for remote sites. I rate this as good

- The goal is to increase the understanding of a particular hydrothermal system and to increase the utilization of that system. The PI did not indicate how this information might be useful to other applications of geothermal energy. The earlier parts of this project, successfully demonstrating an application of low-temperature resources, were very relevant to the current DOE goals.

4.2.1.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Good (3), Fair (2)

Supporting comments:

- Bernie Karl brought in experts such as David Blackwell and Dick Benoit to give the best opportunity for success.

- The CHSR personnel utilized the appropriate scientific/technical methods and procedures to achieve project objectives with the available funding and personnel. The technical approach is based on sound engineering principles and are incorporated into the deployment of the drilling plan. The retainer of Southern Methodist University (David Blackwell, Ph.D.), University of Alaska Fairbanks (UA) (Joanna Mongrain, Ph.D.) and Arctic Drilling to participate in this project is a positive feature.

  The initial project concept was logically planned, well grounded and focused on completion of the specified goals and objectives. The CHSR made the right decisions at the right times. For example, they stopped drilling when water temperatures were getting colder at TG-12.

  The well and reservoir analysis were properly and accurately performed. The UK's GRED III report provided the following conclusion and made specific recommendations as to the sustainability of the CHSR reservoir:

  1. The CHSR reservoir is a shallow predominately conductive zone with a deeper productive zone exhibiting convective behavior. The two zones are separated by a lateral barrier to flow, distinguished by distinct temperature and pressure profiles. The deeper zone seems to be unaffected by cooler water in the shallower zone above. The deeper resource characterized by the isothermal section in TG-9 has not experienced any temperature and pressure declines.

  2. It is uncertain if temperature and pressure declines in Well 7 can be verified. Observations suggest that the field is being managed properly and will be sustainable with the current injection volumes.

  3. The reason for temperature declines at the power plant is illustrated by the influx of cooler water down the wellbore in TG-9. The effect of this can be seen in the dramatic temperature decline in TG-3 and is also affecting the producing temperature of TG-8. Cementing the influx zone in TG-9 was recommended.

  4. Increasing injection volume to TG-7 from Well 1, and deepening Well 1 would reverse the cooling trend seen in Well 7.

  5. Installation of inline flow meters would improve field operations, and help calibrate reservoir models.

  6. To assess the connectivity of TG-12 with the reservoir and determine optimum operating conditions, the TG-12 well should be retested.

- I was not sure if this ranking should be 2 or 3 because there was very little technical detail in the presentation. The deep resource temperature should have been assessed from geochemistry but none of this was presented. The cross sections of the field that were included had no information on the technical data on which they were based. Also they had not been updated to take account of most recent well data. I thought the more recent well testing and pressure

monitoring was sound. My decision to score this at 3 was in part based on the recent well testing and that, given the caliber of the supporting technical team, I believe there may be a lot of technical data that were not presented. I rate this as good.

- The technical barrier is uncertainty about the characteristics of the hydrothermal system at this site. The approach was to drill a deeper well into an area where higher temperatures were expected, and to conduct well tests on several wells in the field. These efforts were successfully carried out, despite the practical issues that impede work in an operating field. The technical plan did not define how the temperature data in this well would be used to increase understanding of the field. Had they found higher temperatures, that would not have been a problem. However, given the result that they drilled through an outflow plume that may have come from any direction, it is not clear what they learned about the system. The result has encouraged the operator to drill in another location, so that is a positive outcome.

4.2.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- Interesting to see an 8 °F increase in the temperature from Well TG-8. This could provide valuable information for future exploration and drilling.

- This project is well thought out as evidenced by CHSR's deployment strategy through temperature surveys, pressure gradient measurements, and well inference testing.

  Temperature Surveys

  A comprehensive set of temperature logs was taken between May 21st and May 25th on TG3, TG9, TG12, Well1, Well 7 and Well 4. Additional logs were taken of TG12 as the well was drilled. The temperature logs allowed for assessment of any resource degradation. The surveys also provided evidence of changes in the shape of the temperature profiles since the start of the power plant in 2006.

  Pressure Gradient Measurements

  Static pressure gradients are useful in determining the stabilized reservoir pressure for a well. Reductions in reservoir pressure inferred that there is insufficient reinjection. Build ups in pressure adjacent to injection wells can indicate low injectivity.

  Well Interference Testing

  An interference test was deployed from June 1-3, 2009. The aim of the inference test was to characterize the reservoir dynamics at Well 7 and simultaneously assess how the production at Well 7 affects the whole field. In a traditional interference test, a well will be shut in and nearby wells monitored for the effect of the shut-in on the bottom hole pressures in the well. Key attributes are how fast the effect of the shut-in well is "felt" at another well. This is an indicator of reservoir connectivity and permeability. The magnitude of the effect can also be analyzed to

assess the connected volume of fluid to both wells.

The level of work productivity was timely and on schedule with respect to the budget. The accomplishments against the planned goals and objectives, technical targets, awards, were on schedule and responsive to the original timelines, goals and objectives.

The project team is well qualified to conduct this research. The CHSR, through the project management of Mr. Karl and subcontractors, has been awarded numerous awards, and has received national and international recognition.

- A good team. I rate this as good.

- The team is good. The drilling was successful. The well testing did as much as could be expected given the fact that the field was operating during the tests. Since there was nothing presented about what the updated model of the system might be, I cannot assess the quality of the team in this area.

4.2.1.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Fair (2), Good (3)

Supporting comments:

- Bernie's perseverance is admirable.

- The project has been successfully completed and achieved its objectives. The milestones accomplished were compatible with the goals and objectives and budget. It appears that the technical, policy and spending plans for the project were carried out successfully. The work presented was clear and the project was executed in a logical manner.

  The project accomplished the following goals:
  1. Located source of hotter resource under Well TG-8
  2. Gained a better understanding of the geothermal resource
  3. Based on information gathered, developed a plan for geothermal resource optimization
  4. Refined information gathered in Phase I

  The CHSR future plans consist of the following:
  1. Further drilling and exploration
  2. Deepen wells, production Well TG-8 and injection Well 1
  3. Plug non-producing wells with chipped bentonite
  4. Update reservoir model

  Weaknesses:
  Phase I:
  DOE Share - $848,000
  Awardees Share - $296,714

  Phase II:

DOE Share - $846,409
Awardees Share - $547,910

Total DOE Award Phase I and II - $1,694,409

What was CHSR's actual project match share for Phase I and II?

A summary of the budget was provided, but a detailed break-down of expenses was not included.

No economic analysis or data were presented to substantiate a favorable return on investment. A clear schedule or Gantt chart describing project trajectory and critical decision points, and beginning and ending dates for each project task, were not provided. Information on due dates and deliverables would have been useful. There was no indication of go/no-go reviews or when they should have taken place.

- I rate this as good.

- The management is not well structured, but the energy and dedication of the PI keeps this project moving on effectively.

4.2.1.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Fair (2), Good (3), Fair (2)

Supporting comments:

- Most of the benefit goes to the local Chena area, but still a good project with potentially valuable information for other resources.

- Overall the project met all technical and operational expectations given its unique location and excellent qualifications of the CHSR, Southern Methodist University, University of Alaska Fairbanks, and Arctic Drilling.

- The presentation could have been strengthened by more technical data. I rated this as good.

- The concern about this project is the specificity of the results which appear to be of use only to this site, and the lack of information to be used to judge how the system model was changed by this work.

4.2.1.6 PI Response

No response.

4.2.2 Electrical Power Generation Using Geothermal Fluid Co-produced from Oil & Gas

Presentation Number: 012
Investigator: Karl, Bernie (Chena Hot Springs Resort)
Objectives: To validate and realize the potential for the production of low-temperature resource geothermal production on oil and gas sites; to test and document the reliability of this new technology; to gain a better understanding of operational costs associated with this equipment; and to help realize that a more distributed power generation network is attainable and an effective solution to energy problems.
Average Overall Score: 2.8/4.0

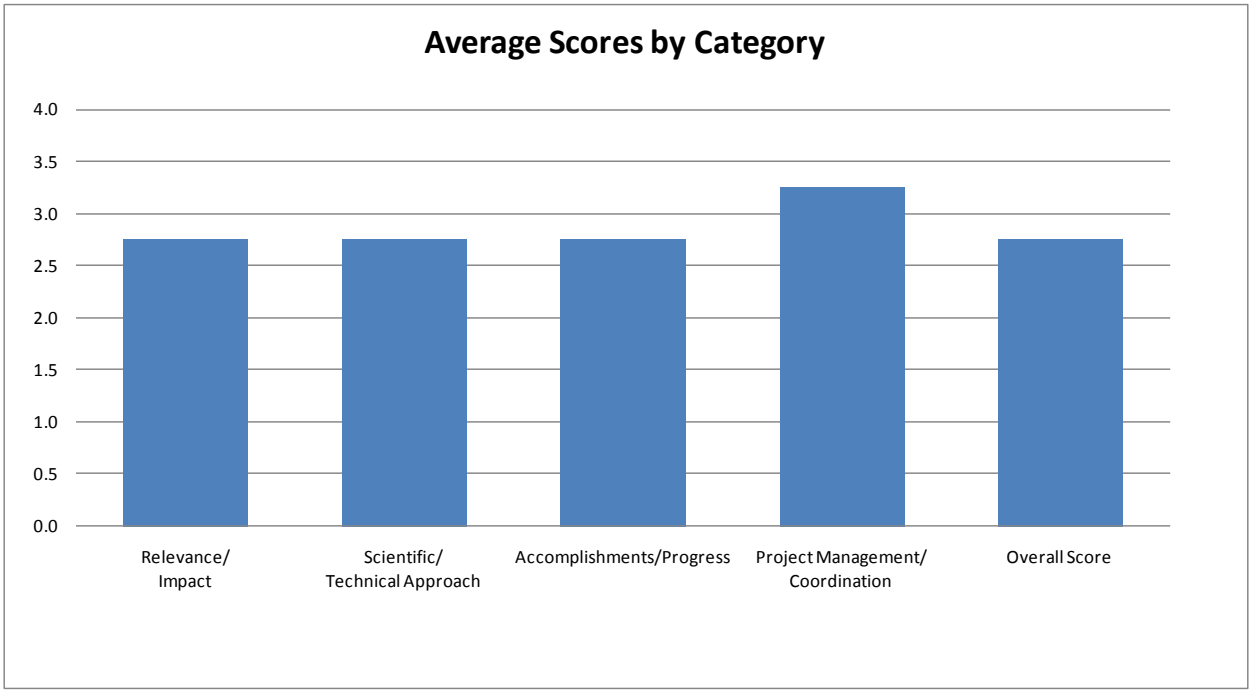


Figure 12: Electrical Power Generation Using Geothermal Fluid Co-produced from Oil & Gas

4.2.2.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Fair (2), Good (3)

Supporting comments:

- The industry can benefit by having a proven, small, mobile unit for generating electricity from geothermal sources. This system can be used on EGS, co-produced/geopressured, or conventional resources, so this project has real benefit. A drawback is that a primary beneficiary is the provider of the power equipment, UTC (now Pratt-Whitney), but there is still good value to this program.

- The primary objective of this project is to demonstrate an economical, distributed generation, geothermal energy co-production technology from oil and gas fields.

  This project does not fit directly into the broader context of conducting research, development

or demonstration of EGS.

The project is innovative and addresses known and some unknown technical barriers. Demonstrating proven ORC technology to exploit geothermal resources addresses a technical barrier of moderate proportions. This is a viable technological application for the geothermal industry in colder climates. The project has successfully established the feasibility of energy production from low-temperature geothermal resources at Chena Hot Springs. The payback of the ORC system is greatly improved by oil and gas recovery.

The project attempts to address the market barriers. However, the question of whether this co-production technology will overcome significant market barriers in warmer climates and other markets with more stringent waste discharge, noise, and air emissions requirements is unknown. This project advances the science and technology but more work is required in addressing whether this technology will work in other low-temperature geothermal co-production fields with different water chemistry and compositions of oil and gas mass fractions. This is dependent not only on the geothermal resource's water chemistry but also on well-head temperatures and pressures, ambient conditions, cost of equipment, engineering costs, site mitigation costs, permitting costs, available infrastructure, and utility power rates.

The project has successfully established the development of a transportable 100 to 200 kWe net power plant (No oil and gas equipment at the Reno location.) The project has successfully provided a foundation for remote distributed power systems.

The project broadens the potential for geothermal co-production in some locations and provides the following additional positive benefits:

- improves the competitiveness of geothermal co-production
- increases resource/electricity availability, flexibility and reliability of geothermal power
- provides a reasonable alternative to fossil fuel in relation to environmental concerns including greenhouse gases, health and safety benefits and mitigating adverse impacts
- reduces capital costs or operation and maintenance costs
- provides a platform for the development of a renewable technology
- includes technology transfer activities as part of the project

Weaknesses:

There was very little discussion on geothermal fluid content and discussion on recovery of oil and gas products. What was the cut ratio at Chena Hot Springs? No discussion was provided to ascertain what happens to the off-spec gas or what quantities of oil and gas are produced and how they factor into the economics of the project.

Questions:

1. How will this project take this technology a step forward towards commercialization?

2. What is the Grantee's own match contribution and what was the match contribution of the subcontractors, if any?

3. What is the likelihood of an oil company incorporating this technology into their operations?

4. Are there any air, land use or water discharge permits required for this project?

- There have been delays due to negotiating with oil companies and so progress has been very slow. I have therefore rated this as fair.

- Water produced in oil and gas fields can be a large resource for geothermal energy production in a large number of states. The goal of utilizing that resource is inhibited by lack of demonstrated experience using that technology. This project contributes to the goal of utilizing that resource by providing a demonstration of the feasibility of using a particular power plant built by a particular company, and has provided stimulus for that company to improve its power plant hardware. I cannot assess how applicable this experience will be to the broader industry.

4.2.2.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Fair (2), Good (3)

Supporting comments:

- There has been a lot of outstanding work in this program, but a critical aspect is missing. One of the biggest risks of power production from co-produced fluids is degradation of heat transfer due to fouling of exchanger surfaces from scale and/or oil buildup. The value of this program would be significantly enhanced if fouling factors and pressure drop in the heat exchangers were carefully tracked and reported.

- The Grantee utilized the appropriate scientific/technical methods, procedures to achieve project objectives with the available funding and personnel.

  The design and technical approaches are based on sound engineering principles and are incorporated into the deployment of the project. Project deployment appears to be well grounded and focused on site-specific characteristics and it addresses engineering design and manufacturing specifications for efficient operations at the Chena Hot Springs Resort.

  The presentation and quarterly status report did not provide an adequate analysis on the effects from build-up of oil, other hydrocarbon and scaling on the heat exchanger and equipment. In addition, no discussion was provided on the frequency and cost of equipment maintenance.

  The presentation did not provide separate discussions on mass, energy balances and a thermodynamic analysis from the project sites. (Chena Hot Spring and Reno, Nevada) Also, the presentation did not provide a discussion on power-plant thermal efficiencies or a description

of power-plant performance at both locations. In addition, no noise data, water, or air emissions data were provided in the presentation or supplemental material for review.

- The lack of progress in this project doesn't allow me to rate this as anything but fair.

- The project is focused on demonstrating the feasibility of utilizing this technology and reducing the "uncertainty risk" for oil-field operators who might want to use it. Through negotiations with possible field sites, the team is improving the product to deal with concerns of the potential users. Until the system is deployed at a site, I cannot assess how well they are managing the experiment and how useful the data will be in encouraging broader utilization. Will we learn enough to reduce concerns about regulatory and operational issues for a variety of locations and power plant designs? I am not sure.

4.2.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Fair (2), Good (3)

Supporting comments:

- No comments.

- The overall quality and qualifications of the research team, equipment and facilities are superior. The project has an excellent chance of successful completion given the support by UTRC, PWPS, Aurora Energy, The Peppermill Resort and Casino, The Geothermal Resources Council, Quantum Resources, and Southern Methodist University.

  The Chena Hot Springs Resort is an excellent location to demonstrate UTRC/PWS's low-temperature ORC technology. How well this technology translates to another location is another matter. While this technology was demonstrated on a skid mounted platform at Reno, Nevada, no discussions on mass, energy balances and thermodynamic analysis from the Reno project site was provided.

  Productivity:

  The level of work productivity underway is timely and on schedule with respect to the budget. The accomplishments thus far against planned goals and objectives, technical targets, and awards seem to be on schedule and responsive to the original timelines, goals and objectives. While, there is no doubt the technology did work, what were the costs? There was no discussion on project levelized costs of electricity or payback calculations.

  Quality:

  The project team is well qualified to conduct this research. UTRC, PWPS, Aurora Energy, Quantum Resources, and Southern Methodist University have successfully demonstrated and provided technical expertise necessary for the completion of this project.

  The Chena Hot Springs Resort, through the project management of Mr. Karl and subcontractors has been awarded numerous awards, and has received national and international recognition.

- No information was provided on the resources and facilities involved beyond the successful mobilization of a mobile binary unit to a site. I acknowledge that a portable unit may have benefits in terms of fewer permitting requirements. However, based on data presented I have rated this as fair.

- The power plant designers obviously know what they are doing. The PI's energy and dedication (both personal and financial) are an important resource for this project. The results to date have been limited by the difficulties in negotiating a site for the tests. I cannot assess how well the project has performed in the effort to resolve these difficulties.

4.2.2.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Good (3)

Supporting comments:

- Bernie's persistence and perseverance have contributed greatly to the success of this program.

- Budget:

  The project has an excellent chance of successful completion given the support by UTRC, PWPS, Aurora Energy, The Peppermill Resort and Casino, Quantum Resources, and Southern Methodist University.

  The budget is reasonable. The cost share provided by the Grantee or the subcontractors was not made clear in detail, but there is an indication of willingness by the Grantee to take a financial risk to make this project a success. The budget seems appropriate for the scope and complexity of the project. This is a workable project given the budget, technical difficulty and qualifications of the Grantee, subcontractors and project participants. The DOE cost share on this project is $724,000 with matching contributions of $724,000.

  The project appears to be compatible with the work statement, budget and Grantee's qualifications. It appears that the technical, policy, business, and spending plans for the project have been carried out successfully. The work presented was clear and the project was executed in a logical manner. The scope of the project is reasonable but there are some minor issues that will require more clarification.

  Weaknesses:

  The presentation and related material did not include an economic analysis or data to substantiate a favorable return on investment. The rate of return on the investment is unknown. Discussion concerning lowering the cost of extracting energy from resources of progressively lower temperature resources would have been useful. Also, no information or data were provided that discussed operation and maintenance costs of production wells and power plants.

  A clear schedule or Gantt chart describing project trajectory and critical decision points, and, beginning and ending dates for each project task were not provided. Information on due dates

and deliverables would have been useful. There was no indication of go/no-go reviews or when they should have taken place.

A scant summary of the budget is provided, but detailed break-down of expenses was not included.

- It is too early in the project to make an assessment of the management of the project but the presenter appears to have made every effort to obtain agreements to locate his unit at an appropriate site. I have therefore rated this as good.

- The management approach has been flexible and reactive, which is probably a good approach for this project. Finding a good site for this test has been a significant challenge, and the PI is reacting effectively to concerns raised by potential partners. The project appears to be based on the assumption that "if we do it, then that will encourage others". That assumption is true to some extent, but the project might have a greater value if there was an assessment of what are the specific barriers to utilization and what data could eliminate these barriers.

4.2.2.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Fair (2), Good (3)

Supporting comments:

- A good program that DOE and Bernie can be proud of.

- Overall the Chena Hot Springs project has met all technical and operational expectations given its unique location and excellent qualifications of the technical and administrative teams.

  Commentary:

  However, not all states in the Union are as lax in their environmental regulatory authority. For example, the State of California, which has the largest geothermal production and significant untapped geothermal potential from hydrothermal resources, and underdetermined geothermal potential from its vast oil and gas production fields, has very stringent environmental requirements that could prevent energy producers from considering doing business in California.

  In attempting to address the technology transfer aspect of this project and other geothermal power generation technologies that could be adapted to California, energy developers must consider many other aspects to their environmental project plans. This applies to power plant operations larger than 50 MW, however, smaller power generators are required to conduct similar assessments. Below is a list of environmental considerations that must be addressed in the planning stages:

  1. Air Quality
  2. Public Health
  3. Transmission Line and Safety
  4. Hazardous Materials

5. Waste Management
6. Land Use
7. Traffic and Transportation
8. Noise
9. Visual Resources
10. Cultural Resources
11. Socioeconomics
12. Biological Resources
13. Soil and Agricultural Resources
14. Water Resources
15. Geological Resources
16. Paleontologic Resources
17. Facility Design
18. Energy Facility Reliability
19. Generating Efficiency
20. Transmission System

In reviewing this project and from what was presented, the Chena Hot Springs project has successfully addressed some of the abovementioned criteria but would not meet the State of California's environmental regulatory requirements.

- Because the project is at such an early stage it is not possible to assess if this project is weak or good. Right now however, I have to rate the project as only fair.

- My only concern is about the generalizability of the experience resulting from this funding.

4.2.2.6 PI Response

No response.

4.2.3 Klamath and Lake Counties Agricultural Industrial Park

Presentation Number: 013
Investigator: Riley, Betty (South Central Oregon Economic Development District)
Objectives: To attract new businesses to Klamath and Lake counties for the purpose of capitalizing on the area's abundant geothermal resources.
Average Overall Score: 3.3/4.0

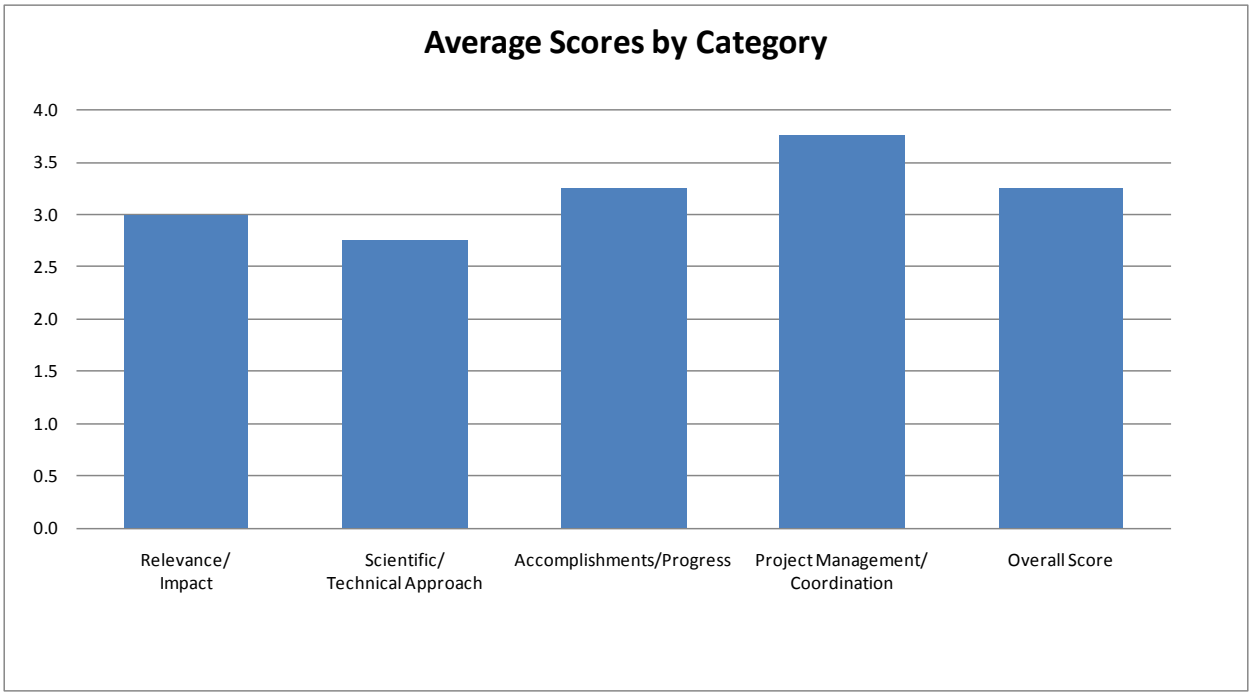


Figure 13: Klamath and Lake Counties Agricultural Industrial Park

4.2.3.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Outstanding (4), Fair (2), Good (3), Good (3)

Supporting comments:

- DOE's contribution was $298,000, and among the benefits is public facilities savings of $170,000 per year. This return is excellent.

- The goal of this project was to attract new businesses to Klamath and Lake counties for the purpose of capitalizing on geothermal resources through the development of a geothermal well on property that would be available for purchase or lease by businesses considering a relocation or expansion into the area.

  This project is a community assistance/improvement project and can have a significant impact on the rural communities with little or no economic resources of their own to establish a business park to attract corporate investment. This is a badly needed project to foster business development in an area that has a viable geothermal resource that could be parlayed for the benefit of the concerned communities.

This project does not in the immediate future involve any research, development and demonstration projects to establish EGS for electricity generation or advance the underlying science and technology or add to the knowledge base.

- The project was well planned and has made the progress required to meet the objectives. The annual savings per year appear to amount to about 50% of the grant which is a very good rate of return.

- The goal of this project is to stimulate the use of geothermal resources in specific counties. This goal contributes a modest amount of progress towards DOE goals and the rate of accomplishment has been very good.

4.2.3.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Fair (2), Good (3), Good (3)

Supporting comments:

- No comments.

- The South Central Oregon Economic Development District (SCOEDD) team planned and developed the appropriate methods and procedures to achieve project objectives with the available funding and personnel. The approach taken is based on reasonable and logical planning and business development practices which were incorporated into the deployment of the project. Project deployment is well grounded and focused on completion of goals and objectives. The project was implemented in the following four phases:

  • Land Parcel Identification
  • Land acquisition and negotiation
  • Resource Development
  • Outreach

  Phase 1 – Land Parcel Identification consisted of identifying suitable land required for geothermal resources, land ownership and zoning to with the best prospects for development of geothermal wells, water availability, utilities, zoning etc. and other regulatory issues. Two site selection reports were prepared in late 2005, early 2006. The reports documented efforts to identify and prioritize potential geothermal sites. The site selection involved the identification of geothermal wells co-located with vacant land. Other factors such as site access, land value, utility availability, well access, presence of multiple wells, owner interest, zoning, piping costs potential, and fees for the use of heat were considered.

  Phase 2 - Land acquisition and negotiation consisted of land evaluation and prioritization. In Klamath County, a lease agreement with Liskey Farms was obtained. This agreement provided for the development of the property for geothermal heating of buildings, irrigation of crops, warming of water and other uses. In Lake County, a lease agreement was executed on a property located directly next to Highway 395, which has several advantages:

- The wells already exist and produce hot water.
- The hot springs directly west of the site and a geothermal spring to the northeast of the site indicate the geothermal resource is close to the surface.
- No geothermal development has been done in this area resulting in no prior water rights or conflicting geothermal rights.
- The landowner is interested in working with the Town, and agreed to a Geothermal Well Development Agreement with the Town.

Phase 3 Resource Development consisted of conducting pump well capacity pump tests, and appropriate water right and consider regulatory requirements. In Klamath County, two re-injection well sites were proposed with funding through the Natural Resource Conservation Service (NRCS) at Liskey Farms. SCOEDD worked with NRCS on the required NEPA process for both the well testing and the in ground piping. NRCS approved the use of their funding for both the well testing and additional piping expanding the geothermal system. Pumping tests were completed in December 2007.

In Lake County, an environmental review to rehabilitate the existing geothermal wells was completed. A NEPA ruling was issued on December 31, 2007 authorizing use of DOE funds for cleaning and pump testing of the geothermal wells. Pump testing indicated water temperatures of 180° to 190 °F were present. A feasibility report completed in January 2009 determined the district heating project would be feasible. The estimated cost of the project is $3.5 million. Savings for Lake Health District and Lake County School District would total $2.4 million over the life of the system.

A review by DOE NEPA staff determined that a full third party environmental assessment (EA) would need to be completed. SCOEDD contracted with RMT, Inc from San Mateo, California to compete this EA. The draft EA has been released for review.

Lake County – Paisley

Through a feasibility study completed with funding from a USDA Value Added Ag grant, it was determined that enough hot water for the development of a 1 MW electrical generation facility was possible. Surprise Valley Electric Coop has taken the lead in the development of this project. This project received $2 million in economic stimulus funding from the US Department of Energy to move forward.

Phase 4 Outreach consisted of a promotional campaign to target industries.

In 2007, Green Fuels of Oregon, Inc. signed a lease with Liskey Farms to develop a Biodiesel production facility in existing greenhouses. Utilizing geothermal water to heat the greenhouses helped lower their utilities and eliminate the high expense of propane.

Local farmer Rick Walsh has located his Fresh Green Organic Garden Community Supported Agriculture facility at Liskey Farms.

Also in 2007, SCOEDD staff has worked with Team Klamath to assist a company that provides Augmentative Biological Controls (ABC) for spider mite pests. The company currently employees eleven fulltime workers utilizing 70,000 sq ft of existing greenhouses at Liskey Farms. Future plans include building an additional 130,000 sq ft.

"Gone Fishing" Farms uses the waste water from the Liskey Farms greenhouses to grow tropical fish for aquariums and tilapia for the food market. Gone Fishing processes up to 300,000 pounds of Tilapia per year which equates to $450,000 in annual sales.

In Lake County, the website sustainable-Lake-County Oregon. com promotes geothermal sites in the community of Lakeview. Once the geothermal heating district is installed, SCOEDD will include the availability of geothermal energy in promoting Lake County's Industrial site through the Oregon Prospector.com.

Both Lake and Klamath Counties expanded their Enterprise Zones to include the geothermal properties identified. Oregon's enterprise zones offer a unique resource to local communities, unmatched by any other business incentive. Besides tax abatement, an enterprise zone lends visibility and focus to local economic development efforts.

- There was not a high level of technical input to this project but the approach was well thought through and there was good outreach and public collaboration.

- The project is designed to eliminate barriers to local use of geothermal resources. The barriers include awareness, drilling risk, regulatory uncertainty. These barriers are not technical. The plan was well organized and focused towards these defined barriers.

4.2.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- No comments.

- The SCOEDD claims that the proposed $10 million investment for geothermal development in Klamath and Lake Counties region could provide up to 50 jobs in a small rural community of 250. A staggering number in a region where employment opportunities are desperately needed.

- This appears to have been a very well balanced project which has resulted in significant cost savings for the community and the generation of many new jobs in a rural area.

- The project has successfully met or exceeded its objectives. Wells have been identified and industries are committed to using them. It appears that additional industries are considering utilizing other sites in the area as a result of this project, saving a town considerable money and creating jobs.

4.2.3.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- This is a well-managed program with good results.
- The SCOEDD personnel have proven that they have worked very hard and have leveraged the small amount of DOE GTP funds to obtain funding from diverse federal, state and private sources to make their corner of Oregon attractive to businesses. The SCOEDD has effectively managed the small grant provided by DOE. They are well organized and have been very effective in managing their funds through proper controls and discipline.
- This project had a well managed team approach to raising the awareness of the potential of local geothermal resources and led to the successful implementation of both district heating and various direct use applications leading to cost saving, investment and job growth in a rural area.
- Management seems well structured and effective.

4.2.3.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Good (3)

Supporting comments:

- An outstanding project but I rated it just good because I didn't consider it "world-class." Still this is a project DOE can be proud of.
- For $297,640 it is amazing what the SCOEDD has accomplished since June 30, 2005.

  Budget:
  Total project funding - $637,848
  DOE Share - $297,640
  Awardee Share - $340,208
- The project objectives were well thought through and the project was undertaken by a well balanced team involving resources, planning, permitting and outreach with the successful implementation of district heating and several new direct use applications. It is an excellent case study that can be used as a demonstration of what is possible in areas with relatively low enthalpy geothermal resources. I rated it as very good.
- This is a very well run project with a small but positive impact on geothermal utilization.

4.2.3.6 PI Response

I am pleased with the comments related to our project and appreciate the opportunity to attend the Peer Review.

4.2.4 Geothermal Testing Facilities in an Oil Field - Rocky Mountain Oil Field Testing Center

Presentation Number: 014
Investigator: Johnson, Lyle (RMOTC)
Objectives: To develop a long-term testing facility and test geothermal power units for the evaluation of electrical power generation from low-temperature and co-produced fluids.
Average Overall Score: 3.3/4.0

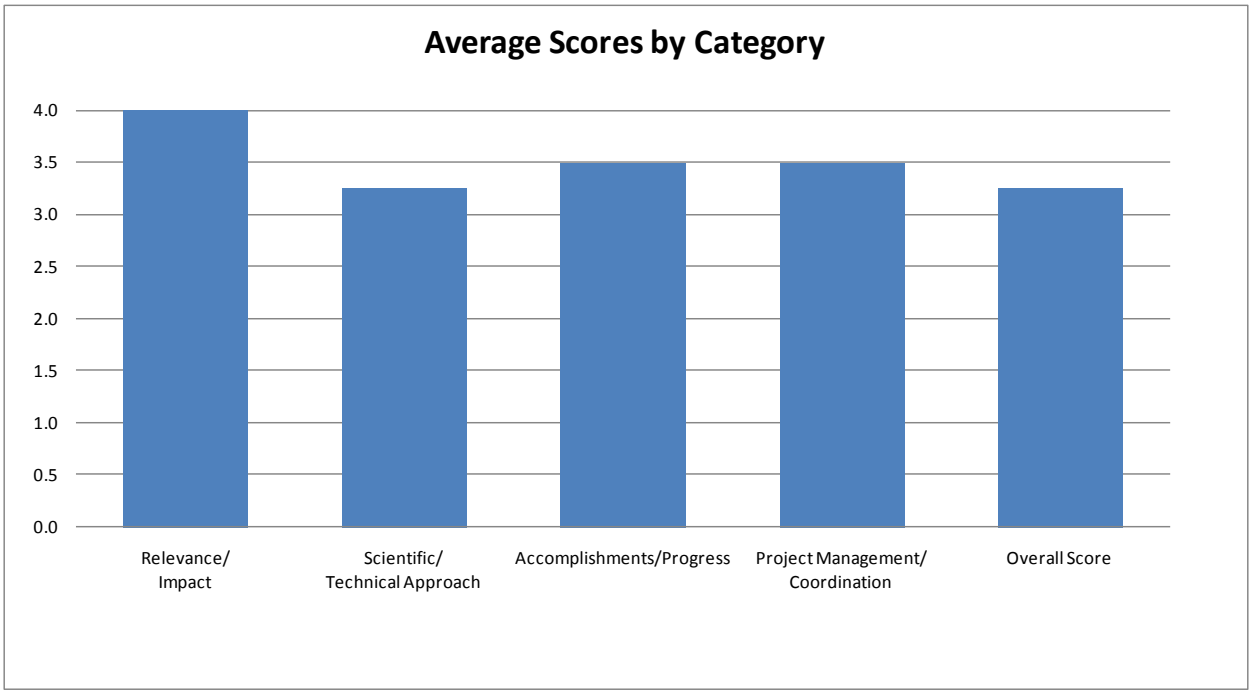


Figure 14: Geothermal Testing Facilities in an Oil Field - Rocky Mountain Oil Field Testing Center

4.2.4.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- Having a test facility operating for an extended period in the field is outstanding.
- The Rocky Mountain Oil Test Center (RMOTC) project proposed to develop a long term testing facility for the evaluation of electrical power generation from low-temperature, co-produced geothermal fluids. The facility would provide the ability to conduct both long and short term testing of different power generation configurations to determine reliability, efficiency and to provide economic evaluation data.

Since August 2008 the RMOTC has effectively demonstrated the operation of an air cooled factory integrated, skid mounted, 250 kW Organic Rankine Cycle (ORC) power plant based on a water temperature of 170 °F and an average ambient temperature of 50 °F.

Concerning EGS, the RMOTC is considering the option of conducting EGS testing.

The project is innovative and effectively addresses known technical barriers for geothermal power generation from an actively operating oil production facility. This is an excellent demonstration site to incorporate geothermal co-production in an oil field environment. The project has successfully established the capabilities of energy production from low-temperature geothermal resources.

This is a viable technological application for the geothermal industry in cooler climates and advances the science and technology but more work is required in addressing whether this technology will work in other low-temperature resource locations with different water chemistry and compositions of oil and gas mass fractions, and whether this co-production technology will be economical enough in warmer climates with more stringent environmental discharge requirements.

It is this reviewer's opinion that smaller ORC units may require a longer payback period just based on economy of scale, and what ORC systems are available in the market. It is anticipated that smaller systems will not be as efficient as a larger ORC unit in climates where the average annual temperatures exceed 50 °F, and have different total dissolved solids, water compositions to RMOTC's production well(s) and have differing flow rates. This however, is dependent on a geothermal resource's water chemistry, well head temperatures and pressures, ambient conditions, cost of equipment, engineering costs, and not to mention site mitigation costs, permitting costs, available infrastructure, and utility power rates.

The project has successfully established the development of an air cooled ORC power plant. The project has successfully proven that a remote distributed power system will work. It also broadens the potential for geothermal co-production in some locations and provides the following additional positive benefits:

- improves the competitiveness of geothermal co-production
- increases resource/electricity availability, flexibility and reliability of geothermal power
- provides a reasonable alternative to fossil fuel in relation to environmental concerns including greenhouse gases, health and safety benefits and mitigating adverse impacts
- reduces capital costs or operation and maintenance costs

- provides a platform for the development of a renewable technology
- includes technology transfer activities as part of the project

As part of their technology transfer, the RMOTC proposed their facility as an active demonstration laboratory to transfer lessons learned to any interested party. It is through these types of demonstration projects that an energy producing company will be informed and may consider implementing this small-scale ORC technology.

- The project is making very good progress toward the objectives and appears to have been well publicized and successful. The project is fortunate in having a high quality water fraction but I am not sure that the water quality has been well characterized. Indeed I would like to see such demonstration plants include water quality analyses for both fluid and gas compositions. The efficiencies and performances of the oil/water/gas separation equipment also should be characterized and perhaps this should be an additional task. Any scaling or evidence of oil build up in the heat exchanges also should be investigated in future studies.

- The question asks about the relationship to EGS systems. This project has nothing to do with EGS. I am reviewing it against the broader goal of expanding the use of geothermal energy, in this case to low-temperature resources. This project provides a platform where power plant manufacturers can test and improve their hardware and oil field operators can gain confidence about the practicality of using co-produced water to generate electricity. The facility has been shown to be functional and is in the process of testing equipment from one manufacturer. Assuming this facility will continue to be available for demonstrations by other manufacturers, it will contribute to the DOE goals.

4.2.4.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Good (3)

Supporting comments:

- There has been a lot of outstanding work in this program, but a critical aspect is missing. One of the biggest risks of power production from co-produced fluids is degradation of heat transfer due to fouling of exchanger surfaces from scale and/or oil buildup. The value of this program would be significantly enhanced if fouling factors and pressure drop in the heat exchangers were carefully tracked and reported.

- RMOTC personnel utilized the appropriate scientific/technical methods and procedures to achieve project objectives with the available funding and personnel. The technical approach is based on sound engineering principles and is incorporated into the deployment of the testing facility. The initial testing facility conceptual design was logically planned and can accommodate future test variations. Project deployment is well grounded and focused on completion of goals and objectives. The test facility addresses engineering design, power plant

specifications for both long and short term testing of different power generation ORC configurations. In addition, the RMOTC designed their OCR test unit to accommodate differing well flow rates and performed an accurate analysis of what the ORC system is capable of handling and achieving optimum power generation. Testing included determining the reliability, efficiency and economic evaluation data.

Before sizing the ORC power plant RMOTC staff performed a resource assessment of their oil field to determine the proper mixed fluid flow rates, temperatures and enthalpy calculations necessary for the proper deployment of a small scale ORC system.

- The approach was well designed and the performance was well described. The modifications made during the test runs were good and overall a very sound technical approach to the work.

- (I rated this as good)The technical barrier is the uncertainty that oil field producers have about using equipment to generate power from co-produced water. The technical approach is to do it and publish all information about the experience, which will reduce the "uncertainty risk" and encourage the use of this technology. This approach will only be effective if the project provides information that allows extrapolation to use at different locations. Having the facility operated by an entity that is not selling particular equipment makes the dissemination of information more likely, and the PI is to be commended for the extent that data are being documented. It is unclear to me what data are needed to convince a user that this approach would be viable given the regulatory issues and conditions in different states and field conditions. I would encourage the PI to evaluate what measurements would be required to make the results from this facility generalizable to the largest number of sites.

4.2.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Good (3), Good (3)

Supporting comments:

- Extended operation on the co-produced fluid has been outstanding.

- The quality and qualifications of the research team, equipment and facilities are superior. The project has an excellent chance of successful completion given the support by Ormat Nevada, Inc. and the GTP.

The location to demonstrate this low-temperature ORC technology at Teapot Dome Oil Field, Natrona County, Wyoming is excellent. The climatic conditions are favorable for this test facility. This is a great test location to further refine the science and make the necessary adjustments to small ORC systems that may eventually go into service nationally and internationally.

This project is well thought out as evidenced by RMOTC's deployment strategy. In Phase 1,

RMOTC installed an air cooled factory integrated, skid mounted 250 kW Ormat ORC power plant. RMOTC performed an analysis of projected generator performance and collected six months worth of data from September 2008 to February 2009. As expected the output power fluctuated with daily ambient temperatures. The net power output averaged 171 kW with a range of 80 to 280 kW. The unit produced over 586 MWh from 3 million barrels of hot water. The online percentage for the unit during this period was actually 91%.

In Phase 2 RMOTC followed up by making various modifications to the ORC system and support equipment. They collected more system performance and temperature data to determine the optimum power generation parameters from September 2009 through April 2010. Phase 2 has averaged 198 kW net power output and produced over 732 MWh from 3.4 million barrels of hot water. The online percentage has been 97%. As of May 18, RMOTC reported that power output of the ORC over the last 60 days had averaged 212 kW with a control set point of 220 kW.

Their present plan is to run the unit for two years and expand operations to accommodate a second 250 kW unit and several smaller 75 kW units.

This reviewer believes that larger ORC systems should be considered for testing to simulate the larger production zones in oil and gas fields in California, Texas, and Louisiana.

The level of work productivity underway is timely and on schedule with respect to the budget. The accomplishments thus far against planned goals and objectives, technical targets, awards, seem to be on schedule and responsive to the original timelines, goals and objectives.

- The work undertaken so far with the air-cooled unit has been very good and the results are good. Planning for the water-cooled units also seems very sound.
- (I rated this as good) This project is making a lot of progress, and the facility is good for the task. The PI has a level of practical experience that will make the results more likely to influence Oil field operators.

4.2.4.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4)

Supporting comments:

- No comments.
- The project has an excellent chance of successful completion given the support by DOE GTP and Ormat Nevada Inc. and RMOTC's match share.

The budget is reasonable, and the cost share provided by the RMOTC is indicative of their willingness to make a financial investment to make this testing facility a success. The budget

seems appropriate for the scope and complexity of the project. This is a workable project given the budget, technical difficulty and qualifications of the RMOTC and Ormat.

Budget:
EERE (GTP) - $775,000 to $1,135,000
FE (RMOTC) - $400,000 to $900,000

The milestones accomplished thus far are compatible with the goals and objectives and budget. It appears that the technical, policy and spending plans for the project have been carried out successfully. The work presented was clear and the project was executed in a logical manner.

Weaknesses:

RMOTC claimed a payback period of 5.1 months but no economic analysis or data were presented to substantiate a favorable return on investment.

A discussion concerning lowering the cost of extracting energy from resources of progressively higher ambient temperatures would have been useful. Also, no information or data were provided that discussed operation and maintenance costs of production wells and power plants.

A summary of the budget was provided, but a detailed break-down of expenses was not included.

- The management has been very effective. My only comment regarding additional work would be to include detailed chemical analysis of water and gas chemistry and some assessment of the efficiency of the water/gas/oil separation process. I was not clear if an actual date for installation and evaluation of a water-cooled unit had been decided.
- (I rated this as outstanding) The project has moved along a path towards successful completion.

4.2.4.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Good (3)

Supporting comments:

- An outstanding project in many aspects, but it could be improved with careful tracking and reporting of heat exchanger performance over time.
- Overall the project met all technical and operational expectations given its unique location and excellent qualifications of the RMOTC and Ormat personnel.

The project attempts to address research and development barriers. However, the question of

whether this co-production ORC technology will overcome significant market barriers in warmer climates such as in California and other markets with more stringent waste discharge, noise, and air emissions requirements is unknown.

Commentary:

The State of California, which has the largest geothermal production and significant untapped geothermal potential from hydrothermal resources, and underdetermined geothermal potential from its vast oil and gas production fields, has very stringent environmental requirements that could prevent energy producers from considering doing business in California. In attempting to address the technology transfer aspect of this project and other geothermal power generation technologies that could be adapted to California, energy developers must consider many other aspects to their environmental project plans.

As California's oil production declines, it becomes increasingly more difficult to extract oil from oil-wells with less of the total fluids produced as oil and more of it as water. The State of California under the auspices of the Public Interest Energy Research and the Geothermal Resources Development Account Programs will provide research and development funding to address this problem through implementation of hybrid projects. Hybrid projects may include another renewable component such as solar, wind, biomass, storage technologies or any variation of geothermal energy co-production from oil and gas fields.

Generation of by-products of spec gas from oil and gas fields is a significant air pollution problem in California. When such gas cannot be conveniently sent to gas pipelines, it becomes "stranded" from commercial markets and a problem for the producer. For most of California's oil production history gas production, even when it is not stranded, has been considered a low value fuel. The gas must be disposed in order to allow continued production of the higher value oil.

In some instances, even pipeline quality gas cannot be sold because there are no natural gas pipelines nearby; similarly, many urban natural gas pipelines are shutdown because of encroaching urban renewal. This is especially challenging in the Los Angeles Basin with its recent proliferation of high rises through several existing oilfields. Gas that cannot be sold into natural gas pipelines must be suppressed, flared or vented. In the Los Angeles basin, venting is not acceptable because of the potential impact on nearby dwellings and businesses; even flaring is increasingly limited because of emissions limitations. If the gas is suppressed or re-injected into the well, it stymies oil production.

California has extremely rigid air emission standards for electrical generators. This electric power generation would reduce emissions. The electricity generated from waste gas would offset the high cost of power otherwise purchased by the oil producer, shifting the economics

significantly in favor of production. If successful, off-gases would generate more power, reduce oil production costs, increase oil production and reduce emissions as well. At the national level, the benefits of increased oil production would reduce import needs, thereby helping towards national security. Off-gases project will reduce methane from vented gas, reduce NOx from flares, and reduce CO_2 by offsetting generation elsewhere, helping towards the goals of the greenhouse gas reduction act, California AB 32.

It would be useful to find means to make electricity from the energy in stranded gas. The electricity may be used by the producer, or sold to the utility. This power would require no additional fuel, thus saving fossil fuel imports, and also cleaning the environment. With new technologies now available, the gas behind shut-in wells or wells once considered uneconomic can be used by conversion into direct heat.

- I questioned if I might rate this as outstanding and a World-class project and perhaps it is almost at that level. However, given that the assessment of the water-cooled unit has yet to take place I have scored it good at the present stage of progress.
- (I rated this as good) This will accomplish the goals of the project, and should encourage more utilization of energy from water in oil and gas wells.

4.2.4.6 PI Response

No response.

4.3 Analysis, Data Systems and Education

This technical track consists of five Analysis, Data Systems and Education projects. Projects in this track consist of a tool to quantify the outcome of R&D activities, a university-level geothermal energy education competition, a geothermal power generation plant project, a systems analysis tool project for geothermal energy development, and a life-cycle analysis project. Figure 15 summarizes Analysis, Data Systems and Education review scores by evaluation criteria for each PI's project and Table 16 presents detailed scores by reviewer.

Figure 15: Analysis, Data Systems and Education Review Scores by Project PI and Evaluation Criteria

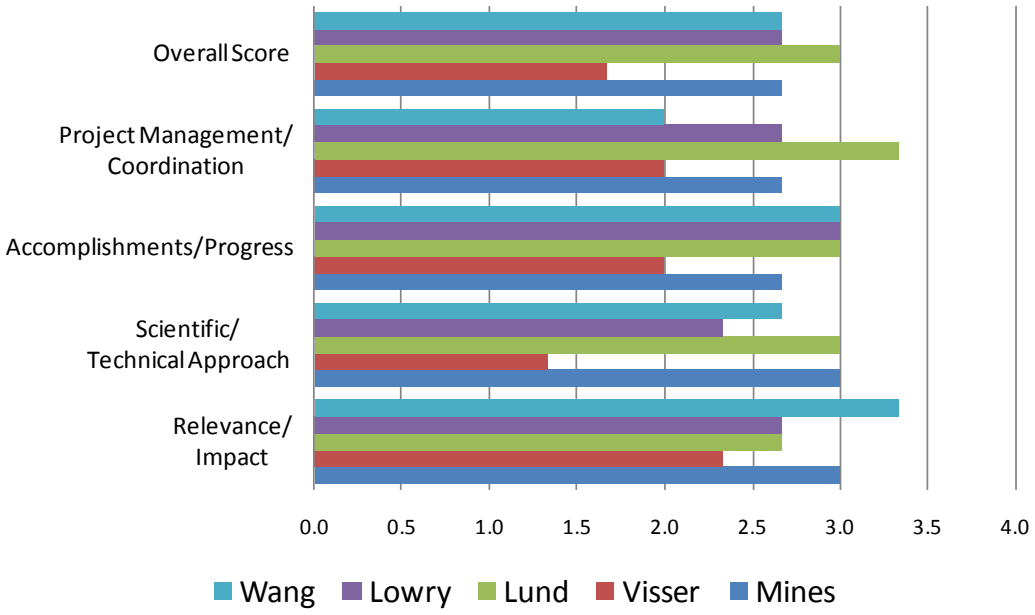


Table 16: Analysis, Data Systems and Education Review Scores

Presentation Title	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Scores
Geothermal Electricity Technology Evaluation Model	Mines	1	2.0	2.0	2.0	2.0	2.0
		2	3.0	3.0	3.0	3.0	3.0
		3	4.0	4.0	3.0	3.0	3.0
		Average	3.0	3.0	2.7	2.7	2.7
National Geothermal Student Competition	Visser	1	2.0	1.0	1.0	2.0	1.0
		2	3.0	2.0	3.0	3.0	3.0
		3	2.0	1.0	2.0	1.0	1.0
		Average	2.3	1.3	2.0	2.0	1.7
Geo-heat Center	Lund	1	4.0	4.0	3.0	4.0	4.0
		2	2.0	2.0	3.0	3.0	2.0
		3	2.0	3.0	3.0	3.0	3.0
		Average	2.7	3.0	3.0	3.3	3.0
Systems Engineering	Lowry	1	3.0	2.0	3.0	2.0	2.0
		2	2.0	2.0	3.0	3.0	3.0
		3	3.0	3.0	3.0	3.0	3.0
		Average	2.7	2.3	3.0	2.7	2.7
Life-cycle Analysis of Geothermal Technologies	Wang	1	3.0	3.0	3.0	1.0	2.0
		2	3.0	2.0	3.0	2.0	3.0
		3	4.0	3.0	3.0	3.0	3.0
		Average	3.3	2.7	3.0	2.0	2.7

4.3.1 Geothermal Electricity Technology Evaluation Model (GETEM) Development

Presentation Number: 001
Investigator: Mines, Greg (Idaho National Laboratory)
Objectives: To provide a tool for estimating the performance and contributions of all phases of a geothermal project to power generation costs; to provide a means of assessing the impact of technology advances; and to provide sufficient detail in characterizing cost contributors that results of DOE R&D can be readily integrated.
Average Overall Score: 2.7/4.0

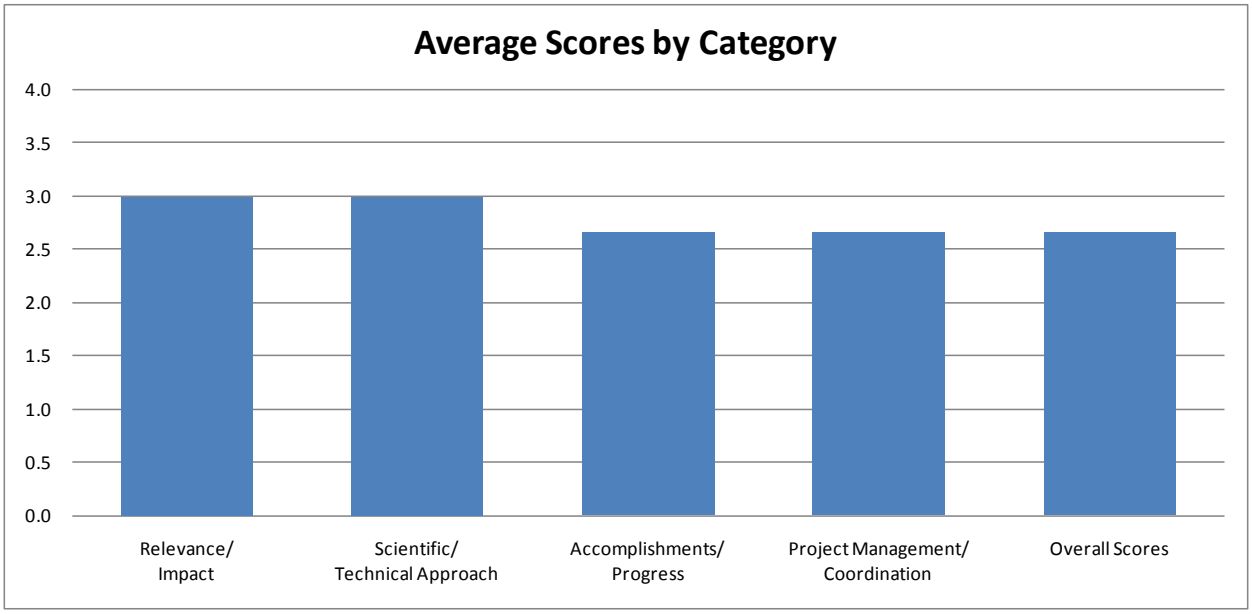


Figure 16: Geothermal Electricity Technology Evaluation Model (GETEM) Development

4.3.1.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Outstanding (4)

Supporting comments:

- As stated in the presentation, the importance of GETEM ". . . to DOE is its ability to analyze the contributors that are the drivers for generation costs and assess technology benefits." If GETEM can truly provide DOE with an analysis of how sensitive final project costs are to each factor involved in developing a geothermal resource, this will be an important piece of work. Based on the presentation and text, the Excel program seems to be very complex, yet very far from achieving its goal.

- GETEM is relevant to barriers W,X, and Y. At present, GETEM is the most used and the most useful model within the GTP portfolio.

- This is an important project that will allow users to assess viability of potential EGS development and allow DOE to better assess the need for funding EGS projects versus other uses of limited funds. The project is making good progress on improving a model that has been under development for some time.

4.3.1.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Outstanding (4)

Supporting comments:

- I am concerned about two factors. These are the reliance on Excel as the platform for the models, and the need already for 400 input parameters before the model can be run, which would seem to be relatively high for use by the general public. However, 400 parameters are probably OK for internal DOE use.

  The version of Excel being used was not explained. Since original model development was completed in 2006, is it Excel 2003? Will the model be updated when Excel 2010 comes out, presumably with new features? What level of Excel expertise is expected for end users? While mention is made of coordination with industry and the public, and industry will be contacted for "feedback on reasonableness of estimates," there is no mention of support for end users. Will this just be an Excel spreadsheet package that is distributed without comment, or will there be a users' guide that explains all the inputs, the ranges of values each input may have, the context of the range, and critically the sources of data for each entry? For example, will there be an explanation of what choices exist for modeling power production if your temperature is 125 ^{o}C, and the benefits and problems with each choice?

  The project has no partners. The presentation notes, however, that there are reviews taking place. Who is doing these is not specified.

  In the brief time of the presentation I was unable to confirm how PPI data will be continually updated, especially by end users. If the program is distributed as an Excel file, will constant updates be provided to end users?

- GETEM is based on a well-defined technical plan and has a reasonable breadth of applicability. DOE and INEL need to define what GETEM will eventually be and what the relationship is with the systems model being developed by SNL. The eventual level of applicability and detail that will be modeled should be defined. The work at SNL appears to possibly be duplicative if proper scopes are not defined. However, the PIs of both projects acknowledge their collaboration.

- The overall approach to modeling embraced by GETEM has been considered solid for several years. The current approach of identifying needed improvements to better incorporate EGS projects seems to be solid as well.

4.3.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- Project seems to be stalled on waiting for low-temperature data. On the one hand, the project claims a 3/10 milestone for "evaluation of low-temperature resources" while the next paragraph notes that that the ". . . cost estimating software package . . . is not yet available . . ." This section is now scheduled for review by the end of September. The text also states that the software will be available in late spring, but I do not recall any progress on this front being noted during the meeting. Progress in some parts, such as resource temperature and pumping, are reported to be good.

- GETEM has had significant use within the GTP. There does not appear to have been adequate review and critique by industry. It is not obvious that industry is using GETEM, but if industry has their own models, it would be valuable to DOE to know how GETEM compares with the industry models. That would be an independent evaluation and perhaps a validation. GETEM has the advantage of being based on a widely accessible platform (EXCEL).

- Project progress is adequate. The PI, perhaps assisted by other talent at INL, is quite competent to do this work due to his years of geothermal experience.

4.3.1.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- This program, like other computer modeling being funded, seems to be developed in relative isolation. Some coordination with other modeling efforts at other labs is noted but my general sense is that these could be improved. I would like to see very close coordination among model developers. Is there any chance that all the models funded by DOE could be based on one front end, so users will not have to learn separate models and programs to answer questions, but instead could learn one program and have multiple options in how they run it?

- Strong management of the task by INL. DOE appears to be adding more "bells and whistles" - these should be defined as part of a long-term scope. DOE needs to maintain close coordination of additional GETEM development with other activities within the GTP (SNL and ANL modeling) to ensure efficient performance of efforts and to avoid duplication of efforts.

- Although no specific decision points were identified by the presenter, it is quite obvious that there are such decision points prior to beginning work on a given module of the GETEM model. The spend plan is being followed.

4.3.1.5 Overall

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- I would like to rate this higher, but at least to me it needs to demonstrate further progress. I think that what has been accomplished so far is useful, but I am concerned that there is not adequate coordination with other DOE efforts. Some thought should be given to porting this work to a web-based format, where updates and user support can be continually provided.

- Good model with strong performance by INL. Needs to be better validated, especially by industry. GETEM is quite useful for evaluating the relative potential of technology advances and research investment opportunities by the GTP. This meets the original goal of GETEM.

- This is a solid project with considerable value to the DOE Geothermal Program and of potential great value to the entire geothermal community. The PI should pay more attention to technology transfer to assist others besides DOE in using the GETEM model. A workshop on use of the model would be a good start on this technology transfer.

4.3.1.6 PI Response

No response.

4.3.2 National Geothermal Student Competition

Presentation Number: 002
Investigator: Visser, Charles (National Renewable Energy Laboratory)
Objectives: To expand university-level geothermal energy education and support expansion of geothermal workforce; to provide universities with challenging, learning-focused geothermal projects and resources to facilitate incorporation of the competition into university curriculum.
Average Overall Score: 1.7/4.0

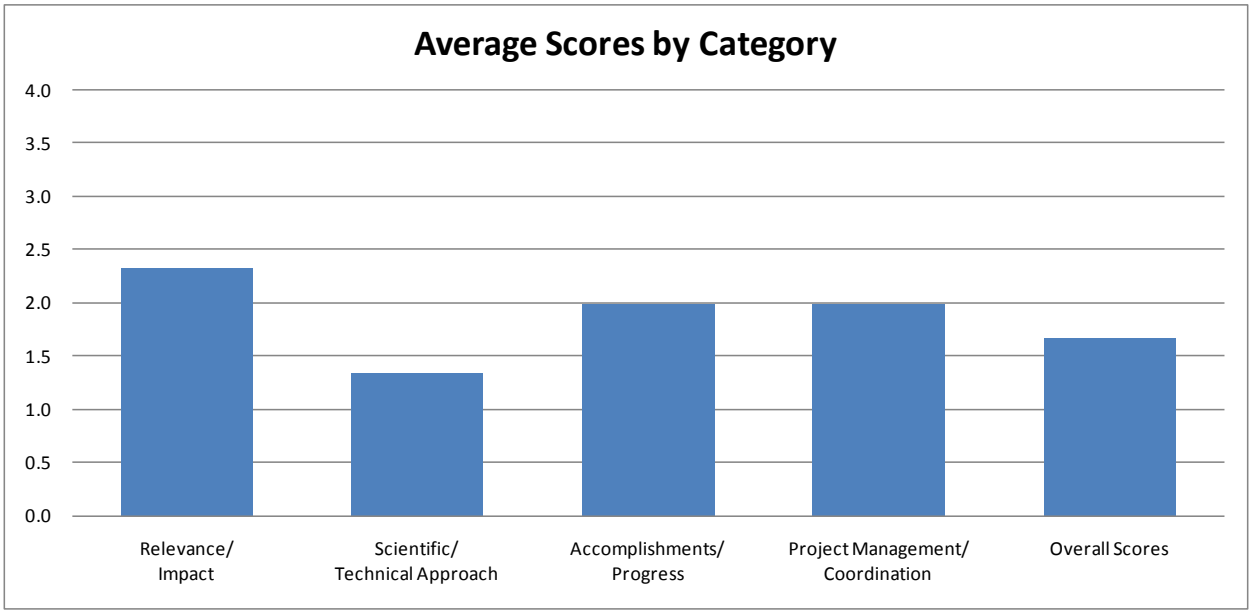


Figure 17: National Geothermal Student Competition

4.3.2.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Fair (2)

Supporting comments:

- The concept of a student competition is good, and the long-term timing is right to raise the profile of geothermal energy in education. This project addresses the barrier of an inadequate education among future professionals in the field.

- This project is relevant to the GTP outreach/education efforts. Student competitions are difficult and this project does have some challenges as detailed in the other sections. Nevertheless, this is an area where the GTP significantly lags other organizations within EERE.

- The goal of increasing interest in geothermal energy among college students is laudable and should be pursued. The next generation of geothermal scientists, engineers, managers and business people needs to be fostered. In this light, the project is quite important. However, the project as presented is not likely to achieve its goals. In addition, the project is not specifically addressed to EGS.

4.3.2.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Poor (1), Fair (2), Poor (1)

Supporting comments:

- Limiting the first project to the Rio Grande Rift is perhaps a near-fatal flaw in the program. I strongly suggest that, especially since workshops are planned for participating faculty, that they be instructed in how to find local (i.e. near each university) geothermal resource and development data. Why, for example, would an OIT team participate in a study of the Rio Grande Rift, when it would be much more practical for them to study local resources and development? While as professionals we know that case studies are transferrable, persuading today's students of this may become a difficult hurdle.

  The yet-undeveloped link with low-temperature resources will be critical, as many universities are finding this attractive (see all the talks about groundwater heat pumps at the meeting). Making projects local may help faculty broker additional support from their university administrations.

- Could be a "good" rating, but there are some significant challenges. Other DOE student contests have a much more physical aspect, such as the PV powered solar car with the race being the competition, and the Solar Decathlon where students build a structure and the thermal performance and aesthetics define the competition. This is difficult for GT in the sense of having hardware as a defining attribute. What is defined is a paper competition and it may be difficult to excite students with a potentially limited incentive for participation, especially for schools that are not currently involved with geothermal energy. To a certain extent, this competition would have a potential conflict, or potentially benefit to engineering design classes - very dependent upon the situation. The schedule proposed by NREL does not fit well with academic schedules for the soon-to-be-released solicitation.

- The technical approach to the project goals has several problems. First, it almost certainly would be a more effective use of the money to fund graduate and under-graduate students through scholarships for geothermal study or through support for faculty-based projects. Second, there is geothermal expertise at the university level in every state in the west and in many schools throughout the country as well. It is not obvious that there is a need to expand to more schools rather than supporting existing university programs. The number of schools able to teach geothermal energy is not the problem. Rather, helping students see a career in geothermal energy is the problem. Third, the choice of the Rio Grande Rift as a study area is questionable due to the relative lack of information on this area, especially subsurface information, relative to that in any of the more active geothermal regions. It seems unlikely that the sort of projects contemplated would supplement the Rio Grande database in any meaningful way. Fourth, the project schedule is unrealistic in that proposals would be required to be written during this coming summer, when most students are absent from campus, and the project duration upon their return to school is too short.

4.3.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Poor (1), Good (3), Fair (2)

Supporting comments:

- Although original contract timing issues impact this, the current expectation that faculty will be able to assemble interdisciplinary teams during the summer seems to me to be unrealistic.

- Good progress per plan, but perhaps the plan should be revisited. There are Reviewer concerns about how students remote from the Rio Grande Rift will relate to and will be able to access and appraise data without some on-site field work. Perhaps the Rio Grande Rift is too geographically restrictive and participants should be able to choose a geological province germane to their area. What software (e.g. GETEM) and background data (e.g. the unpublished analysis by Dr. Laura Butterfield of NREL - the PI has a copy) will be provided to the participants? How will interdisciplinary teams be formed and function? What's the incentive for participation, from both student and professor perspectives? What monetary resources will be provided to participating schools? These questions were not answered during the review.

- The NREL geothermal experience needed to direct this project is quite limited, especially in the area of geothermal geology, geochemistry and geophysics – essentially the subsurface domain. NREL needs to seek outside help to scope a better project.

4.3.2.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Poor (1)

Supporting comments:

- I am concerned that the project has serious calendar issues with a typical academic year, and that it lacks flexibility to incorporate undergraduate and graduate students at appropriate levels. The program schedule seems to have been developed without regard to university schedules. Universities are different from national labs, etc., and schedules matter a lot. There are many excellent student competitions in engineering, energy and math, but these seem not to have been thoroughly evaluated for what makes them successful. I get the feeling that rather than adapting "the best of the best" that this project is reinventing a whole process. There should be university faculty helping with the development of this; none are listed. Advertising for this can also take additional time. While electronic communications are quick, distributing posters so interested students can be made aware of the opportunity will take a while, especially since many universities are now out for the summer. Expecting feedback from schools prior to the end of October will greatly limit the participation of students, and therefore limit the ability of this project to achieve its goals.

- This student competition is challenging and each phase will be a learning experience. The RFP is ready for issue. It will be necessary for DOE/NREL to have significant on-site and remote interactions with participants. Consideration should be given to having industrial partners or mentors who will also have involvement with the student participants. This would give a real-world flavor to the competition. It is not obvious what funding will be provided to the participating schools and how it will be managed.

- See (2) above for schedule problems. No decision points are evident.

4.3.2.5 Overall

Ratings of Three-member Peer Review Panel: Poor (1), Good (3), Poor (1)

Supporting comments:

- Comments on timing, advertising, coordination with faculty and students are detailed above. The lack of faculty participation in the planning process and the near-total disregard for university schedules may doom this project. It is a good idea, but the execution so far is poor. While the presentation states that "Growth in participation, recognition, complexity and funding is expected in future years" there is no plan included that explicitly states how the first year will be assessed. What constitutes success, and how is it defined?

- This project is badly needed by the GTP, and although it is far from perfect in the current scope, it should be considered a learning experience with improvements made in subsequent solicitations. The existing scope may need some tweaking, but is sound. "Just do it" may be appropriate.

- The entire project seems to be poorly planned, but the goals are important. It would be worthwhile for DOE and NREL to speak to people involved in educating scientists, engineers, business students, etc. to arrive at a project that has more chance of having an impact. This particular project should be extensively revamped.

4.3.2.6 PI Response

To address issues raised, the plan for the National Student Competition has been substantially revised.

To address the concerns regarding the schedule, NREL has coordinated with EERE and university professors to attempt to improve its alignment with the academic year.

The NREL project team has coordinated with Solar Decathlon representatives to help model the competition and discuss lessons learned. We were strongly advised to “widen the net” as much as possible in the first year of the competition to ensure adequate participation. This included opening the project up as much as possible to include schools geographically and academically outside the “usual geothermal suspects.”

With the new emphasis on cross-disciplinary geothermal development, the decision was made to retain the Rio Grande Rift trend as the area of study. In addition to strict technical evaluation, it brings land-use and policy aspects to the project. It is expected that this will be a “build year” for the competition and that subsequent competitions will expand greatly into other geographic locations and types of assessments.

4.3.3 Geothermal Power Generation Plant

Presentation Number: 003
Investigator: Lund, John (Oregon Institute of Technology)
Objectives: To drill a deep geothermal well and a geothermal power plant on the Oregon Institute of Technology campus.
Average Overall Score: 3.0/4.0

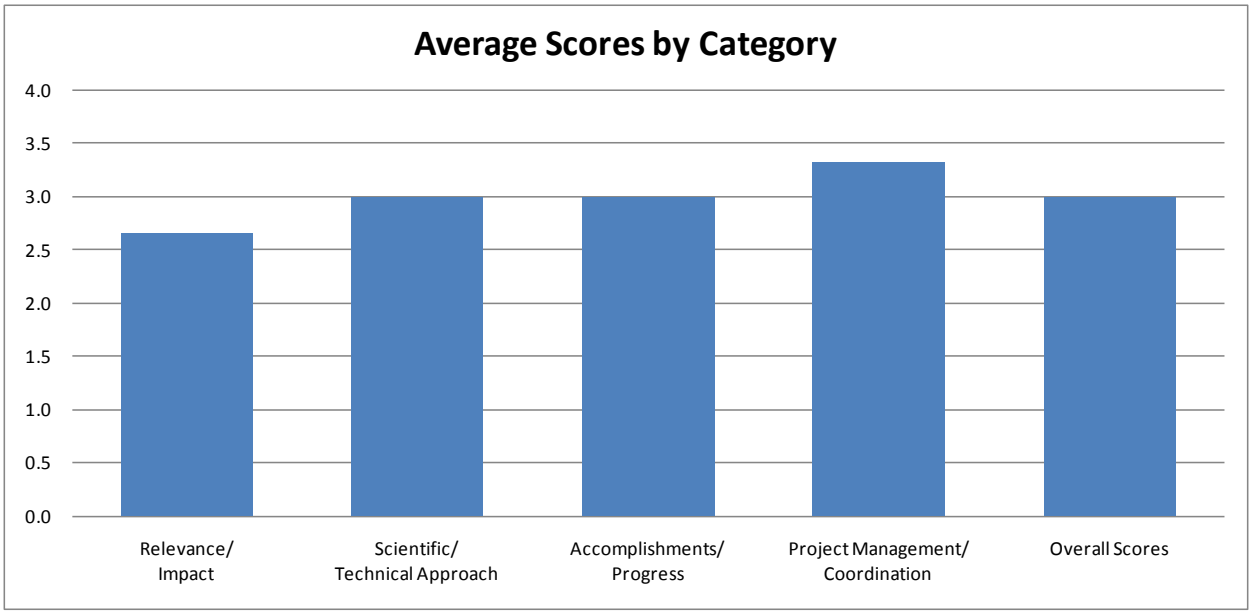


Figure 18: Geothermal Power Generation Plant

4.3.3.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Outstanding (4), Fair (2), Fair (2)

Supporting comments:

- This project will get power on-line. While the location of the OIT campus near geothermal resources makes it distinctive, this project will be a useful demonstration of geothermal potential for other governmental and educational facilities.

- Congressionally mandated project with good cost-sharing. This is a demonstration project that addresses barrier W, but is not germane to EGS. The PI made the point during his presentation that the electricity produced from this low-temperature GT project would not be cost-effective compared to grid supplied electricity, so perhaps an important part of the project would be a final report addressing what should be done by the GTP to make it cost-competitive -- or perhaps there is a lower limit below which the project size is too small for cost-competitiveness - obviously a function of context. The PI and the GTP should explicitly address this point.

- This project does not significantly advance EGS goals, but otherwise is a good project in a good location. The PI is quite honest about potential problems, and a few big ones still remain, including successful negotiations with Johnson Controls.

4.3.3.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Outstanding (4), Fair (2), Good (3)

Supporting comments:

- This project will demonstrate the generation of power from lower-temperature resources. The design and execution of the technical approach will achieve the goals of the project.

- The project plan was reasonably well-developed. Not obvious the economics and field difficulties were completely addressed, although the PI is a seasoned GT professional. The use of subcontractor Optim was good to define the faults and to use directional drilling to intersect the fault. The assumptions made a priori may have been unjustified, i.e. an anticipation of 300 °F compared with the 190 °F actual.

- The technical approach has been well thought out and appears to be sound. The PI has extensive geothermal experience, a big plus for this project. The approach has been carried out well. However, it seems prudent to perform a tracer test at the earliest opportunity to help determine whether or not the new well is in communication with injection wells elsewhere on campus. If this were to be true, the project would have to be rethought.

4.3.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The project is providing a high value compared to costs, especially when considering intangible aspects such as educational opportunity for other potential geothermal end users. The team is high quality. A partner to build the power plant is still needed, but they are in negotiation with one vendor.

  The resource has a lower temperature than anticipated, which has led to some changes in the program. These changes are being handled well, and ironically may in the end provide greater value as a demonstration of how high-quality energy can be produced from relatively lower-quality resources.

- Reasonable project plan and coordination between numerous entities - challenging to say the least for a university environment. Plan should address potential short-circuiting of injectate and how this would be dealt with if it becomes a problem.

- The productivity has been fair, with some schedule delays. Several major hurdles remain. The team assembled for the project consists of some of the best and most experienced people in geothermal development.

4.3.3.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- The project has been well managed so far.

- Production well has been drilled and tested to 1,500 GPM flow. Water rights are being secured for 2,500 GPM, non-consumptive. Some concern on this reviewer's part of potential short circuiting and premature thermal drawdown. The potential for student involvement should be better defined.

- Successful conclusion of the project seems a bit tenuous, especially with the present budget. For example, what if agreement can't be reached with Johnson Controls, or if there is found to be a connection between the new production well and existing injection wells? The State of Oregon cost share is a positive factor.

4.3.3.5 Overall

Ratings of Three-member Peer Review Panel: Outstanding (4), Fair (2), Good (3)

Supporting comments:

- This project gets power on line, and will provide an educational platform for future geothermal professionals.

- Congressionally mandated project that most-likely would not have been done by the private sector. Better analyses should have been done before project initiation. However the project was done, so the GTP should work with OIT to ensure this system and auxiliary systems are used as educational tools for the benefit of the GT industry. No benefits will accrue to the EGS effort.

- If successful (by no means guaranteed at this point), this project would be a showcase to supplement the existing geothermal installations on the OIT campus. Since OIT has a worldwide reputation, this project will receive wide publicity, whether successful or not. One distraction in the presentation is numerous grammatical errors in the PowerPoint slides.

4.3.3.6 PI Response

My only comment really is that this was not intended to be an EGS project. That was just where we were placed for our Program Review.

4.3.4 Systems Engineering

Presentation Number: 004
Investigator: Lowry, Thomas (Sandia National Laboratories)
Objectives: To develop a physics based systems level simulation and analysis tool for geothermal energy development.
Average Overall Score: 2.7/4.0

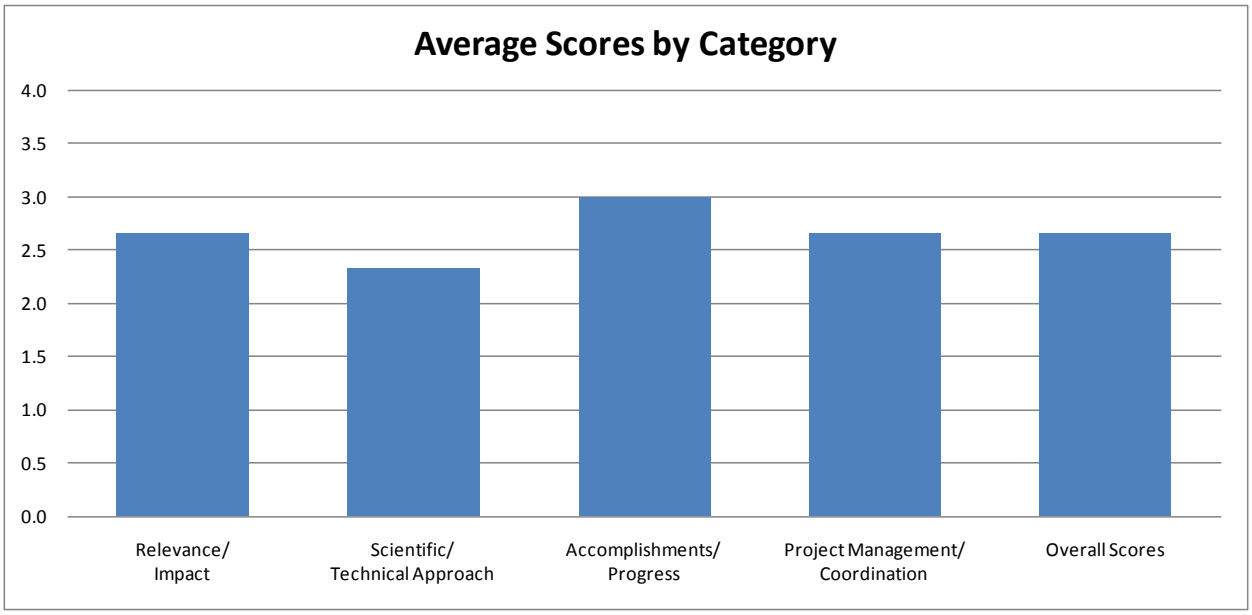


Figure 19: Systems Engineering

4.3.4.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Fair (2), Good (3)

Supporting comments:

- The systems dynamics approach may prove to be a valuable analysis tool.
- This is a high-level model that simulates GT electric systems including EGS, and that addresses barriers W,X, and Y. The only rationale for not giving this project a "good" rating is lack of definition of scope and potential duplication with GETEM, along with use of a proprietary platform. Use of the completed model should allow DOE and others to conduct orderly analyses - a function now performed with GETEM. One can argue that the PI's claimed result of "Identify points to maximize efforts....." is already known and that this model will not provide additional depth of knowledge. DOE and SNL must better define the purpose and scope of this project.
- The project addresses an EGS goal that would help DOE and the industry analyze potential EGS projects. The model could also be extended to other geothermal development options. The promise is for a new tool to help design and manage EGS projects.

4.3.4.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Fair (2), Fair (2), Good (3)

Supporting comments:

- While the overall project seems well founded, I do not see documentation that the extensive efforts of DOE in the 70s, 80s, and 90s have been incorporated. I am concerned that while the physics is soundly based on early papers (e.g. Snow 1968), work in the last 40 years, especially DOE-funded drilling and reservoir engineering efforts, might have refined some of the assumptions used. I note that this project has been presented at a Stanford workshop, which is good. But what has been incorporated or changed as a result of feedback from the presentation?

- Again, this should be a "good" rating if DOE and SNL would decide on the desired level of detail that this model will address. The resulting model can range from essentially a "macro" wherein major components such as conversion can continue to be treated as a "black-box" with parametric input by the user; to the other extreme of a "micro" wherein there are routines to do detailed component calculations. In the latter case there may be duplicative efforts, e.g. with GETEM and the CO_2 efforts at LBNL. The latter approach will be very costly - present funding is just the "tip of the iceberg". This is not necessarily bad if it is what the GTP decides it needs as efforts such as GETEM have been sort of ad-hoc in definition and this approach is much more systematic. Again, "What's it gonna be when it grows up?".

  A much more accessible computer programming platform than Pro-Sim should be used. The current platform costs about $300 or more per user with a bulk purchase - this will somewhat limit the use of the resulting program.

- The technical approach appears to be sound and the project well executed.

4.3.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The presenter seemed to understand the nuances of this effort, and explained them well. Some of his slides, however, were dense and illegible. The tiered approach to the program will allow good flexibility. I do not recall the status of the beta version being clarified. The presentation calls for a May to June delivery, and we are there. Has it been delivered?

- Very competent PI, with a good approach on an ill-defined project plan. There appears to be significant progress. This reviewer questions whether both the deterministic (essentially rating a specified system) and the stochastic (essentially designing a system to meet specified goals) are needed. It is hard to imagine a casual user being able to input a meaningful probability density function for the stochastic applications. As stated above, this project needs to have close collaboration with some other GTP efforts such as GETEM, as acknowledged by the PI.

- Sandia's team has the capability of doing this project well, and can draw on a large pool of talent if needed.

4.3.4.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- It was noted during the presentation that coordination with industry is at the stage of "silently developing a list of targets," and that coordination with other lab modeling efforts is still in the planning stage. It seems to me that both industrial input and coordination with other national lab modeling efforts should be increased. Coordination among labs is critical, but it is not sufficient to produce a successful end product. Modular development of the program will allow multiple decision points for further directions or termination.

- Reasonably good project management with an ill-defined project plan as discussed previously. However, this project should be better defined in scope with development of a long-range plan giving costs including maintenance and technical-assistance (to users) costs - with agreement by DOE.

- There is no explicit mention of decision points in this project. The project seems to be well managed.

4.3.4.5 Overall

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- Great idea to base a systems analysis on good physics. But I fear that the goal of providing" a platform for public education and interaction" will be lost through use of terms such as "points of attack" and "parameter space." The presentation did not identify how the general public will be reached by this project. I would like to see very close coordination among model developers. Is there any chance that all the models funded by DOE could be based on one front end, so users will not have to learn separate models and programs to answer questions, but instead could learn one program and have multiple options in how they run it?

- Potentially a "good" or "outstanding" rating with better definition of the project scope and plan. Platform should be public domain, or common and easily accessible. Relationship of this project to other GTP projects must be better defined, as must the ultimate use and costs.

- The model being developed in this project has some overlap in its goals with the GETEM model, which has been under development for several years. As a predictive tool for EGS reservoir performance, the model seems to also overlap the capabilities of several widely available reservoir simulators. This is not necessarily a bad thing since a new approach will afford the opportunity to compare model results for vetting purposes. With the amount of funding available ($625,000), however, it seems unlikely that the model will reach the state of capability that either GETEM or simulators such as the various TOUGH incarnations has. This type of

model-development project often never reaches a stage where it is “finished”, and it appears that the total amount of funding may not be enough to yield a truly useful model. The project staff should interact with other modelers in geothermal energy to take advantage of their expertise and help vet the model. DOE should consider how much more money they are willing to commit to make this new model most useful.

4.3.4.6 PI Response

No response.

4.3.5 Life-cycle Analysis of Geothermal Technologies

Presentation Number: 005
Investigator: Wang, Michael (Argonne National Laboratory)
Objectives: To develop greenhouse gas (GHG) emissions profiles of geothermal technologies; to develop water resource impacts of geothermal technologies; and to address GHG and water issues of other power generation technologies for comparison purposes.
Average Overall Score: 2.7/4.0

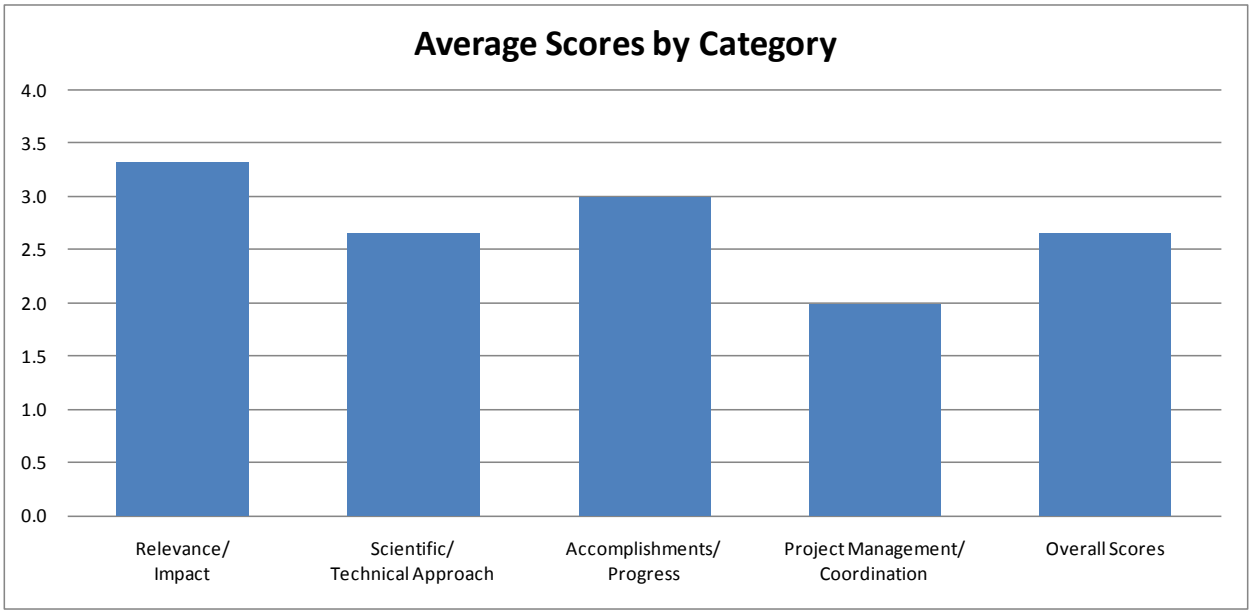


Figure 20: Life-cycle Analysis of Geothermal Technologies

4.3.5.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Outstanding (4)

Supporting comments:

- Well-founded modeling of comparative GHG contributions by various energy sources is critical, and this project is making good progress in developing a rigorous basis to estimate these.
- This project is relevant to barriers W,X, and Y. The questions of net life-cycle energy benefits and GHG mitigation benefit accruing to GT need better answers and this project should provide those quantifications. The question of fracturing water, water losses for EGS system operation and cooling water requirements and availability for power plants are of crucial importance to viability of GT expansions, especially EGS.
- The project addresses EGS as well as other types of geothermal generation and the goals are sound. If successful, this project would produce some much needed information.

4.3.5.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Fair (2), Good (3)

Supporting comments:

- The technical approach seems relatively well founded, but I am concerned that data from previous DOE programs are not being included. I am also concerned that documentation of meta-data about assumptions included in parameters and sources of data are not being fully documented. For example, there is extensive DOE-funded and other literature about their work to "evaluate correlations between key reservoir properties and chemical constituent concentrations." The presentation did not express to me exactly what new material this project is bringing to the table. The meta-data question is critical. This analysis is based on compilation of data from many sources (literature, industry experts, ICARUS, etc.), and documentation of these sources will help end users, especially as the data are integrated into GREET.

- Well defined technical approach using accepted techniques. PI needs to ensure equal bases for comparison, i.e. ICARUS was used to estimate GT materials requirements whereas literature values were used for conventional (coal, nuclear and gas) power plants. Use of ICARUS needs to be validated. However, the overall scope of the project is ill-defined. A logical end-point needs to be defined for basic model development, along with the extent of the effort for annual updates and model maintenance.

- The technical approach seems to be sound.

4.3.5.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The productivity of the team seems to be good. They have compiled mammoth amounts of data (e.g. 53,000 chemical analyses), and seem to be making good progress about analyzing these and incorporating them into their models. They do not, however, seem to be sharing the results of their compilations.

- The graphics (at least in the presentation) are not well done, e.g. perhaps the parametric benefit should be (energy out)/(energy in) rather than the inverse. This would better imply a benefit and would be more readily grasped by the reader. Scenarios need to be standardized to ensure there are no scale benefits, i.e. a 1000 MW coal plant versus fifty 20 MW EGS plants. Overall, good progress.

- Progress on this project seems to be satisfactory, but percentage completion and project end dates were deemed to be “Not Applicable” – this should be explained. The project team seems to be fully capable of carrying out this project. Although they have limited geothermal

experience, they appear to be interacting well with others having more experience, and this type of communication should be continued and strengthened.

4.3.5.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Poor (1), Fair (2), Good (3)

Supporting comments:

- The project overview slide states that the project end date and percent complete are not applicable. The investigators therefore seem to feel that ending or redirecting this project is not appropriate. Thus the DOE guideline above that decision points be appropriately placed in the research plan is not met. Critical management checks and controls are missing. Is this project really intended to last forever?

- Would be rated as a "good" if the project scope and extent were better defined. This reviewer was somewhat irritated by an implied attitude exemplified by "Project End Date: Not applicable" and "Percent Complete: Not applicable". While this valuable project (especially GHG mitigation extent) may be on-going, there is a phase to develop and apply the model, and a phase to provide annual updates. The PI and the GTP must define the scope, detail and the potential costs of this project. It should not be open-ended.

  Absolutely no question that the project team is highly competent and are good managers.

- There is no mention of decision points in the project, but the project appears to be carried out well.

4.3.5.5 Overall

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- While this project has shown some good results so far, it seems to be working in relative isolation from data and efforts outside the national labs. For example, the compiled geochemical data are exceptionally valuable, but there is no plan to share these data with other DOE programs, such as the efforts by Drs. Snyder and Allison, which were featured at the meeting.

  I would like to see very close coordination among model developers. Is there any chance that all the models funded by DOE could be based on one front end, so users will not have to learn separate models and programs to answer questions, but instead could learn one program and have multiple options in how they run it?

  The investigators must, however, be thanked greatly for their many presentations to the

geothermal community. It is critical to get their efforts out and reviewed, and they are doing this well.

- There must be a better definition of the project plan. This is a needed effort by a strong performer.
- This is an important project that will help decision makers and others at the state and federal levels compare costs and environmental consequences of our electrical power generation infrastructure. It should show geothermal energy in a favorable light compared with some of the other energy technologies.

4.3.5.6 PI Response

No response.

4.4 High-temperature Tools and Drilling

The following six projects address the development and demonstration of exploration tools, sensors, down-hole pumps, and drilling systems for high-temperature environments. Figure 21 summarizes High -temperature Tools and Drilling review scores by evaluation criteria for each PI's project and Table 17 presents detailed scores by reviewer.

Figure 21: High-temperature Tools and Drilling Review Scores by Project PI and Evaluation Criteria

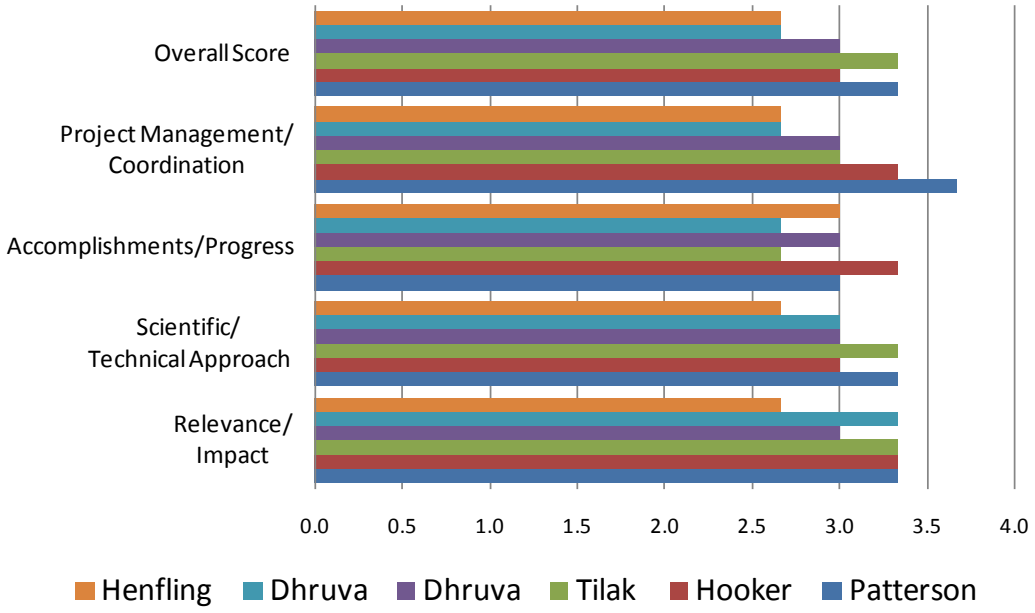


Table 17: High-temperature Tools and Drilling Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Detecting Fractures Using Technology at High-temperatures and Depths - Geothermal Ultrasonic Fracture Imager GUFI	Patterson	1	4.0	4.0	3.0	4.0	4.0
		2	3.0	3.0	3.0	4.0	3.0
		3	3.0	3.0	3.0	3.0	3.0
			3.3	3.3	3.0	3.7	3.3
The Development and Demonstration of an Electric Submersible Pump at High-temperatures - High-temperature Motor Windings for Down-hole Pumps Used in Geothermal Energy Production	Hooker	1	3.0	3.0	3.0	3.0	3.0
		2	3.0	3.0	4.0	3.0	3.0
		3	4.0	3.0	3.0	4.0	3.0
			3.3	3.0	3.3	3.3	3.0

Table 17 (continued): High-temperature Tools and Drilling Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Development of Tools for Measuring Temperature, Flow, Pressure, and Seismicity of EGS Reservoirs - 300 °C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems	Tilak	1	4.0	4.0	3.0	3.0	4.0
		2	3.0	3.0	2.0	3.0	3.0
		3	3.0	3.0	3.0	3.0	3.0
			3.3	3.3	2.7	3.0	3.3
High-temperature Pump Monitoring - High-temperature ESP Monitoring	Dhruva	1	3.0	3.0	3.0	3.0	3.0
		2	3.0	3.0	3.0	2.0	3.0
		3	3.0	3.0	3.0	4.0	3.0
			3.0	3.0	3.0	3.0	3.0
Extending the Temperature Range of Electric Submersible Pumps to 338 °C - Hotline IV - High-temperature ESP	Dhruva	1	3.0	3.0	2.0	2.0	3.0
		2	3.0	3.0	3.0	3.0	2.0
		3	4.0	3.0	3.0	3.0	3.0
			3.3	3.0	2.7	2.7	2.7
Fielding of HT seismic tools and evaluation of HT FPGA Module - Development of a HT Seismic Tool	Henfling	1	3.0	3.0	3.0	3.0	3.0
		2	3.0	3.0	3.0	3.0	3.0
		3	2.0	2.0	3.0	2.0	2.0
			2.7	2.7	3.0	2.7	2.7

4.4.1 Detecting Fractures Using Technology at High Temperatures and Depths - Geothermal Ultrasonic Fracture Imager (GUFI)

Presentation Number: 015
Investigator: Patterson, Doug (Baker Hughes Oilfield Operations Incorporated)
Objectives: To develop an ultrasonic borehole televiewer that can operate at temperatures as high as 300 °C and in depths as great as 10,000 m.
Average Overall Score: 3.3/4.0

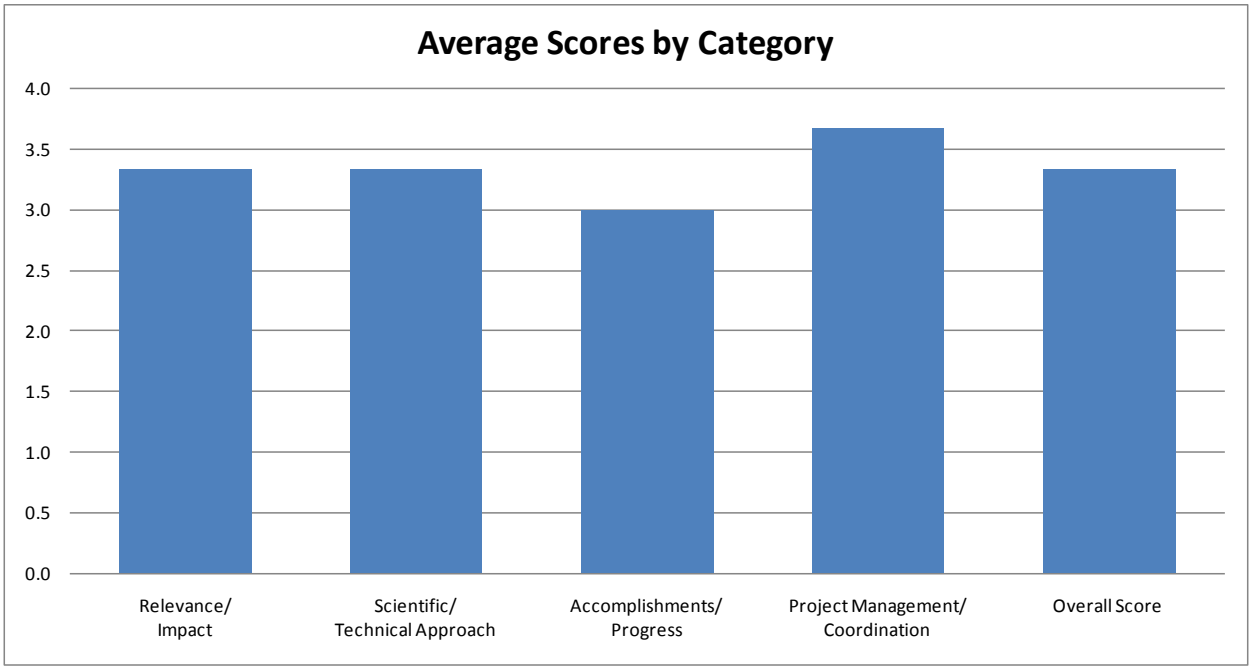


Figure 22: Detecting Fractures Using Technology at High Temperatures and Depths – Geothermal Ultrasonic Fracture Imager (GUFI)

4.4.1.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Knowledge of the size and location of fractures is extremely important in designing injector and/or producing zone placement. Visualization (by ultrasound) is one of the best ways to do this.
- Successful completion of this research would provide a tool for determining the location of fractures which is key to engineering or improving geothermal reservoirs.
- Success in developing EGS technology will depend on measuring the characteristics of fractures created in high-temperature rock formations. The proposed tool would contribute to that understanding by identifying and measuring the width of fractures that intercept a borehole. This particular technology would not yield much information about fracture characteristics

outside the borehole. However, some additional insight may be gained by comparing fracture detection data with data from different boreholes.

4.4.1.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Ultrasonic imaging is probably the best way at present for visualizing fractures. The combination of external transducer / flasked electronics looks to have the best chance of success in the immediate future

- The research is focused on getting the sensing equipment to work at elevated temperatures and pressures similar to what one would encounter in a geothermal reservoir. Much of the work is being done in a lab, where sensitive equipment prohibits the simulation of actual well bore conditions -- things such as vibrations, salt concentration, lowering and raising the sensing equipment.

- The project begins by examining the basic issues, primarily the sensor material needed to survive the 300 °C contact with well bore fluids. Mechanical support of the sensor and electric connections at these temperatures also are critical. These components are tested separately, then together at the required temperature. Other system components can be protected from such high temperatures and will be upgraded later in the project. The principal investigator indicated during the presentation that pressure testing also will be accomplished, but was not clear where in the project timeline. In addition, this reviewer is concerned whether the various components will be subjected to simultaneous T and P conditions that would be found down-hole.

4.4.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Although it is in its relatively early days, the project appears to be on track. The project team is very experienced and they have access to good experimental facilities.

- This research appears to be on track.

- The research team seems to be well qualified, although little information on this subject was presented except for the degree levels of the researchers. The equipment and facilities used for work to date appear to be quite adequate. The progress, compared to cost expended is presented as being within the planning parameters. In general, the project seems to be about on track.

4.4.1.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The team has a good track record in the field. I liked the fact that they are already looking for field test facilities and partners. I also liked the idea that the televiewer is intended to be added to/integrated with an existing suite of logging tools (Nautilus Ultra). Although the rest of the tools do not yet have sufficient high-temperature capability this is obviously a future development target

- The presentation indicates a high level of cooperation.

- The project is well planned in terms of the phases, and a major decision point is identified at an appropriate place in the timeline.

4.4.1.5 Overall

Ratings of Three-member Peer Review Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Overall, a project directed to advancing our technology in an important field. The project has made good progress so far and the team has a good track record. I like the overall plan, looking ahead to integration with other instruments and towards field testing.

- This project appears to be a good investment.

- The early work appears to have met project milestones and to have achieved the desired results so far. If this project ultimately leads to a down-hole tool that can identify fracture intersections with boreholes in EGS systems, it should contribute successfully to the creation of high-temperature geothermal reservoirs for power production in impermeable igneous rocks.

4.4.1.6 PI Response

No response.

4.4.2 The Development and Demonstration of an Electric Submersible Pump at High Temperatures - High-temperature Motor Windings for Down-hole Pumps Used in Geothermal Energy Production

Presentation Number: 016
Investigator: Hooker, Matthew (Composite Technology Development, Inc.)
Objectives: To develop and demonstrate electric submersible pump (ESP) motor windings that utilize inorganic electrical insulation systems for high-temperature use.
Average Overall Score: 3.0/4.0

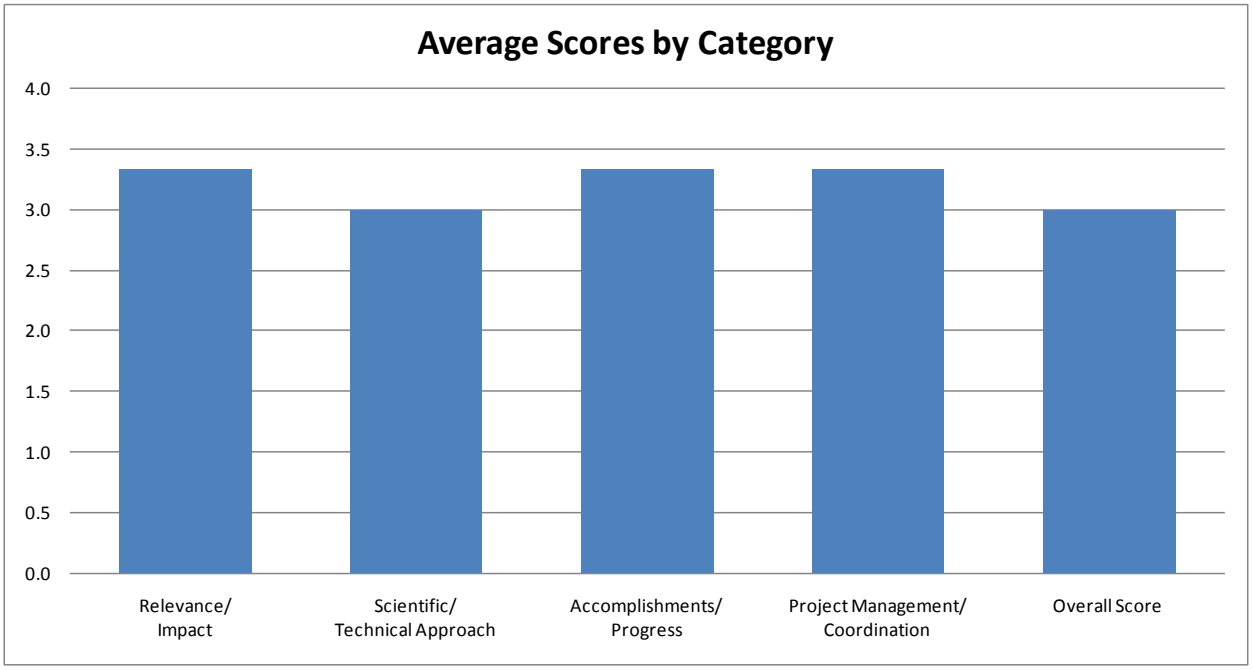


Figure 23: The Development and Demonstration of an Electric Submersible Pump at High Temperatures – High-temperature Motor Windings for Down-hole Pumps Used in Geothermal Energy Production

4.4.2.1 Relevance/Impact of the Research

Ratings of Three-member Reviewer Panel: Good (3), Good (3), Outstanding (4)

Supporting comments:

- Electric Submersible Pumps are an essential component of many geothermal systems (except those in which there is a natural flow of steam to the surface). The author notes that of the causes of failure in ESP systems, pump motor failure is (just) the largest single contributor, at 32 %. However, not all motor failures are due to failure of the insulation on the wires, and so, while important, work to improve the insulation will solve only one of a number of causes of failure.

- We absolutely need pumps that can operate at higher temperatures for EGS to be successful.

- An ultimate objective of Enhanced Geothermal Systems research is a down-hole electric pump capable of moving 300 °C geothermal fluids at high rates through boreholes several inches in diameter from depths of up to 10 km to the ground surface. Present down-hole pumps used by the oil industry are designed for much smaller diameters and lower temperatures.

  While scaling up the diameter, length and power of down-hole pumps for EGS service appears to be possible with an extension of present technology, survivability at high temperatures is not. A major weakness is the breakdown of insulation on the copper motor windings. This project's objective is to develop and prove new materials that will provide the necessary electric insulation at temperatures of 250 °C for long periods of time, as in years. A second aim is to assure that the new insulation can be applied to the motor windings in manufacture.

  Improving the high temperature of other down-hole pump components will doubtless be important, but the motor winding insulation is critical and absolutely essential.

4.4.2.2 Scientific/Technical Approach

Ratings of Three-member Reviewer Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The scientific approach and the proposed improved insulation material appear to provide very significant improvements over the current PEEK material, and there seems to be a high probability of success. The development of testing procedures (first laminate then as coatings to wires) is logical and appears successful. Incorporating glass fiber braid looks like giving superior mechanical properties as well as creep resistance.

- The approach of the research team is focused on increasing the temperature capability of the pump by increasing the temperature capability of the electrical resistance material.

- The investigation of inorganic materials for electrical insulation at high temperatures is an appropriate course of action. Early coordination with a wire manufacturer is important. Testing of candidate materials is the correct first step. This leads to making scaled down motor windings with the qualified materials, in collaboration with the wire maker. However, the first tests confirm temperature resistance only at 250 °C.

  The sample "statorettes" are constructed with the new wire in coordination with a down-hole motor manufacturer. The resulting assemblies are to be subjected to electrical tests at 250 °C temperatures .

4.4.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Reviewer Panel: Good (3), Outstanding (4), Good (3)

Supporting comments:

- The project is proceeding as planned, with good progress. I like the steady progression from laminate to single wire to "statorette" testing. I also like the fact that the new insulation is

strong and flexible enough that wire so insulated can be used to build motor windings using conventional techniques.

- The team has tested in the lab a material with 300 °C capability. It looks promising.

- Appropriate materials have been identified and applied effectively by a wire manufacturer. Then the wire has been fabricated by a down-hole motor manufacturer into the statorettes, which then will be tested at high temperatures. The project therefore is about where it should be at this stage, and appears to be on track toward achieving its objective at 250 °C.

4.4.2.4 Project Management/Coordination

Ratings of Three-member Reviewer Panel: Good (3), Good (3), Outstanding (4)

Supporting comments:

- The research teams appear competent, and the collaboration between experts in the different domains (Wood Group, New England Wire and CTD) is logical and valuable.

- There are two partners working on this project and they appear to be working well together.

- The coordination with the wire maker and motor manufacturer seems to have been accomplished almost seamlessly, resulting in the project being on track.

4.4.2.5 Overall

Ratings of Three-member Reviewer Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The project is going well, and looks as if it will deliver as proposed. My only reservation is that the solution will address only one of the reasons for the failure of EGS projects, (pump motor failure) and within the domain of pump motor failure, only one of the possible reasons for motor failure.

- Testing a specimen in a lab environment and testing in a well are very different. This project has a long way to go, but it does promise to significantly raise the temperature rating of electrical insulation.

- Successful completion of this project is likely to lead to the desired down-hole pump motor technology, able to function at temperatures up to 250 °C, significantly better than other present technologies. It should be noted that the pump motor may get hotter than the fluid being pumped, and future design and testing should account for this if the pump is to function in a 250 °C environment for long periods of time. Future research will be necessary to develop motor winding insulation that will survive at 300 °C.

4.4.2.6 PI Response

No response.

4.4.3 Development of Tools for Measuring Temperature, Flow, Pressure, and Seismicity of EGS Reservoirs – 300 °C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems

Presentation Number: 017
Investigator: Tilak, Vinayak (GE Global Research)
Objectives: To develop a platform of electronics technologies that can operate at 300 °C and 10 km depth enabling the measurement of temperature, flow, pressure and seismicity in a EGS reservoir.
Average Overall Score: 3.3/4.0

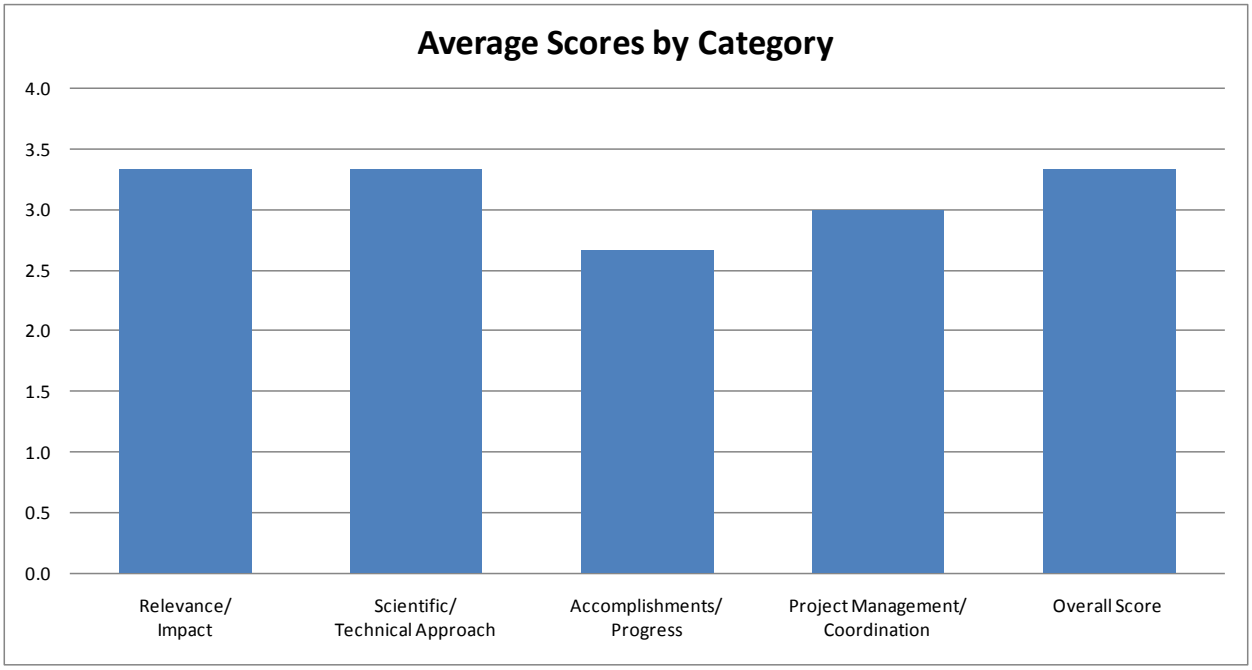


Figure 24: Development of Tools for Measuring Temperature, Flow, Pressure, and Seismicity of EGS Reservoirs – 300 °C Capable Electronics Platform and Temperature Sensor System for Enhanced Geothermal Systems

4.4.3.1 Relevance/Impact of the Research

Ratings of Three-member Reviewer Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Knowing temperature, flow, pressure and other properties of geothermal wells UNDER HOLE BOTTOM CONDITIONS is extremely important, so any progress that can be made to increase the resistance of tools to measure these properties is important. All such tools will have electronic components, that must either be flasked to resist the high-temperature (and pressure) conditions or be capable of standing those conditions directly. While flasking offers a simple solution, flasks eventually warm up and so have to be removed from the well to avoid overheating. For long-term installation, there is no alternative to having components that survive indefinitely under high-temperature conditions. This project addresses that need.

Building an operational amplifier for high-temperature operation is a good demonstration project as well as being valuable in its own right.

- This research would allow electronics to be placed in the well at temperatures up to 300 °C. This would empower all types of new data collection and diagnostics, especially helpful for monitoring reservoirs so that corrective actions can be taken to extend the life of EGS reservoirs.

- The primary objective appears to be development of an electronics package that can survive a 300 °C down-hole environment and feed temperature and/or other information to a data collection system either down-hole or at the ground surface. A secondary objective appears to be development of a temperature sensor that will measure high temperatures and provide output to the electronics package. Such a system will be necessary to furnish information about down-hole conditions to geothermal system operators at the surface.

  It is likely that the resulting technology will have broader application in other high-temperature environments, such as power plant operations.

4.4.3.2 Scientific/Technical Approach

Ratings of Three-member Reviewer Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Silicon carbide-based electronics offer excellent potential for high-temperature application. Building a SiC based Operational Amplifier is a good demonstration project as well as being useful in its own right.

  The parallel efforts to find sensors and passive components to be associated with the SiC electronics is a logical approach towards an eventual complete system. Simultaneous development of ceramic packaging is also a valuable contribution to the overall goal. The use of accelerated aging methods is useful but needs to be checked for validity by some real long term tests.

- The silicon circuit appears to have the temperature rating and sensitivity required for monitoring temperature and pressure. The next step is to package a device for testing in well conditions.

- The approach for the first year was to qualify appropriate materials and components for service at 300 °C; to develop a temperature sensor to operate in the same conditions; and to qualify characteristics of materials for a packaging system. This appears to have been accomplished in terms of the sensor and an amplifier and measurement of the temperature resistance of candidate components. Later work will focus on assembling the components into working subsystems and testing at high temperatures.

4.4.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Reviewer Panel: Good (3), Fair (2), Good (3)

Supporting comments:

- Development of the Operational Amplifier is a good achievement. Parallel development/testing and integration of passive components appear to be progressing well, and the collaboration with Auburn University concerning packaging is valuable. The future plan, to continue development of the electronics package and to make a temperature sensor appear logical and feasible.

- This project is about 4 months behind schedule due to a breakage of equipment/supplies that had to be reordered. They are making every effort to catch up and prevent a similar set back.

- The objectives for year 1 are reported to have been achieved, including development of a temperature sensor and an integrated circuit amplifier with preliminary tests at room temperature. However, survival times for the components have been estimated by modeling based on results of short term tests, and should be investigated further with longer duration testing conducted in parallel with ongoing development work. This will help to validate the modeling. To the extent that the final elements would be subjected to high pressures simultaneously with high temperatures, they should be so tested. This is especially true for the temperature sensor, unless the final packaging will protect it while still allowing accurate temperature measurement.

  The solid state amplifier appears to have passed a short term test at 300 ^{o}C.

4.4.3.4 Project Management/Coordination

Ratings of Three-member Reviewer Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The project appears to be running well.

- Hind sight is 20/20 and this project would not have suffered the delay had additional supplies/equipment been on hand. They appear to be working to overcome the schedule.

- The various work elements are planned in a reasonable sequence. Some work on packaging elements was done, but it is not clear how much of this work was contributed by the subcontractor. A specific decision point is identified at the end of year 1.

4.4.3.5 Overall

Ratings of Three-member Reviewer Panel: Outstanding (4), Good (3), Good (3)

Supporting comments:

- Overall, a valuable project. Long-term, down-hole measurements of reservoir conditions must eventually rely on the use of electronics that can survive indefinitely under hole-bottom conditions. Silicon carbide-based circuitry offers this possibility so research in this field can provide the essential first steps that will ultimately lead to the development of a wide range of sensor (and possibly other) down-hole tools.

- The silicon offers a far higher temperature than other materials. This research has a high promise and should be continued, it is key to continuously monitoring reservoirs and real time data.

- Overall, the work in progress should result in a temperature resistant solid state apparatus for measuring temperature down-hole in Enhanced Geothermal Systems. (Final packaging and testing will need be done in separate projects.) If this project succeeds, the resulting capability will be applicable to other EGS monitoring systems. Consequently coordination between this and related work should be maintained where possible in view of proprietary matters.

4.4.3.6 PI Response

No response.

4.4.4 High-temperature Pump Monitoring - High-temperature ESP Monitoring

Presentation Number: 018
Investigator: Dhruva, Brindesh (Schlumberger Technology Corp.)
Objectives: To develop a down-hole monitoring system to be used in wells with bottom hole temperature up to 300 °C for measuring motor temperature, pump discharge pressure, and formation temperature and pressure.
Average Overall Score: 3.0/4.0

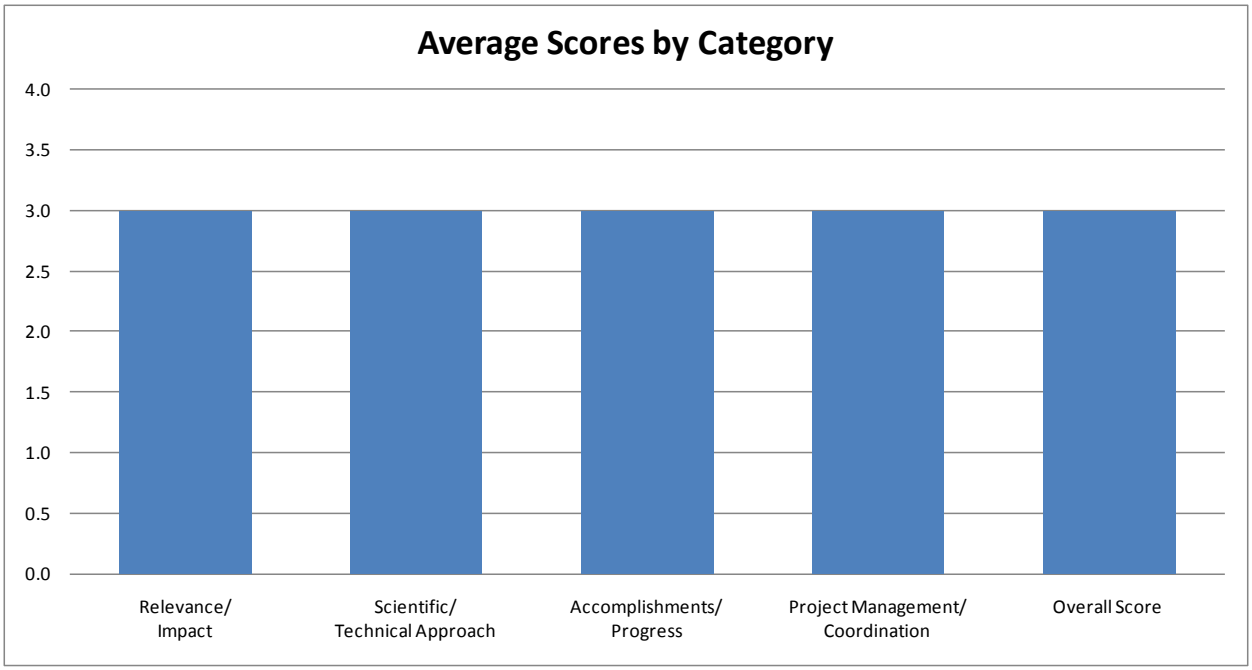


Figure 25: High-temperature Pump Monitoring - High-temperature ESP Monitoring

4.4.4.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Making temperature and pressure measurements under deep geothermal well conditions is valuable both for monitoring pump function (motor temperature and discharge pressure) and for determining reservoir properties (temperature and pressure).

  Two approaches are being followed, each of which should provide a robust and long-lived sensor. It is not clear if the two sensors are alternatives, each capable of doing two jobs, or whether each is destined for a particular application.

- This project builds on previous research and experience. It is trying to improve the equipment in addition to having it operate under a higher temperature requirement. They are having some issues with drift, which is slowing down the research, until they can solve this problem. It

appears they have a solution. I would note that in research especially, one cannot anticipate all issues.

- For the extraction of hot water from a deep EGS, down-hole pumps will be necessary. They will have to have pumping capability an order of magnitude greater than the present generation of electric submersible pumps, which are designed primarily for the petroleum industry, and which are not designed to work at temperatures of 300 °C. Consequently, relatively large pumps that can operate at those temperatures are essential to the success of EGS power production. Furthermore, measurements of the operating pump motor temperature and output pressure will be needed for the proper operation of this equipment.

4.4.4.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- It is not entirely clear whether two sensor styles are needed - the fiber optic sensor for pump discharge pressure and another pressure sensor for the formation pressure, and then other sensors for motor and formation temperature, or whether e.g. the fiber optic pressure sensor is capable of making both pressure measurements. Apparently development of two styles of pressure sensor is going on, but whether they are equivalent or destined for different applications is unclear.

  Abandoning the Free Piston Stirling Cooler was a good strategic move, as maintaining moving machinery in the down-hole environment is always difficult. Having different sensors that can survive uncooled in the environment is much to be preferred.

- The approach of extending the range of current instruments seems very logical. I would add that this approach does, at least at the outset, exclude new ideas. The drift issue appears to have brought a new search for materials into this research.

- Objectives: Develop temperature and pressure sensors that can measure both characteristics in the down-hole fluid and in the electric submersible pump in a geothermal well. A temperature limit of 300 °C is specified as the ultimate goal, but current testing is performed at somewhat lower temperatures to determine characteristics of materials and components at intermediate levels.

4.4.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Good progress has been obtained so far. However, field testing will eventually be required and additional funding will be required for that work to be done

- They have some promising results for monitoring temperature and pressure at 290 °C. They still have to package and prepare for a well test.

- The project is approaching the 300 degree limit with appropriate designs. Lab equipment and the capabilities of researchers seem adequate for the task.

4.4.4.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Good (3), Fair (2), Outstanding (4)

Supporting comments:

- Project management appears to be good, and is internal to the Schlumberger group, so that should minimize difficulties in communication.

- This project is running about 6 months behind schedule and they anticipate completion in fourth quarter 2010.

- An initial approach, a down-hole Stirling cooler proved to be impractical and at a decision point was dropped from further consideration, and an alternative approach was adopted. The new approach is tailored to remaining time and resources, and is on track to achieve the project objective. This necessary midstream change of approach is indicative of heads-up research management.

4.4.4.5 Overall

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Overall, it is somewhat confusing to disentangle the different threads in the work as it is progressing. However, steady progress is apparently being made. Attention should be given to planning the next steps, viz. towards a field test, that will involve finding a suitable collaborating company and test location.

- This project is running behind schedule and over budget. The researchers expect to spend more of their own money to complete the research.

- This project, although with revised objectives, appears to be leading to the development of down-hole systems that will provide the desired temperature and pressure data in the well and in the pump to the operators of an EGS well.

4.4.4.6 PI Response

No response.

4.4.5 Extending the Temperature Range of Electric Submersible Pumps to 338 °C - Hotline IV - High-temperature ESP

Presentation Number: 019
Investigator: Dhruva, Brindesh (Schlumberger Technology Corp.)
Objectives: To increase the temperature rating of high-temperature ESPs.
Average Overall Score: 2.7/4.0

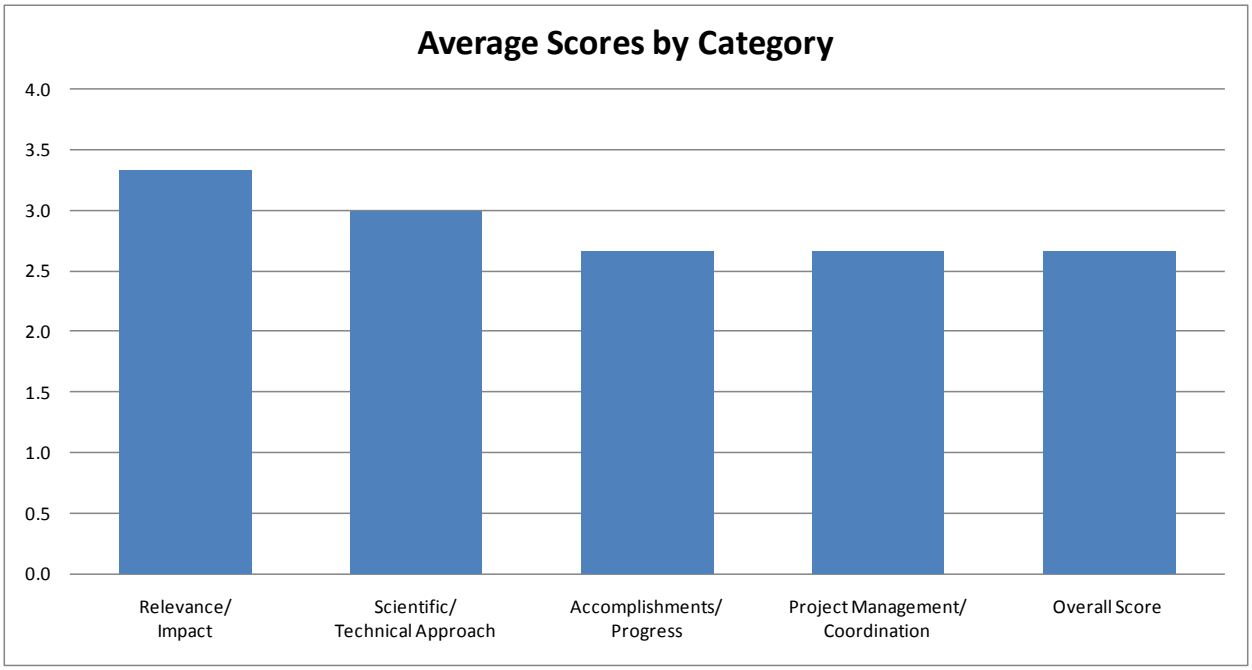


Figure 26: Extending the Temperature Range of Electric Submersible Pumps to 338 °C - Hotline IV - High-temperature ESP

4.4.5.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Outstanding (4)

Supporting comments:

- This is a broad-reach project to improve the thermal resistance of down-hole pumps. The approach is to examine simultaneously all parts of the system and to make improvements in all components commensurate with reaching the desired goal. This means examining and improving a wide range of materials, including e.g. elastomers for seals, electrical insulators, bearings etc. As such, the results of this research , while being specifically applicable to pumps, should have more general applicability to many geothermal problems.

- Pumps that can operate at higher temperatures are key to developing economic EGS reservoirs.

- As noted in reviews of other projects, down-hole pumps capable of moving large quantities of hot (300 °C) geothermal fluid from substantial depths to the wellhead will be essential to the success of Enhanced Geothermal Systems for electric power production. Such pumps do not

now exist. A major barrier to their development is the temperature requirement.

The research conducted in this project is part of a larger industrial program to improve down-hole pump technology. Because it fits into the overall pump technology effort, it is likely to lead to commercial pumps with the necessary geothermal characteristics. However, the present project is concerned only with pumps that will operate reliably at the 300 ^{o}C temperature. Other operating parameters, such as motor power and pump diameter are not considered here.

4.4.5.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- The scientific approach is good. It starts with an examination of failed components, (what failed, how it failed and what was the underlying cause) and then proceeded to address the needed corrections. Usually these related to the identification and selection of better materials, but there were also more global improvements, e.g. simplifying installation on the rig floor and integration of a new high-temperature monitoring system.

- The approach to this problem is to evaluate all the non-metallic parts of the pump motor assembly and to try to build the electrical portion of the pump to withstand higher operating temperatures. Since the electrical part of the pump has to survive both the high temperature of the brine and the increased temperature caused by rejection of heat from the electric components of the pump, improving the efficiency of the mechanical pump and the electric components would reduce heat rejection and therefore enable the pump to operate in higher temperature EGS reservoirs. I thought it might be good to look at the mechanical efficiencies of the pump.

- The overall technical approach is to examine all components and materials in existing down-hole pumps with the higher temperature ratings, and to study prior failure of pumps in commercial service to identify the weak points. The development work then will focus on the weak links. This approach seems to have been successful to date in:

  1) achieving incremental improvements in pump performance at temperatures greater than those for which existing commercial pumps are qualified, and
  2) identifying critical areas in which improvements are required for 300 degree service.

4.4.5.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- Progress has suffered a number of setbacks, some of which were probably beyond the control of the project managers, but the project is definitely behind schedule.

- The comparative data used in the presentation might not be isolated enough to be useful. For example a 1500 HP motor and a 320 HP motor were displayed operating at temperatures of

218/288 °C and 150/205 °C, respectively. The first temperature was the brine temperature and the second temperature was the motor temperature. Since the motor temperatures were not measured it's not clear how the second temperature was obtained. This data needs to be validated. One pump has been tested to 260 °C. They still have a ways to go.

- Since the company conducting the research is already in the down-hole pump development business, the facilities, equipment and corporate experience available to this project's researchers are excellent. Coordination with another research team in the same company conducting related research is an advantage. Analysis has identified the pump motor temperature as being greater than that of the geothermal fluid to be pumped, and a probable cause of pump failure. A method for predicting pump motor temperatures suggests thermal limits for internal motor components. Thermal testing of a motor at 260 ^{o}C was accomplished.

4.4.5.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Fair (2), Good (3), Good (3)

Supporting comments:

- Project management appears well organized, apart from the fact the project is, in fact, behind schedule (see above)

- Coordination with researchers and industry (Conoco Phillips).

- This company has a well defined schedule for carrying out R&D projects from concept to field testing of prototypes, and this project fits nicely into the plan. Due in part to unexpected circumstances, this project is behind schedule and will run short of DOE financing before reaching the planned objectives, However, the future demand for a suitable pump appears great enough that the company evidently plans to carry out additional research at its own expense to continue development of a pump suitable for EGS service.

- Any decision points were not identified in this paper.

4.4.5.5 Overall

Ratings of Three-member Peer Review Panel: Good (3), Fair (2), Good (3)

Supporting comments:

- A useful project, with the object of increasing pump performance. The approach looks systematic; it considers all components in turn , with the object of increasing the performance of all the components simultaneously so as to improve the performance of the entire system. The improvements, and experience gained, should be of broad value in advancing the thermal resistance of a wide range of down-hole geothermal equipment.

- This team has a ways to go to get to the 300 °C goal, the current test is only 260 °C.

- The company had made significant progress in improving the temperature resistance of down-hole pumps. The long range plan appears to favor meeting the temperature criteria first, then

scaling up the size and pumping capacity. This is a good approach because thermal issues are likely to be more difficult to overcome, Furthermore, the commitment of this company to develop pumps suitable for EGS service is an asset.

4.4.5.6 PI Response

No response.

4.4.6 Fielding of HT-seismic Tools and Evaluation of HT-FPGA Module - Development of a HT-seismic Tool

Presentation Number: 020
Investigator: Henfling, John (Sandia National Laboratories)
Objectives: To design, fabricate and field test two high-temperature seismic tools in an EGS application; to work with commercial partners in the development of the tool; and to develop two electronic designs.
Average Overall Score: 2.7/4.0

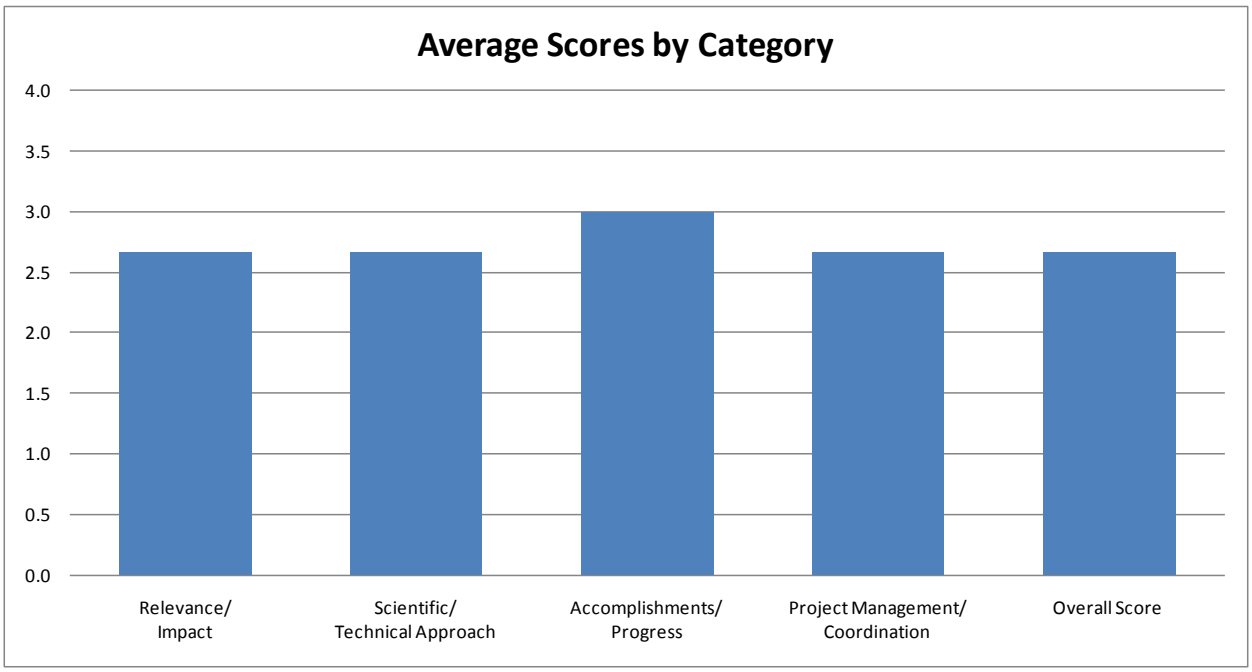


Figure 27: Fielding of HT-seismic Tools and Evaluation of HT-FPGA Module - Development of a HT-seismic Tool

4.4.6.1 Relevance/Impact of the Research

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- Collection of seismic data from geothermal wells are of importance in several areas. Probably most important is in the detection and location of rock fracture events while the well is being stimulated (hydrofractured). This is required in a large number of geothermal wells. Subsequent operation of the well results in pressure changes that in turn create rock fracture events that then can be interpreted to give information on reservoir behavior. Generating seismic information of this type is thus of broad value in almost all geothermal wells.
- The goals of this project could be a stepping stone to higher temperatures. Current goal is 200 °C seismic tools.

- A viable Enhanced Geothermal Systems technology will require down-hole seismic monitoring systems to evaluate the characteristics of the accessible reservoir created by fracturing between wells. Such seismic tools must survive the rigors of the down-hole temperature environment, and other EGS related research and development programs have 300 °C as a goal.

  This project's stated objective mentions "HT" but does not specify a value. Later within the report the figure of greater than 240 °C is mentioned as "desired." The temperature limitation of existing seismic equipment is identified as 125 °C.

  The work reported by this project will advance the temperature resistance of a down-hole seismic tool by a significant amount (to about 200 °C). However, the ultimate achievement of suitable performance at 300 °C may lag other EGS program achievements.

4.4.6.2 Scientific/Technical Approach

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- The scientific and technical approach is based on making improvements to an existing seismic tool that was developed previously by Sandia. Improvements included increasing the thermal resistance of the tool (obviously) but also improving the clamping mechanism, shock resistance etc.

  Considerable effort is going into the selection and integration of the electronic components, with the requirement to balance signal-processing capability against resistance to high temperatures. This appears to be well thought out and correctly executed.

- Approach is to start with known tools/packing and modify the tools for a higher temperature environment. Appears to be making progress and the breakaway portion of the tool will provide an option that reduces the cost of failure.

- The approach is to begin with existing equipment, evaluate the performance of subsystems, seek improvements in each, and then apply the improved components to an improved system assembly. This strategy seems logical and straightforward, but when the technical barriers are considered, may not be the most effective approach.

  Progress is good in some areas; however, some of the subsystems are available only from outside commercial sources and the limitations of these components inhibit progress toward EGS goals. Thus, the rate of progress toward program goals is to some extent beyond the control of the researchers. Consequently, the scope of the research effort is inadequate to fully support progress toward the EGS program goals.

4.4.6.3 Accomplishments, Expected Outcomes and Progress

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Good (3)

Supporting comments:

- Progress has been good (allowing for interruption of funding in 2008) and expected targets are being achieved. Field tests remain to be done.
- The project appears to be on track.
- The overall quality of what has been accomplished is good. The mechanical issues for the down-hole tool have been addressed. Temperature resistance of the motor that drives the clamping mechanism is a weakness, but similar issues are being addressed on other EGS research projects, and those results should eventually be applicable to this problem. The stepper motor as a "place-holder" is a good way to move forward to testing the hardware. The lack of sensor technology that will meet the project specifications has slowed progress. In-house development of a suitable sensor is not in the project scope, and since this is a critical component, its lack is a weakness in the development of the desired tool, and EGS program management may wish to address this shortcoming.

  The quality of research personnel and the available facilities appear adequate for the present project scope and objectives.

4.4.6.4 Project Management/Coordination

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- The project is largely complete. Interruption of funding in September 2008 delayed work. The project is being supported by collaborative work in Halliburton and Harvey Mudd College. This appears to be working well.
- Working with industry for a real world test (Raft River).
- Firm decision points appear to be lacking. Coordination with project partners and suppliers of commercially available components is good. The selected technical approach is being followed correctly. This work has identified barriers to development of a seismic tool that will satisfy EGS program needs. The researchers also have made progress toward a system that is a substantial improvement over current technology. But the project seems nowhere close to developing a system that will satisfy EGS program requirements. Plans to take the development of an EGS seismic system to the next level are a bit fuzzy.

4.4.6.5 Overall

Ratings of Three-member Peer Review Panel: Good (3), Good (3), Fair (2)

Supporting comments:

- A well run project overall. There is a need for high-temperature seismic logging capability in geothermal wells, and this project is moving steadily forward in that direction. Much of the required progress is in the area of complicated signal-processing capacity. COTS equipment is being used, with alternative approaches that balance processing capability against thermal resistance.

- The project is producing solid basic advancement.

- The project objectives appear to be inadequate to support the broad overall goals of the EGS program on an acceptable schedule. It appears that this project is under-planned and underfunded. Other EGS program funded R&D projects on high-temperature electronic circuits, components and cables for transmitting data from down-hole equipment to the wellhead may be applicable to the seismic detection problem. Some critical issues are being worked on by other groups at Sandia. However, coordination with other research projects performed by industrial groups may be problematical due to proprietary issues. But waiting for appropriate electronic components to appear as off-the-shelf items may not be the optimum strategy.

  Perhaps this research group should first focus on development of a seismic sensor that will operate up to 300 ^{o}C, and in the later stages of the EGS program, coordinate with other groups that are developing electronic components, circuits, signal cables, seals and packaging suitable for high-temperature, down-hole conditions.

4.4.6.6 PI Response

No response.

4.5 Seismicity and Seismic

The seven projects in the Seismicity and Seismic technical track entail efforts to develop tools and methodologies for characterizing reservoir dynamics, including protocols for induced seismicity, tools for simulating induced seismicity and geothermal production in EGS, and high-temperature, high-pressure tools for monitoring EGS. Figure 28 summarizes Seismicity and Seismic review scores by evaluation criteria for each PI's project and Table 18 presents detailed scores by reviewer.

Figure 28: Seismicity and Seismic Review Scores by Project PI and Evaluation Criteria

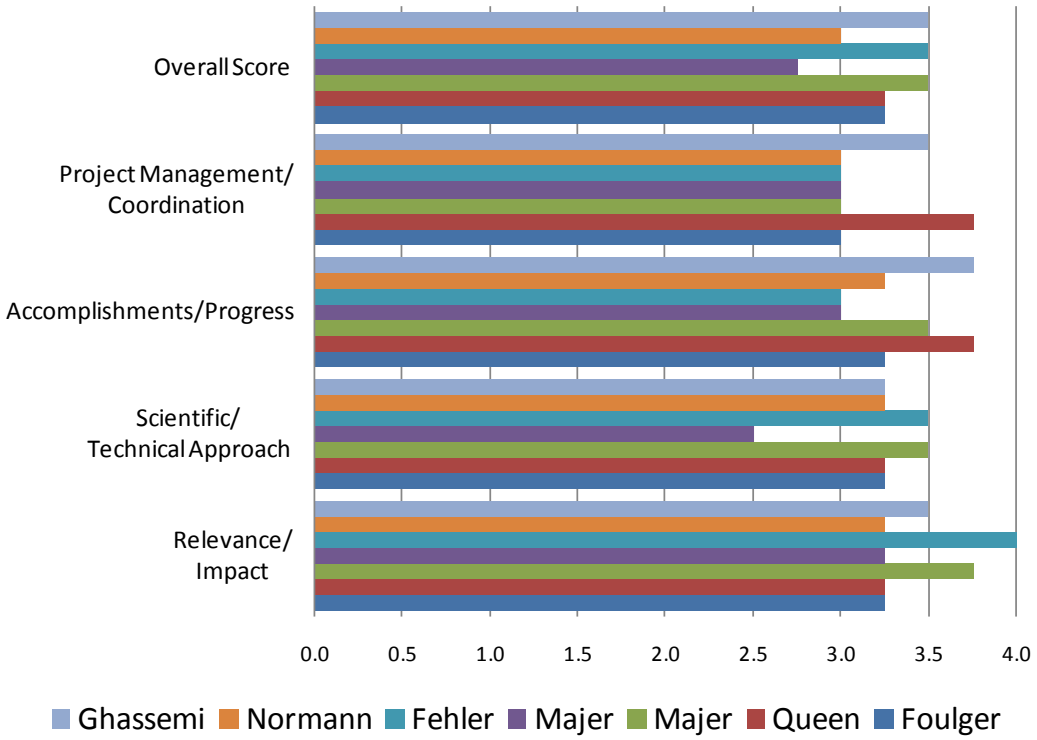


Table 18: Seismicity and Seismic Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Micro-earthquake Technology for EGS Fracture Characterization	Foulger	1	3.0	3.0	3.0	3.0	3.0
		2	3.0	3.0	3.0	3.0	4.0
		3	4.0	4.0	4.0	4.0	4.0
		4	3.0	3.0	3.0	2.0	2.0
		Average	3.3	3.3	3.3	3.0	3.3
Seismic Fracture Characterization Methods For Enhanced Geothermal Systems	Queen	1	3.0	2.0	3.0	4.0	3.0
		2	3.0	3.0	4.0	4.0	3.0
		3	3.0	4.0	4.0	4.0	3.0
		4	4.0	4.0	4.0	3.0	4.0
		Average	3.3	3.3	3.8	3.8	3.3

Table 18 (continued): Seismicity and Seismic Review Scores

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Micro-seismic Study with LBNL - Monitoring the Effect of Injection of Fluids from the Lake County Pipeline on Seismicity at The Geysers, California Geothermal Field	Majer	1	3.0	4.0	3.0	3.0	3.0
		2	4.0	3.0	3.0	3.0	3.0
		3	4.0	3.0	4.0	3.0	4.0
		4	4.0	4.0	4.0	3.0	4.0
		Average	3.8	3.5	3.5	3.0	3.5
Development of an Updated Induced Seismicity Protocol for the Application of Micro-earthquake Monitoring for Characterizing Enhanced Geothermal Systems	Majer	1	3.0	3.0	2.0	3.0	3.0
		2	3.0	2.0	2.0	3.0	2.0
		3	4.0	2.0	4.0	3.0	3.0
		4	3.0	3.0	4.0	3.0	3.0
		Average	3.3	2.5	3.0	3.0	2.8
Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System Reservoir	Fehler	1	4.0	3.0	3.0	4.0	4.0
		2	4.0	3.0	3.0	3.0	3.0
		3	4.0	4.0	3.0	3.0	4.0
		4	4.0	4.0	3.0	2.0	3.0
		Average	4.0	3.5	3.0	3.0	3.5
Well Monitoring Systems for EGS	Normann	1	3.0	3.0	4.0	3.0	3.0
		2	3.0	3.0	3.0	3.0	3.0
		3	3.0	4.0	3.0	4.0	3.0
		4	4.0	3.0	3.0	2.0	3.0
		Average	3.3	3.3	3.3	3.0	3.0
Analysis of Geothermal Reservoir Stimulation using Geomechanics-based Stochastic Analysis of Injection-induced Seismicity	Ghassemi	1	3.0	3.0	3.0	3.0	3.0
		2	4.0	3.0	4.0	4.0	4.0
		3	3.0	3.0	4.0	4.0	3.0
		4	4.0	4.0	4.0	3.0	4.0
		Average	3.5	3.3	3.8	3.5	3.5

4.5.1 Microearthquake Technology for EGS Fracture Characterization

Presentation Number: 021
Investigator: Foulger, Gillian (Foulger Consulting)
Objectives: To understand how EGS fracture networks develop; to develop technology to determine accurate absolute three-dimensional positions of EGS fracture networks; to understand the physical source processes of earthquake moment tensors; to develop new technology for determining three-dimensional seismic wave-speed structures of reservoirs; to transfer state-of the art microearthquake EGS technology to industry.
Average Overall Score: 3.3/4.0

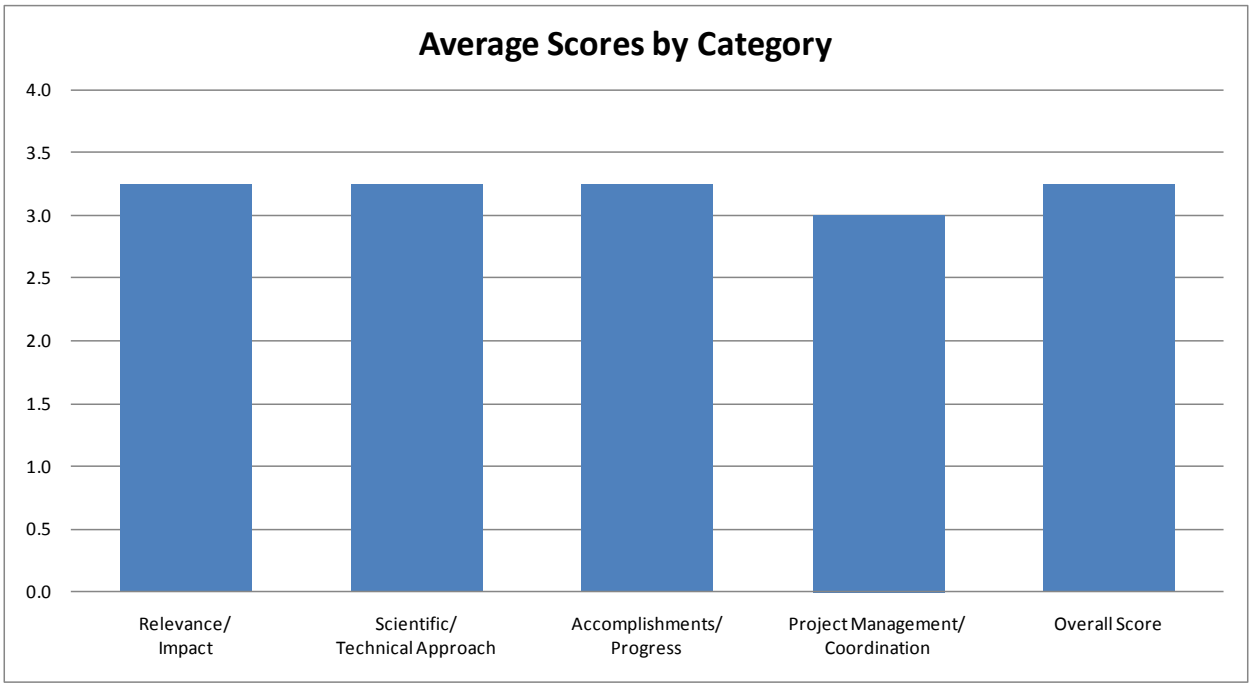


Figure 29: Microearthquake Technology for EGS Fracture Characterization

4.5.1.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- This project develops tools and methodology for characterizing reservoir dynamics using microseismicity. The main approaches are improved earthquake locations (including both relative and absolute locations) and source characteristics such as full moment tensor solutions. The latter may in principle provide valuable information about the type of failure (slip on a fault versus volume change) and bear on fluid transport within the geothermal reservoir.

- More examples of locations and inversions of real data would have been useful to see. Progress has been made on the coding aspects but the applications have not shown significant improvement over earlier studies.

- Two of the major impediments to understanding the role of microearthquakes (MEQ) in EGS have been the incomplete understanding of their mechanisms, and inaccurate/imprecise MEQ locations. This project aims to develop technology that will aid in both situations. Progress toward this goal is appropriate for project length.

- This microseismic software development project, if successfully completed, will make an important contribution to the Geothermal Program mission. The project activities will illuminate, not necessarily solve, known technical barriers, such as how fractures migrate when fracturing the rock. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.1.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Techniques developed by the PIs will be helpful for monitoring geothermal production. Some questions raised by the panel include (1) likely trade-offs between absolute earthquake locations and the 3-D velocity model and (2) the minimum earthquake magnitude for which a full moment tensor solution can be obtained. If the magnitude is sufficiently large (given surface or shallow borehole observations), the amount of earthquakes available for such analysis will be relatively small, limiting its overall usefulness. These issues need to be carefully addressed.

- Technical approach is good, methodology is clear and researchers are competent. Most of the techniques presented are established and well known. I would have liked to see more advanced (creative) methodologies developed - what about anisotropy?

- The project discards inefficient and incomplete prior attempts at software solutions, while building on them for their new techniques. It is remarkably well-focused. They have narrowed their work to include only P and S wave amplitudes, rather than matching waveforms, and this makes the work easier, although less precise, while allowing smaller earthquakes (and therefore larger numbers of earthquakes) to be studied.

- The overall technical approach is good. Microseismic tools like this are very important if microseismic locations as a function of time are considered important. However, it is not clear from the presentation that the authors are aware of the literature which means that this work might have already been done or can be done better with other techniques, i.e., not state-of-the-art R&D. This reviewer is familiar with other location codes and techniques that were not

mentioned by the authors. It looks like there are adequate resources and more than sufficient rigor of the work elements, as well as procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline.

4.5.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- During the first year of the project the main advance was the development and testing of the computer codes. This part of the project seems to be on track.

- Research team is excellent. Bruce Julian is a leader in the field and will bring significant insight into the management and progress of this effort. At this point in the research it is still too early to tell if major advances will be made through this work.

- The team is highly qualified for this project, and they are deploying appropriate effort to it.

- The overall quality of the research team, equipment and facilities is very good given the list of partners. That being said, relevant experience and the balance of appropriate skills of the research team are unknown because individual contributors were not listed. There are several accomplishments to date and the results look promising, but the project is, according to my rough calculations, behind schedule (report says 30% scope done in 1.4 years out of 3.1 years total or 45% schedule = behind schedule by 15%). I was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.1.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Fair (2)

Supporting comments:

- The work accomplished so far indicates a fairly effective management.

- I would have liked to see more actual application at this point in time. Assessment of absolute locations and the errors involved should have been done.

- It appears that the project is well-managed.

- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically on track and project decisions points are appropriately placed.

4.5.1.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Fair (2)

Supporting comments:

- The project is in the initial phase and it is hard to evaluate the overall outcome at this point. The initial presented results using limited sets of data look encouraging. It will be important to demonstrate the utility and applicability of the full moment tensor inversions for microearthquakes.

- Overall I rate this effort significant. The researchers have a lot of experience working in the geothermal area and are computation experts. I have high confidence that they will make a significant contribution.

- If this project is successful, and it appears that it will be, the products (software) will be useful in other fields. It will assist other investigators in studying any EGS field.

- Overall, this reviewer recommends that the project proceed. However, it might be prudent to ask the research team to put a white paper together surveying and discussing the entire field of microseismic location algorithms and software available and why they have decided to build their own. It is recommended that the PI accelerate the tasks to catch-up on schedule variance.

4.5.1.6 PI Response

No response.

4.5.2 Seismic Fracture Characterization Methods for Enhanced Geothermal Systems

Presentation Number: 022
Investigator: Queen, John (Hi-Q Geophysical Inc.)
Objectives: To develop surface and borehole seismic methodologies using both compressional and shear waves for characterizing faults and fractures in Enhanced Geothermal Systems.
Average Overall Score: 3.3/4.0

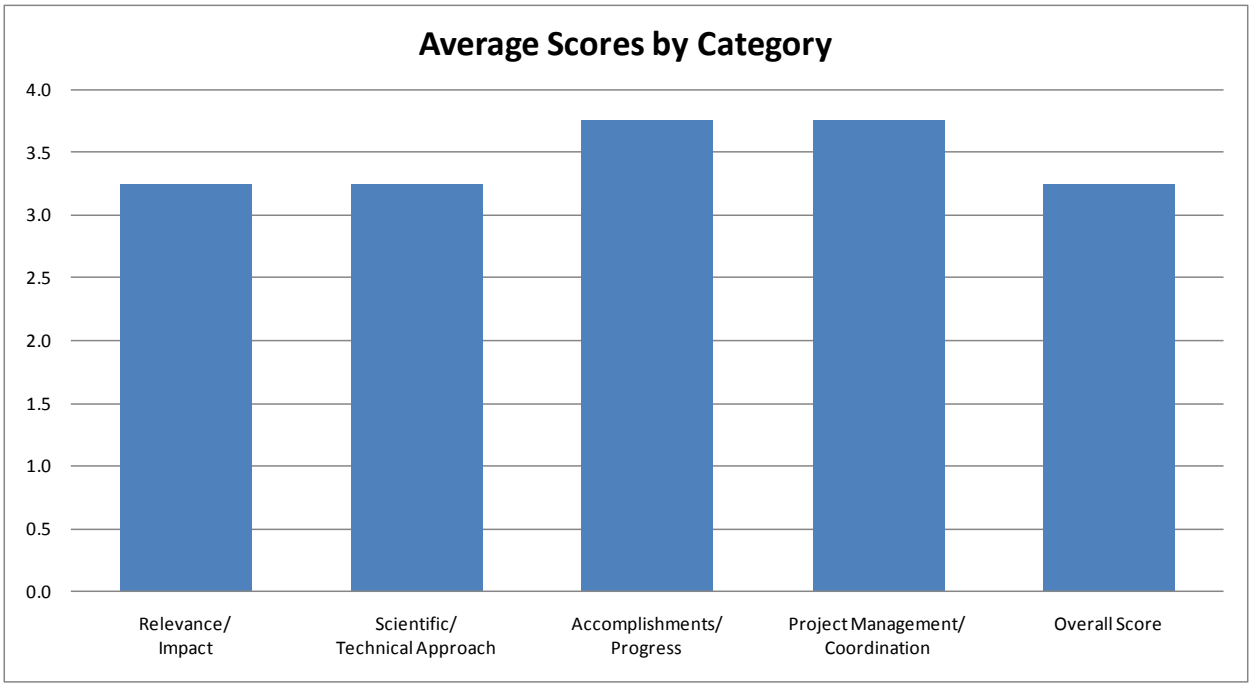


Figure 30: Seismic Fracture Characterization Methods for Enhanced Geothermal Systems

4.5.2.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- Characterization of fracture properties of subsurface reservoirs has been a challenging task, especially in geothermal areas. Seismic profiling/tomography provides the highest resolution of all available geophysical techniques, but its utility for mapping fluid-filled fractures and/or pore space is yet to be demonstrated. This project is still in the initial phase. Only models have been explored so far. Some presented results look encouraging, but the actual data analysis will be crucial for demonstrating the concept.

- This research is critical for "ground truthing" of geological structures in the geothermal area. The lack of estimation of Q (attenuation), or the lack of the discussion of this problem, prevents

me from assigning an excellent score. The program is focused on one geothermal field so the results will not be transferable to other localities (without significant additional investment).

- This project tries to solve a nagging problem: the inability to image the subsurface in typical EGS fields. It does so by developing highly sophisticated and detailed models for guiding processing of seismic data. It appears to have made good progress, but as in all field projects, the real test will come when data are acquired.

- This advanced seismic imaging and gravity method development project, if successfully completed at Brady's HS, should make an important contribution to the Geothermal Program mission. The project's activities could solve known technical barriers, such as what was the pre-existing structure and fracture distribution before stimulation. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.2.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Fair (2), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- The PIs have done some forward calculations using idealized models of seismic wave propagation through fractured rocks. The subsurface structure of the test site was approximated using a layered structure with subvertical discontinuities representing faults. Seismic velocities were assigned to different layers, and the time-dependent wave field was calculated for the assumed sources. The purpose of this simulation was to demonstrate that the presence of fractures has an effect on the seismic wave propagation (and can be in principle detected using surface and/or borehole measurements). The effect of fractures was simulated by introducing anisotropy in the seismic velocity structure. The PIs have shown a potentially measurable effect, but it remains unclear how robust this approach will be when actual data are analyzed. In particular, effects of randomly oriented cracks on seismic anisotropy are not well understood. Uncertainties in the (isotropic) velocity structure may trade off with effects of anisotropy. Attenuation of seismic velocities is not considered, which may present a problem (attenuation is likely to be increasingly significant in highly fractured reservoirs). Effects of anisotropy may be subtle and difficult to detect.

- The lack of estimation of Q (attenuation), or the lack of the discussion of this problem, prevents me from assigning an excellent score.

- The technical approach brings in the current state-of-the-art in controlled-source seismology, especially including borehole geophysics. At first glance, the project appeared to be a grab bag of technologies, but on questioning, it became clear that there was, indeed, a scheme behind it. The near-offset VSP will be used to provide a better baseline velocity model, on which a

multi-offset VSP and 3-D survey will be designed. The micro-gravity survey will assist greatly with the shallower parts of that model. The timing and sequence of events is appropriate with this goal.

- The overall technical approach is outstanding. Seismic methods at this over-sampled resolution will provide a detailed look at subsurface fractures and faulting which are very important. Coupling these analyses with gravity and merging it all into a 3-D model will be very significant and is considered by this author state-of-the-art R&D. It looks like there are adequate resources and more than sufficient rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline.

4.5.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- The performed work appears to be on schedule. The PIs are qualified to accomplish the tasks specified in the proposal.

- The researchers are making reasonable head way in achieving the stated goals of wave characterization in complex media.

- The past accomplishments of the team, and the resources brought to bear, are impressive. Of course, the work is still in early development stage.

- The overall quality of the research team, equipment and facilities is outstanding given the list of partnering organizations and individual team members. Relevant experience and the balance of appropriate skills of the research team are outstanding with some team members known to this reviewer. There are several accomplishments to date and the results look very promising, and the project is, according to my rough calculations, on schedule (report says 33% scope done in 1.2 years out of 3.3 years total or 37% schedule = on schedule). Was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.2.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- A positive outcome of this project critically depends on the expertise of PIs and efficiency of their collaboration with operators of the target geothermal site. It appears that the "simulation"

phase of the project is completed, and preparation for the field data collection are well under way.

- Project seems to be managed well.
- The project appears to be well-organized and managed.
- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically on track and project decisions points are appropriately placed. This project has very good project management and coordination.

4.5.2.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- This project is in a "high risk/high potential yield" category. Seismic mapping of subsurface fracture systems is an extremely challenging task, and some of the proposed goals may be overly optimistic. Insights obtained in the course of this work may be valuable for guiding future investigations.
- The two dimensional nature of the modeling from VSP seems somewhat limiting.
- This is a high-risk, high-payout project. It may fail, and if it does, nobody else will attempt this work for a long time, because there are few people who could do it so well as this team. If it succeeds, it will change the way exploration for EGS is carried out.
- Overall, this reviewer enthusiastically recommends that the project proceed ahead. In the reviewers opinion this project is one of the best in all the projects reviewed and should be funded as a high-priority project if funds are limited. The amalgamation of geophysical methods and a 3-D model is a very powerful technique and should provide insightful data and information to the EGS program.

4.5.2.6 PI Response

No response.

4.5.3 Microseismic Study with LBNL - Monitoring the Effect of Injection of Fluids from the Lake County Pipeline on Seismicity at The Geysers, California, Geothermal Field

Presentation Number: 023
Investigator: Majer, Ernie (Lake County)
Objectives: Upgrade and continue operation of a high resolution seismic array for five years at The Geysers as well as expand the array to record seismicity from any new additional DOE EGS sites at The Geysers as they come on line; to use microearthquake monitoring to understand and intelligently manage the effects of fluid injections and stimulations to aid in the optimization of EGS.
Average Overall Score: 3.5/4.0

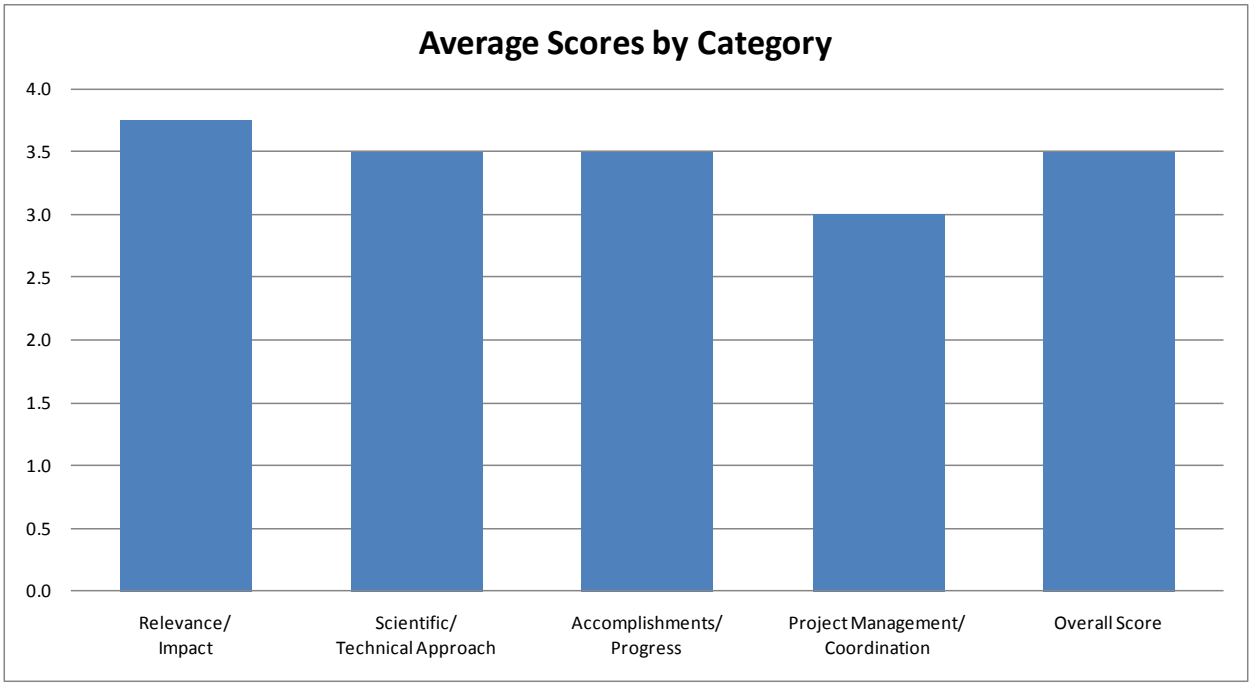


Figure 31: Microseismic Study with LBNL – Monitoring the Effects of Injection of Fluids from the Lake County Pipeline on Seismicity at The Geysers, California, Geothermal Field

4.5.3.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- The first phase of the project was to upgrade the existing seismic network at The Geysers geothermal field in northern California, including an addition of 6 new stations, and strong motion instruments. The instrument deployment seems to be on track.

- The seismic array at The Geysers is critical to our understanding of geothermal processes. We must support this work and use The Geysers as a laboratory for comparison with all other studies of seismicity in geothermal settings.

- This project is essential. But it is not really RESEARCH in a basic sense, nor will it create new information except for details of one site. It does, however, demonstrate an excellent way to deal with public perceptions and to maintain baseline monitoring for EGS studies. It is an excellent demonstration project.

- This microseismic injection-monitoring R&D project at The Geysers, if successfully completed, will make a very important contribution to the Geothermal Program mission. The project activities could solve known technical barriers, such as reservoir validation, scale up, and long-term sustainability as well as illuminate scientific issues including how fractures migrate when fracturing the rock and under what conditions. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.3.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4)

Supporting comments:

- Analysis of high-quality seismic data from a large active production site are clearly warranted for better understanding of the nature of injection-related seismicity. The PI team is capable of performing the tasks outlined in the proposal.

- I did not see significant "new" technical innovations in the technical report. Hypocenter locations were shown, although little discussion of the error or variation over time was discussed. What is the meaning of the donut hole in seismicity? How did earlier seismicity maps show that region? I would have expected to see some of that information presented if the researchers are going to focus on that as a major goal of this research.

- The approach is excellent, but there should also be a Broadband instrument (or two or three) involved.

- The overall technical approach is outstanding. Monitoring, locating and performing MEQ source mechanism calculations and correlating these with The Geysers injection/production data are very exciting and important tasks. It looks like there are adequate resources and more than sufficient scientific rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and in the project timeline.

4.5.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- The project is in the initial stages, so little data are available for analysis and evaluation. The data that do exist clearly show a causal relationship between the injection rates and the overall seismic activity. Further work will refine the spatiotemporal patterns of the induced seismicity and geothermal production.
- Still too early to know what the results of this effort are going to be.
- The team is amazingly productive and focused.
- The overall quality of the research team, equipment and facilities is outstanding given the PI and list of partners. Many of the researchers are known to this reviewer and are top-notch. Relevant experience and the balance of appropriate skills of the remainder of the research team seem to be very good. There are several accomplishments to date, the results look promising, and the project is, according to my rough calculations, on schedule (10% scope done so far in 0.6 years out of a total of 5 years or 13% schedule consumed = behind schedule by 3%). I was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.3.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- The project involves a productive collaboration between seismologists at Livermore and UC Berkeley. The work plan is carefully outlined and so far appears to be executed in a timely manner.
- I am not sure - there were many unanswered questions - the lead PI was not here and the presenter could not answer some of the critical questions.
- It is difficult to judge the project management. The PI was unable to present, and the presenter was unfamiliar with some aspects. Perhaps the rating should be higher, or perhaps lower; I cannot really tell.
- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically, on track. However, project decisions points were not discussed.

4.5.3.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- The Geysers is an excellent target for understanding relationships between the induced seismicity and geothermal production. This project will provide important insights into our understanding of microearthquakes, as well as potential for larger events, in an actively developed geothermal field (largest in the US).

- Overall the project is progressing in a reasonable manner. I strongly support the continuation of The Geysers project.

- This project is an excellent demonstration project, accomplishing (apparently) all that it set out to do.

- Overall, this reviewer enthusiastically recommends that the project proceed ahead. In the reviewers opinion this project is one of the best in all the projects reviewed and should be funded as a high-priority project if funds are limited. This microseismic injection-monitoring R&D project at The Geysers will solve known technical barriers that should provide insightful data and information to the EGS program.

4.5.3.6 PI Response

No response.

4.5.4 Development of an Updated Induced Seismicity Protocol for the Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems

Presentation Number: 024
Investigator: Majer, Ernie (Lawrence Berkeley National Laboratory)
Objectives: To develop an updated protocol/best engineering practices to address public and industry issues associated with induced seismicity; to identify critical technology and research needs/approaches to advance the understanding of induced seismicity associated with deep well injection and production; and to perform community outreach and education.
Average Overall Score: 2.8/4.0

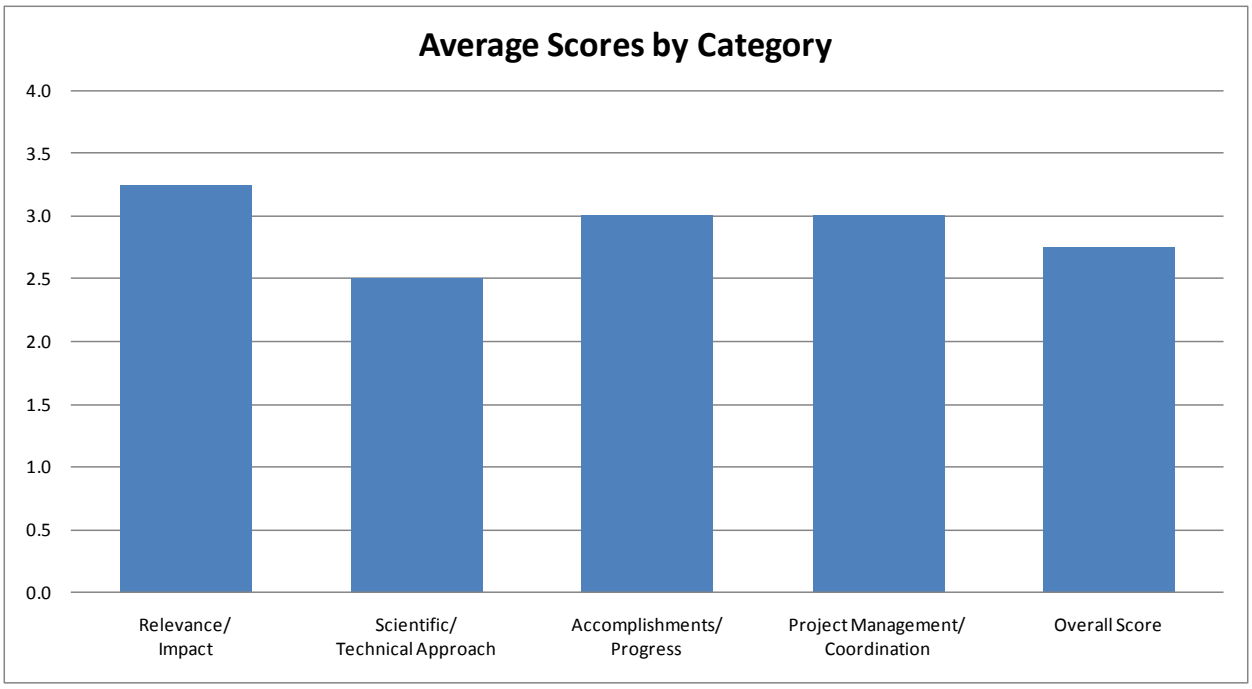


Figure 32: Development of an Updated Induced Seismicity Protocol for the Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems

4.5.4.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The issue of induced seismicity is clearly paramount for geothermal operations, especially in or near populated areas. The use of best available science is necessary to address the associated risks. This project is developing guides and protocols to identify and evaluate seismic hazards associated with geothermal production through a series of workshops and discussions with a broader community. The problem is complicated by the fact that the occurrence of "natural"

earthquakes is far from being understood, and separation of "induced", "triggered" and "background" seismicity is not straightforward.

- The project seems to be important but I am not sure how this mission is best pursued and I was not convinced by the presentation that the direction is correct.

- This project is extremely important for DOE's goals. It has made excellent progress.

- This induced-seismicity protocol development project, if successfully completed, will make an extremely important contribution to the Geothermal Program EGS mission. The project activities will enable approaches to barriers, such as, siting, leasing, and permitting issues and technical barriers such as reservoir validation. If this project is successfully completed, this reviewer is certain that the EGS program will benefit and that the results will surely enable future EGS projects.

4.5.4.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Fair (2), Fair (2), Good (3)

Supporting comments:

- Issues of induced seismicity are not new, and general relationship between fluid injection and earthquakes is fairly well understood in the context of the effective stress and the Mohr-Coulomb failure theory. The goal of "mitigation" of seismic risks due to fluid injection is, however, rather tenuous. It is not clear what is meant by "mitigation". Fluid injection is known to stimulate seismic activity, and the level of that activity depends on a local tectonic regime.

- They need a sociologist on the project to try to estimate if the connection between the stated goals and progress towards achieving those goals is actually converging. Has there been a real raising of awareness by the public? How can one know if the goals are being achieved? By what measure can we know if the connection to the public is being made?

- Here is where I am concerned: this project seems to assume that the scientists and engineers are capable of determining, and will determine, just what it is that the public needs, and then will engage the public in forums where the scientists and engineers will tell them what they have been determined to need to know. This is the wrong approach. While scientists and engineers need to get their house in order, and this project is accomplishing this goal extremely well, at some point PRIOR to issuing protocols, there must be a genuine ENGAGEMENT in DIALOG with the social scientists, public figures, land-use planners, insurance companies, emergency management planners and first responders, and so on. Only through this dialog will we be able to ensure that appropriate aspects are incorporated, from the end-user's point of view, and the end-users are the companies involved and the public they deal with. The

investigators seem to think that the end users are the scientists who will then explain this stuff to the ignorant masses. That approach will not work well.

- The overall technical approach is good. Developing an induced seismicity protocol and identifying R&D needs is probably the most important project that needs to be done or otherwise EGS is doomed. It looks like there are adequate resources and more than sufficient scientific rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and in the project timeline.

4.5.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Fair (2), Fair (2), Outstanding (4), Outstanding (4)

Supporting comments:

- There is a need for a deeper and broader involvement and education of the general public in this process.

- Meetings were convened and protocols were discussed but I could not figure out how they would tell if they were progressing.

- The team has been extremely productive and efficient.

- The overall quality of the research team, equipment and facilities is outstanding given the PI and list of participants. Many of the participants are known to this reviewer and are world-class. Relevant experience and the balance of appropriate skills of the remainder of the participants are very good. There are several accomplishments to date, the results look promising, and the project seems to be on schedule. I was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.4.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- The PIs were fairly effective in organizing workshops, establishing a dedicated website and building a scientific community (both in the US and internationally) to address the project goals.

- Management seems to be reasonable. More interaction with the public may be useful. Perhaps a means to assess progress would be helpful too.

- This is difficult to judge. The project seems to be managed well.

- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically on track. At the panel review a reviewer recommended greater public interaction and this reviewer agrees. Moreover, in this reviewer's experience as Superfund manager at LLNL for 10 years, experts cannot tell the public what needs to be done, the experts need to listen to the concerns of the public and address those concerns directly and in person, otherwise, this will not convince them the induced-seismicity is not a problem.

4.5.4.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Fair (2), Good (3), Good (3)

Supporting comments:

- Development of a science-based protocol and/or engineering guide for dealing with induced seismicity issues is critical for a successful operation of a geothermal plant. This project provides a necessary framework for developing such a protocol, although some issues (such as the mitigation strategy and procedures for interaction with the general public) need to be addressed in a more explicit fashion.

- I could not understand how the progress of this project was going to lead to a deeper understanding of the mission as stated.

- For accomplishing a forum of scientists and engineers to discuss technical issues, this project has been amazing and the best in the world. For accomplishing the goal of evaluating needs of the public and trying to meet those needs, it is falling short due to the lack of engagement of non-scientists.

- Overall, this reviewer enthusiastically recommends that the project proceed with the modification of increased public interaction. In the reviewer's opinion this project must be successful if EGS is going to move forward and should be funded as a high-priority project if funds are limited.

4.5.4.6 PI Response

No response.

4.5.5 Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir

Presentation Number: 025
Investigator: Fehler, Michael (Massachusetts Institute of Technology)
Objectives: To better understand and model fluid injection into a tight reservoir on the edges of a hydrothermal field; to use seismic data to constrain geomechanical/hydrologic/thermal model of reservoir; to model for flow network to predict injection and production response of reservoir; and to use model and data analysis to develop improved stimulation methodologies leading to improved production during EGS development.
Average Overall Score: 3.5/4.0

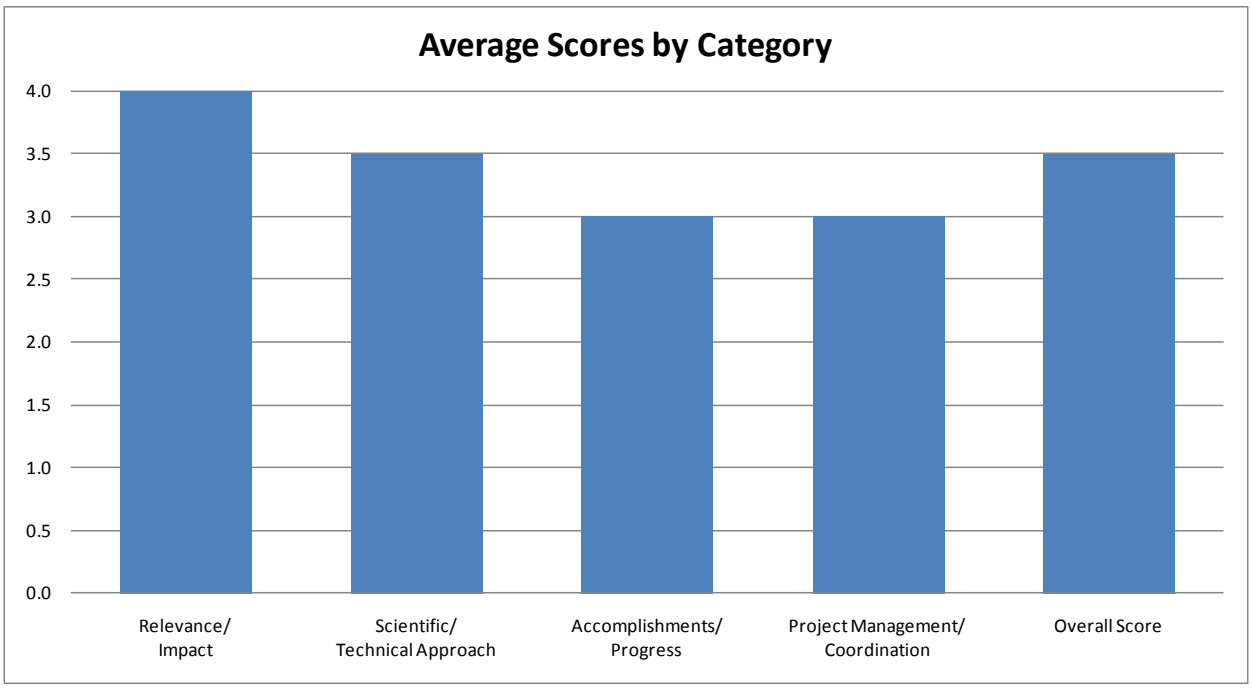


Figure 33: Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir

4.5.5.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- This project makes use of a proprietary data set collected by Chevron in the Salak geothermal field in Indonesia. The ultimate goal is to characterize subsurface fracture system and reservoir permeability (possibly, their temporal evolution) using microseismicity. This work is well aligned with DOE goals and holds a promise of substantially improving our understanding of relationships between fluid injection, fracturing, and associated seismicity.

- The work stated here is highly relevant to our understanding of seismicity, flow and crack distribution in geothermal settings. It would be good to see a few more advanced applications being developed.

- The project is trying to tie together explicitly the microearthquakes, velocities, and reservoir behavior (as best known based on data provided). It is very likely going to be the best such study available.

- This combination of detailed high-resolution microseismicity and Green's function interferometry with a state-of-the-art geomechanical model to characterize a stimulation project, if successfully completed at Salak in Indonesia, should make an important contribution to the Geothermal Program EGS mission. The project's activities could solve known technical barriers, such as constraining reservoir models using geophysical data and improving reservoir development scenarios. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.5.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- The main premise of the project is that induced microearthquakes highlight locations of fractures and fluid pathways within the geothermal reservoir. This is a reasonable assumption, but the details of relationship between induced seismicity and effective hydraulic permeability are still rather poorly understood. One big unknown is the background stress. The PIs hope to characterize stress within the reservoir using earthquake focal mechanism data. It is unclear how efficient this approach will be given difficulties with focal mechanism solutions for small events.

- Application of HypoDD seems complicated and may be a waste of time. The lead PI is an expert in scattering and it would be good if the team concentrated on that aspect.

- The presenter provided almost exclusively the seismicity side of the project, which is, as one might expect, setting new standards for the state of the art. The reservoir modeling side was less well covered, and it is difficult to judge, but is likely to be just about as good, based on what was said.

- The overall quality of the research team, equipment and facilities is outstanding given the list of partnering organization (e.g., Chevron) and individual team members. Relevant experience and the balance of appropriate skills of the research team are outstanding with some team members known to this reviewer. There are several accomplishments to date but most are initiations of tasks not completions. Not a lot of results and it is not clear if the project is on

schedule or not because the scope completion percentage question was not provided. According to the calendar the project should be 34% done. My guess is the project is behind schedule. Also, this reviewer was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.5.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- Analysis of seismic data has already begun and initial results are encouraging.
- To date the main accomplishment has been to organize the agreements between the participants - scientific accomplishments are at this point a little too sparse to assess fairly.
- Perhaps this should be "outstanding" but the project is still young, and they have just gotten started with the data provided.
- The technical, policy, business, and spend plans for the project are not presented clearly, the individual tasks make sense and are, at least logistically, on track and there is one appropriately placed project decision point. Because this is a University-led project, the technical plan predominates and policy, business and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed.

4.5.5.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Fair (2)

Supporting comments:

- The PI is doing a great job coordinating efforts of the MIT and Chevron teams. This is a multi-disciplinary study involving data collection, seismic analysis and geomechanical modeling, all parts being important to the success of the project.
- Project has slowed down due to complex negotiations with partners. We did not get to see any data because of concern for proprietary interests - so it was difficult to assess the long term likelihood of success. The problem of proprietary data is significant because if the PI's cannot share the results with the larger community there will be no significant benefit to those advancing the field.
- Again, this is difficult to judge, but seems to be a network of like-minded scientists/engineers with a common goal and disparate backgrounds and talents. Given the track record of the PI, this method is likely to work well. But it isn't obvious that there are systematic approaches to ensuring progress.

- The technical, policy, business, and spend plans for the project are not presented clearly, the individual tasks make sense and are, at least logistically, on track and there is one appropriately placed project decision point. Because this is a University-led project, the technical plan predominates and policy, business and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed.

4.5.5.5 Overall

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Monitoring of seismicity, fracture system evolution, and productivity of geothermal wells in response to thermal stresses due to injection of cold water is a clever experiment. Insights gained from this work will be directly applicable to strategies for development of Enhanced Geothermal Systems.

- Overall this project looks like it will be promising, but the lack of data presented and the slow initial progress due to partner sluggishness formed a barrier to a clear assessment of progress.

- In spite of some less-than-outstanding grades in specific areas, this project is nearly certain to develop a piece of work that will set the standard for incorporating data and modeling in EGS.

- Overall, this reviewer enthusiastically recommends that the project proceed ahead. In the reviewers opinion this project is one of the top projects among all the projects reviewed and should be funded as a high-priority project if funds are limited. The combination of detailed high-resolution microseismicity and Green's function interferometry with a state-of-the-art geomechanical model to characterize a stimulation project is innovative and should be a very powerful technique that should provide insightful data and information to the EGS program.

4.5.5.6 PI Response

No response.

4.5.6 Well Monitoring Systems for EGS

Presentation Number: 026
Investigator: Normann, Randy (Perma Works and Frequency Management International)
Objectives: To address the immediate needs of the Geothermal EGS industry for monitoring hydraulic fracturing activities, reservoir recovery testing, well interconnectivity and production monitoring while creating the ability to build-in future reservoir controls.
Average Overall Score: 3.0/4.0

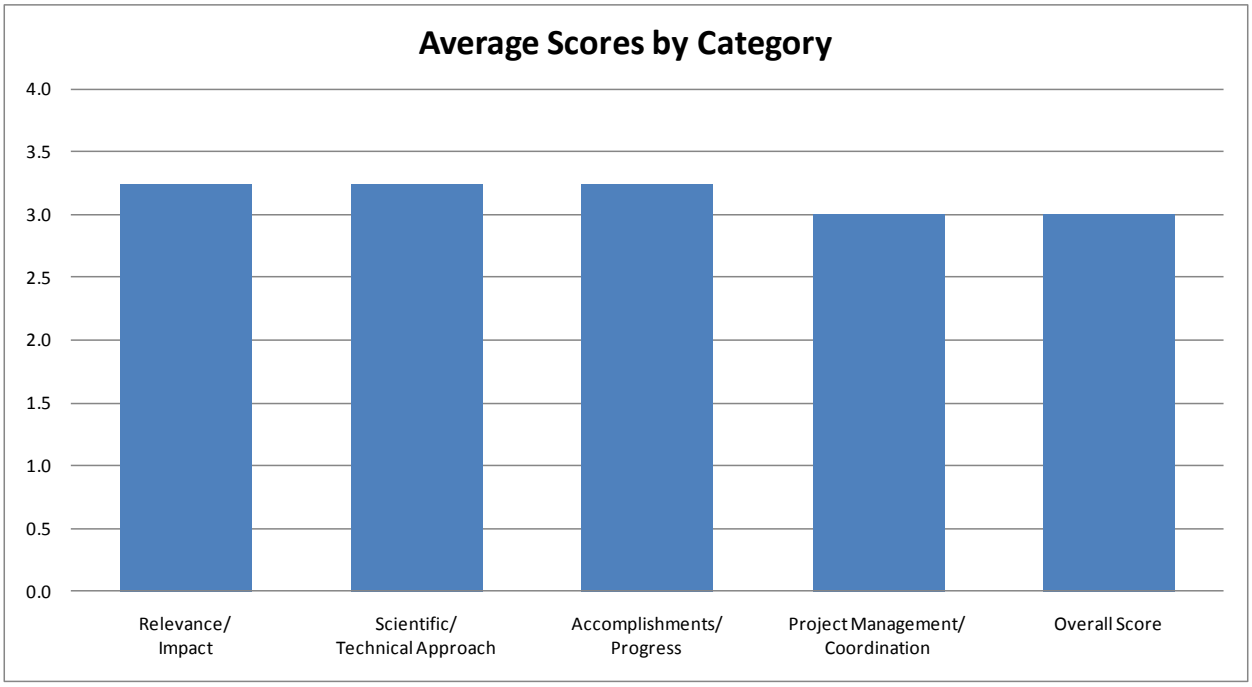


Figure 34: Well Monitoring Systems for EGS

4.5.6.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- This projects develops instrumentation and sensors that are capable of operating in a high-temperature regime appropriate for borehole conditions in geothermal production areas. The PI has demonstrated working prototypes of such equipment. These developments are relevant for the DOE goals as continuous in situ monitoring of geothermal production will improve operation of EGS.

- New borehole tools are critical for making progress in management of geothermal fields.

- This project is intended to provide high-temperature, high-pressure tools for monitoring EGS. This is sorely needed. The project seems to be on track.

- High-temperature (HT) geothermal tool development is very important for it enables the solution of many other EGS barriers and if successfully completed, should make a very important contribution to the Geothermal Program mission. The project's activities should provide a better understanding of known technical barriers, such as reservoir creation, validation and sustainability, as well as inter-well connectivity and overall reservoir management. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.6.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- This is primarily a technological development. The PI team is at the leading edge of high-temperature sensor production both nationally and internationally.

- Not clear how deep the instruments will be able to perform. Other than temperature and pressure, what other tools could be attached to the borehole device?

- The investigators are dealing with subcontractors for appropriate materials and approaches. They have isolated the problems to deal with, and have mapped out a nice approach to reaching a final product -- starting with analog tools, then digital tools, and finally leading to fiber-optic. They may well succeed, but if they don't, they will have the intermediate products which will themselves be of great use.

- The overall technical approach looks good. HT tools will make a significant difference to EGS monitoring and understanding while providing cost savings. Adequate resources are evident, however, this reviewer is not able to assess if there is sufficient rigor of the work elements, procedures and methods to achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clear tasks descriptions are provided. What are not evident are a project timeline and a delineation of tasks and subtasks by partner.

4.5.6.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Good (3)

Supporting comments:

- A high-temperature probe was developed and successfully tested.

- The borehole tool looked to be useful and the levels of temperature resistance are improving - I think the cabling may be a problem in real world situations. Cramming high-tech instruments down hot boreholes is a very tricky business and testing in the labs is only part of the rigorous assessment that needs to be performed.

- It appears that the project has accomplished its goals so far; the investigators seem to have great experience and are likely to succeed.

- The overall quality of the research team, equipment and facilities looks good given the long list of partnering organizations and the assumption that more is better—none of the partners are familiar to this reviewer. Relevant experience and the balance of appropriate skills of the research team looks okay, however, this reviewer is not an expert in this field of HT tool development. This reviewer knows none of the team members. There are several accomplishments to date and Phase I is completed (33%). According to the calendar the project should be 47% completed so my guess is that the project is behind schedule by 14%, which is significant. Also, this reviewer was not able to ascertain the accomplishments as compared to costs to date (Cost of Work Performed) since current costing was not given.

4.5.6.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Fair (2)

Supporting comments:

- All bits and pieces required for a successful completion of the project appear to be in place. The PIs are maintaining a dialog with other potential producers of high-temperature borehole sensors and are investigating plans for commercializing their product.

- Management looked to be good - it is too early to tell if the product will be priced at a level useful to researchers outside of industry.

- This is difficult to judge, but it appears that the project management is extremely business-like, and is working well.

- The technical, policy, business, and spend plans for the project are not presented simply or clearly in one place. The individual tasks make sense and are on-track and there is one appropriately placed project decision point. Because this is a for-profit, private company, the business plan predominates and the technical, policy, and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed that includes all of the requisite plans described.

4.5.6.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- New equipment produced under this project will be beneficial for monitoring of EGS reservoirs.
- This looks to be a reasonable effort overall - it is not clear how non-commercial research teams will benefit. The testing is in the early stages and needs to be checked in situ in real wells at realistic depths.
- This project is valuable, and is likely to succeed in delivering tools that can be deployed long-term in producing or injecting wells. I see no weaknesses, but also find little risk - it is a project that needs to be done.
- Overall, this reviewer recommends that the project proceed. In the reviewer's opinion, this project is a very important component of the overall EGS portfolio and should be funded. HT geothermal tools and sensors that can be left in place for long periods and during stimulation tests is a real improvement, saving costs and providing a never-before available capability that should have significant impact and gather pertinent data for all other projects in the EGS program.

4.5.6.6 PI Response

No response.

4.5.7 Analysis of Geothermal Reservoir Stimulation Using Geomechanics-based Stochastic Analysis of Injection-induced Seismicity

Presentation Number: 027
Investigator: Ghassemi, Ahmad (Texas A&M University)
Objectives: To develop a model for seismicity-based reservoir characterization (SBRC) by combining rock mechanics, finite element modeling, geostatistical concepts to establish relationships between microseismicity, reservoir flow and geomechanical characteristics.
Average Overall Score: 3.5/4.0

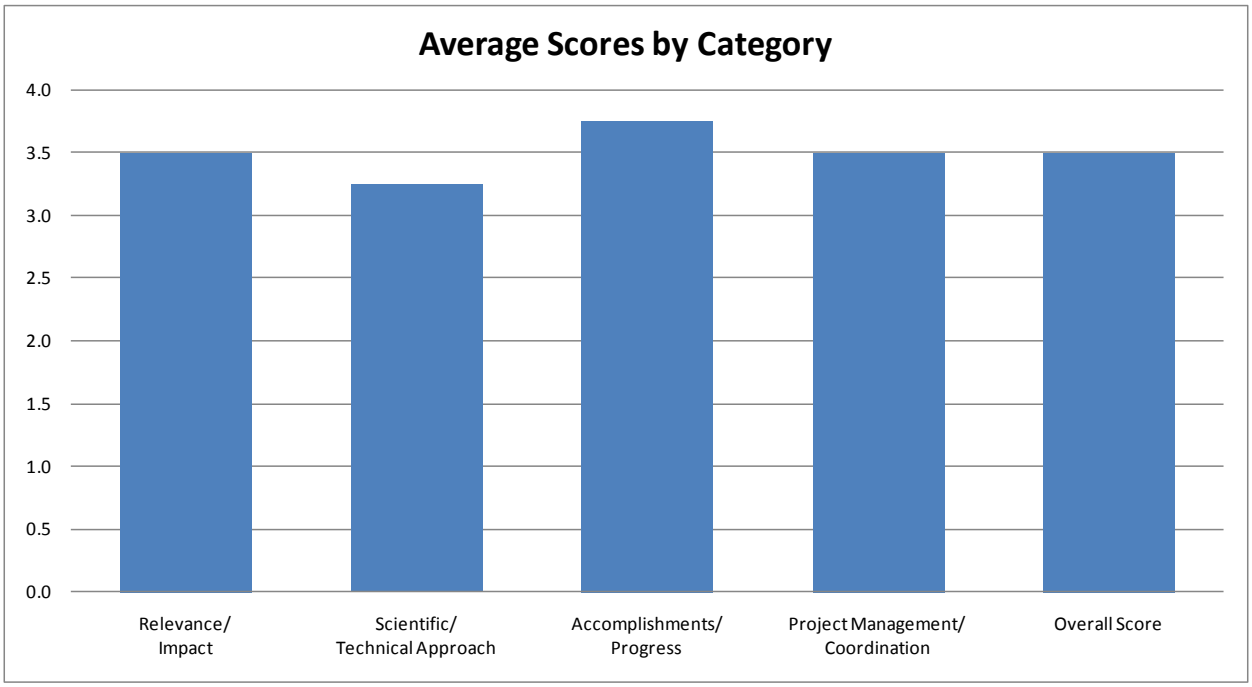


Figure 35: Analysis of Geothermal Reservoir Stimulation Using Geomechanics-based Stochastic Analysis of Injection-induced Seismicity

4.5.7.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4)

Supporting comments:

- This project aims at developing better numerical tools for simulating induced seismicity and geothermal production in EGS. If successful, it may provide useful input into estimates of seismic hazard relationships between induced seismicity, changes in fracture density, fluid injection/withdrawal, background stress, and geothermal production. All factors are important for an efficient operation of EGS.
- Connection between FEM of reservoir properties and seismic response is critical to understanding the application of seismic techniques to exploration.

- This project intends to bring a combination of deterministic and stochastic approaches to EGS reservoir modeling, incorporating locations of MEQs and velocities in the study. This is an admirable goal, and is in line with DOE objectives. There are many ways to accomplish this, and the investigators have chosen a specific way, writing new programs from scratch, that may prove quite successful. They have made excellent progress.

- This project aims to develop a model for seismicity-based reservoir characterization by combining rock mechanics, temperature, finite element modeling (FEM), with geostatistical concepts, and if successfully completed, should make an very important contribution to the understanding of the relationships between microseismicity (MEQ), reservoir flow and geomechanical characteristic of EGSs, as well as, advance the Geothermal Program mission. The project's activities should provide a better understanding of known technical barriers, such as a more accurate prediction of the reservoir's response to stimulation. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.7.2 Scientific/Technical Approach

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- The PI and his team developed a new Finite Element (FE) code to calculate stresses and deformation due to fluid injection into a borehole. The code makes use of the damage mechanics formulation to relate computed strains to potential seismic activity, via a stochastic model. This approach is one of many possible implementations of the damage mechanics formulations and needs to be carefully benchmarked and validated before it can be used for routine interpretations of data from geothermal production sites. In particular, it is unclear if damage simulated via reductions in the effective elastic constants of rocks is a good proxy for the likelihood of earthquake occurrence. Alternative approaches (described in literature in recent years) include, for example, bulk yielding based on the rate-and-state of friction formulation.

- Needs larger three-dimensional models to be of use in real applications. Parallel computational grids should be employed.

- There are so many different aspects of reservoir modeling that are themselves multi-faceted. The investigators have chosen a specific approach that is focused, and is going to produce good results.

- The overall technical approach looks outstanding. A verified 3-D poro-thermoelastic FEM with damage mechanics and stress dependent permeability coupled with a geostatistical description of rock permeability and criticality, a stochastic description of rock mass stress and strength to predict MEQs is very innovative and valuable. Adequate resources are evident (graduate

students), and there is sufficient rigor to the work elements, procedures and methods to achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clear tasks descriptions are provided. What are not evident are a project timeline and a delineation of tasks and subtasks. The overall quality of the research team, equipment and facilities looks good given the PI's experience and publication history. However, the credentials of the graduate students were not presented and cannot be evaluated. As long as the professor is involved with the details of the project this will be high-quality R&D. Relevant experience and the balance of appropriate skills of the research team cannot be assessed. This reviewer does not know the PI but was impressed by the quality and clarity of his presentation.

4.5.7.3 Accomplishments, Expected Outcomes and Progress

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- The PI and his team have written and benchmarked a new FE code tailored to simulate injection-induced damage and seismicity. The code appears to be working as expected. Future plans include conducting laboratory experiments on rock fracture at high pressures and temperatures. Results from these experiments will be used to further test the code predictive capabilities.
- Looks like significant progress has been made by students in the modeling.
- The results to date are phenomenal.
- There are several significant accomplishments to date and results look very promising. The PI estimates project completion between 25 to 30%. According to calendar the project should be 32% completed so my guess is that the project is on schedule and there is no schedule variance. This reviewer was not able to ascertain the accomplishments as compared to costs to date (Cost of Work Performed) since current costing was not given.

4.5.7.4 Project Management/Coordination

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The PI has reached the stated milestones and the software development and testing appear to be on track.
- Project is progressing at a good pace and I expect important results will be applicable very soon.

- The project seems to be very well-managed. It is being run as a typical university project, dependent on students and their Ph.D. goals. The PI seems to be able to corral these energies nicely, and direct the students very well.

- The technical, policy, business, and spend plans for the project are not presented simply or clearly in one place. The individual tasks make sense and are on-track but project decision points were not mentioned. The business plan predominates and the technical, policy, and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed that includes all of the requisite plans described and appropriate decision points put in place.

4.5.7.5 Overall

Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4)

Supporting comments:

- While there exist a number of numerical codes (both commercial and academic) capable of performing similar tasks, this project is worthwhile as it focuses on specific aspects of modeling of geothermal reservoirs. Also, it provides training for students and early-career scientists. The PI may want to look at the existing literature on high-temperature rock fracture experiments.

- Overall I would say this project is excellent. I await the results from the modeling and connection to real world data.

- The project is a good one, and is accomplishing its goals, even if some of the effort being put out is directed toward giving students experience at things that could have been done more efficiently different ways. It will be good to have the first fully-coupled P-T reservoir model explored, and this will lead to competing models, and that is good for the industry as a whole.

- Overall, this reviewer enthusiastically recommends that the project proceed. In the reviewer's opinion, this project is an outstanding contribution to the overall EGS portfolio and should be funded. If it can be verified, a 3-D poro-thermoelastic FEM with damage mechanics and stress dependent permeability coupled with a geostatistical description of rock permeability and criticality, a stochastic description of rock mass stress and strength to predict MEQs is very innovative and valuable asset to the EGS program.

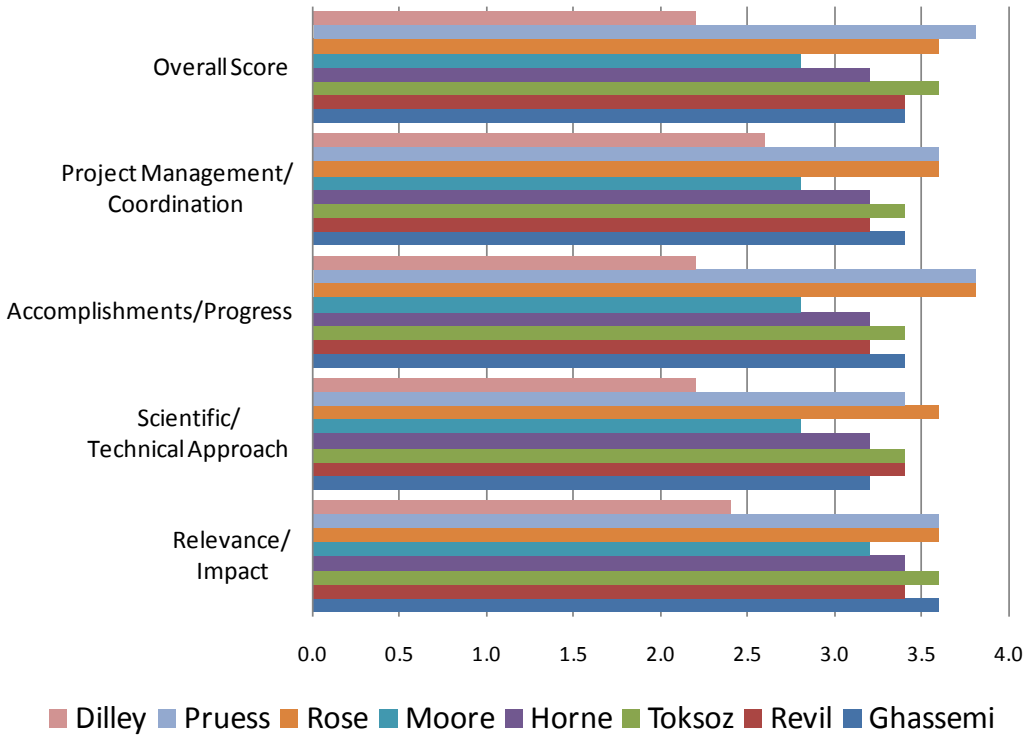
4.5.7.6 PI Response

I thank the reviewers for their comments and suggestions. They will help us in improving our approach where necessary to achieve the project objectives.

4.6 Reservoir Characterization

This technical track consists of eight Reservoir Characterization projects. These projects address instrumentation and the use of this data in modeling the underground environment. Some of these projects utilize nanosensors and seismic tomography and another investigates the effectiveness of proppants. Figure 36 summarizes Reservoir Characterization review scores by evaluation criteria for each PI's project and Table 19 presents detailed scores by reviewer.

Figure 36: Reservoir Characterization Review Scores by Project PI and Evaluation Criteria[3]



[3] Please note: the score of the Horne Reservoir Characterization project may have been affected by the reviewers not receiving his project summary report. GTP would like to note the PI's summary report was received by the Program, but due to an oversight the report was inadvertently not transmitted to the PeerNet system for the panel's peer reviewers to view.

Table 19: Reservoir Characterization Review Scores[4]

Project	Principal Investigator	Reviewer	Relevance/ Impact	Scientific/ Technical Approach	Accomplishments/ Progress	Project Management/ Coordination	Overall Score
Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs	Ghassemi	1	4.0	4.0	4.0	3.0	4.0
		2	3.0	3.0	3.0	4.0	3.0
		3	4.0	3.0	3.0	3.0	3.0
		4	4.0	3.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.6	3.2	3.4	3.4	3.4
Joint Inversion of Electrical and Seismic Data for Fracture Characterization and Imaging of Fluid Flow in Geothermal Systems	Revil	1	4.0	4.0	4.0	2.0	4.0
		2	3.0	3.0	3.0	3.0	3.0
		3	3.0	3.0	2.0	4.0	3.0
		4	4.0	4.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.4	3.4	3.2	3.2	3.4
Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems	Toksoz	1	4.0	3.0	4.0	3.0	4.0
		2	3.0	3.0	3.0	4.0	3.0
		3	4.0	4.0	3.0	3.0	4.0
		4	4.0	4.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.6	3.4	3.4	3.4	3.6
Fracture Characterization in Enhanced Geothermal Systems by Wellbore and Reservoir Analysis	Horne	1	2.0	2.0	3.0	2.0	2.0
		2	4.0	4.0	3.0	4.0	4.0
		3	4.0	3.0	3.0	3.0	3.0
		4	4.0	4.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.4	3.2	3.2	3.2	3.2
The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs	Moore	1	2.0	2.0	2.0	2.0	1.0
		2	4.0	4.0	4.0	4.0	4.0
		3	3.0	2.0	2.0	3.0	3.0
		4	4.0	3.0	3.0	2.0	3.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.2	2.8	2.8	2.8	2.8
Tracer Methods for Characterizing Fracture Creation in Engineered Geothermal Systems	Rose	1	3.0	3.0	4.0	3.0	3.0
		2	4.0	4.0	4.0	4.0	4.0
		3	4.0	4.0	4.0	4.0	4.0
		4	4.0	4.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.6	3.6	3.8	3.6	3.6
Tracer Methods for Characterizing Fracture Stimulation in Engineered Geothermal Systems (EGS)	Pruess	1	4.0	3.0	4.0	3.0	4.0
		2	3.0	4.0	4.0	4.0	4.0
		3	4.0	3.0	4.0	4.0	4.0
		4	4.0	4.0	4.0	4.0	4.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	3.6	3.4	3.8	3.6	3.8
Chemical Signatures of and Precursors to Fractures Using Fluid Inclusion Stratigraphy	Dilley	1	1.0	2.0	1.0	1.0	1.0
		2	3.0	2.0	2.0	3.0	2.0
		3	3.0	2.0	2.0	3.0	2.0
		4	2.0	2.0	3.0	3.0	3.0
		5	3.0	3.0	3.0	3.0	3.0
		Average	2.4	2.2	2.2	2.6	2.2

[4] See footnote 3.

4.6.1 Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs

Presentation Number: 028
Investigator: Ghassemi, Ahmad (Texas A&M University)
Objectives: To develop a 3-D numerical model for simulating mode I,II, and III (tensile, shear, and tearing) propagation of multiple fractures using the virtual multi-dimensional internal bond (VMIB), to predict geothermal reservoir stimulation.
Average Overall Score: 3.4/4.0

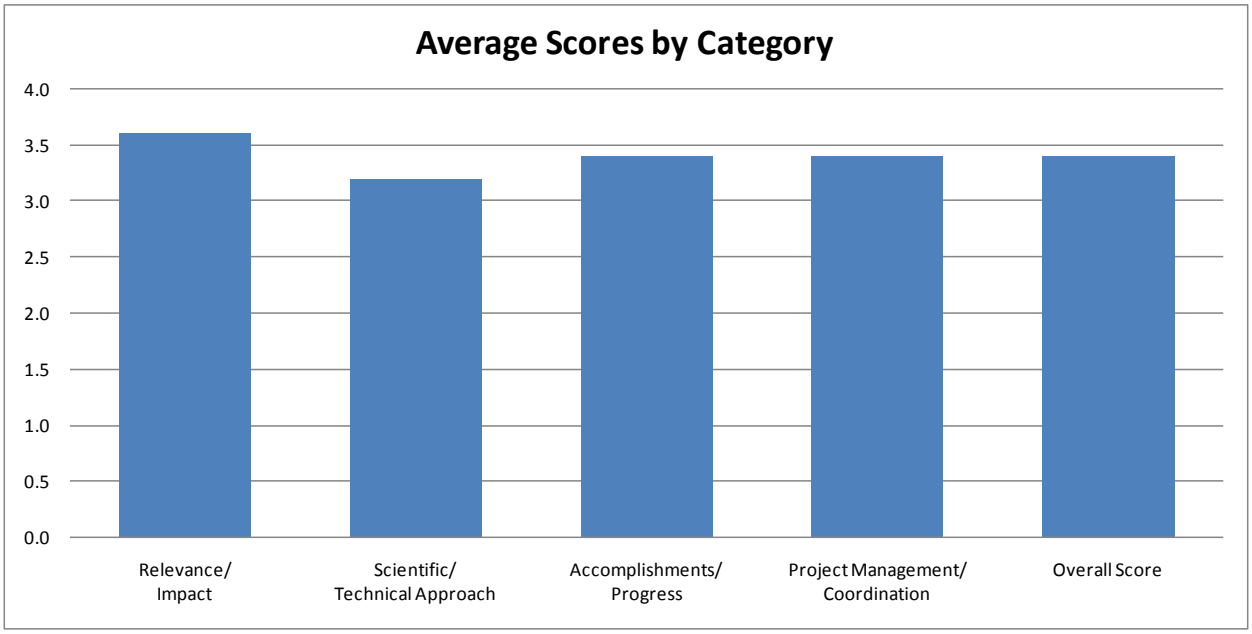


Figure 37: Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs

4.6.1.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The development of fractures is critical to developing EGS. This project advances a fundamental model aimed at understanding fracture development for a variety of domains. Such a model (dubbed VMIB) provides a significant research tool to advance the science.
- This project addresses critical barriers of the GTP using an innovative approach to fracture mechanics: the predictive modeling of reservoir stimulation. This is a very important problem which despite being identified as a key barrier has received little attention and funding from DOE.

- Fracture networks, connectivity, orientation and location are critical to site characterization. In addition, fracture initiation and propagation determine the ability of the reservoir to respond to stimulation. This research focuses on developing a 3-D computational model that incorporates all three types of fracture modes to more realistically simulate fracture propagation. This research can significantly advance our understanding of fracture interaction, propagation and network formation.

- Determining the effect of production on fracture creation and propagation is a key issue for exploiting geothermal reservoirs. Accurate numerical prediction can reduce costs and identify possible difficulties and, thus, is an essential element of the program.

- Only 25 to 30% completed, so difficult to judge ultimate impact, but investigators are making good progress.

4.6.1.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- The virtual multi-dimensional internal bond method is sharply focused for fundamental understanding of fracture processes, which are critical to EGS development. Comparison to experimental data was impressive. I would have liked to see more information about the role of fluid pressure and gradients thereof. More discussion of the limitations and weaknesses of the approach would have been appreciated.

- The numerical approach based on VMIB (similar in spirit to peri-dynamics approaches) can potentially overcome significant difficulties in fracture mechanics, namely: path identification, mixed-mode propagation, crack propagation in heterogeneous media. The method has been validated on a specific example. The project has focused on the 2-D situation, and the extension to 3-D is far from trivial.

- Numerical studies will incorporate a range of parameters to more closely model reservoir properties such as non-linearities in rock deformation, rock heterogeneities and fracture interactions. Numerical results have been compared to analytical results for validation. Models will be calibrated with results derived from lab and field experiments. To date rock heterogeneity was not explicitly described - how different are the rock units? Are they representative of those found in EGS systems? How will upscaling from one fracture to a reservoir occur? To date, it appears that the modeled processes are isothermal. Incorporating thermal changes will improve the utility of the model.

- This is a very interesting approach that has its basis in a method (VMIB) used successfully in computational material science studies of fractures. Integrating this with a FEM code that

includes thermal and pore fluid effects in a computationally efficient way is a significant challenge. Preliminary results are promising, but the test examples have not been very challenging. I would like to see more emphasis on comparing the results with observations in experiments and the results of other types of numerical simulations before progressing to more complex field simulations. For example, there have been a number of observational and computational studies of fracture growth and interaction. How does this method compare with those results, even in the absence of fluid and temperature effects? Do the computations adequately capture the behavior of laboratory specimens for a range of pressures and loading paths? I realize that the goal here is to treat more complicated and general situations, but each of the elements needs to be tested thoroughly. Although this may seem to slow progress to the ultimate goal (field simulator), I think it is necessary to have confidence in the end result.

- Good scientific approach and organization.

4.6.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Given that this project only started last fall, considerable progress seems to have been made. The project is well founded scientifically, and has great potential for the future. I did not note any honors or awards, but the method and the progress were remarkable.

- While still in its early stage, the project has already led to 4 articles, and some significant numerical results.

- Stated completion is approximately 30%. Numerical models are being developed and tested for a subset of controlling processes. Algorithms for various processes have been incorporated. Verification of fracture propagation modeling with lab studies was completed for a subset of fracture modes. A publication has resulted and presentations at national meetings given. Quality of the researchers and facilities are excellent.

- Productivity has been excellent both in terms of progress toward goals and publication of the results. Ghassemi is experienced and expert in numerical geomechanical simulations.

- Well qualified performers. They have some good initial results.

4.6.1.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The project is well structured, and has achieved impressive results to date. I did not notice checks and controls in the management plan.

- The project is following its timeline, proof of an efficient management.

- Project management appears effective but little information was presented.

- Project management (Team is essentially Ghassemi with graduate students) is simple and has been effective. Collaboration with Alta Rock on a field test of hydraulic fracture mentioned in the presentation was vague, but this may be down the road a bit.

- Limited information on this metric, but no red flags.

4.6.1.5 Overall

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- I found this to be a very impressive model, with significant potential applications for EGS. Some difficulties may be encountered when dealing with pre-existing fractures, but this could be dealt with by using broken or nonexistent bonds between the “particles”.

- This is a high-risk project as it relies on a numerical approach that has not been strongly validated before being applied to geothermal reservoir stimulation. No information other than the copy of the presentation overhead slides was available on PeerNet.

- A project summary was not submitted for this study. Consequently additional details were lacking.

- There are many numerical simulators of fracture growth and interaction, pore fluid and temperature coupling. Admittedly many of these are for more specialized problems but the superiority of the present method is unclear (at least to me).

- Very important project for geothermal R&D.

4.6.1.6 PI Response

I thank the reviewers for their comments and suggestions. They will help us in improving our approach where necessary to achieve the project objectives.

4.6.2 Use of Geophysical Techniques to Characterize Fluid Flow in a Geothermal Reservoir

Presentation Number: 029
Investigator: Revil, Andre (Colorado School of Mines)
Objectives: To develop and test combined geophysical techniques to characterize fluid flow, in relation to fracture orientations and fault distributions in a geothermal system.
Average Overall Score: 3.4/4.0

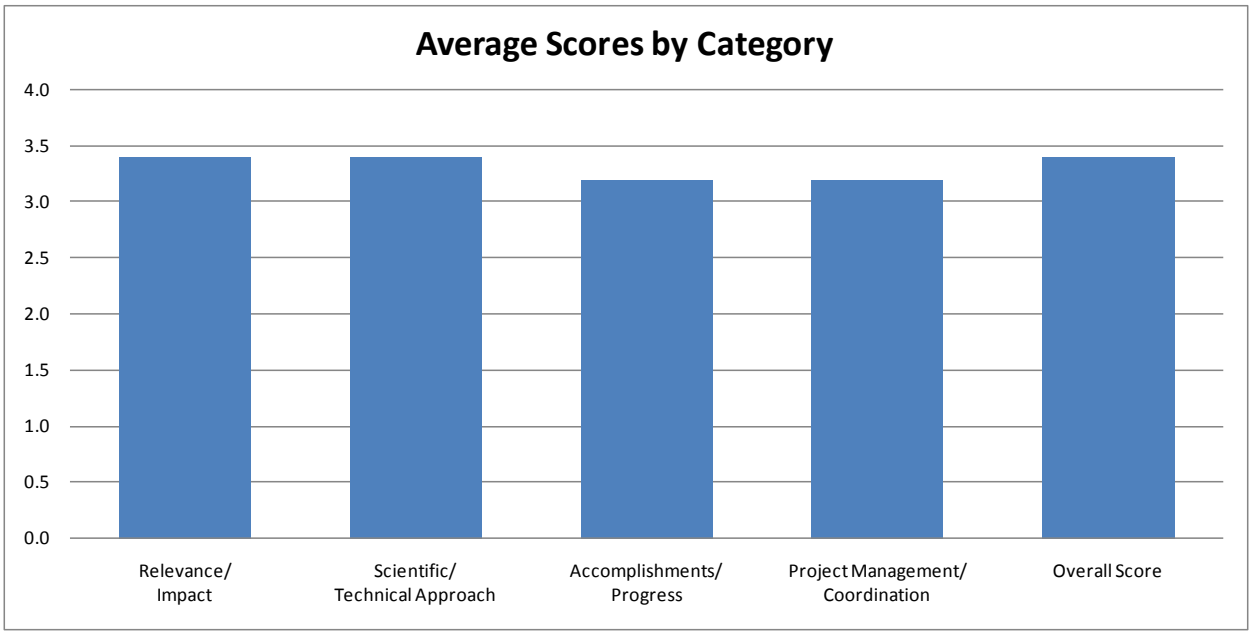


Figure 38: Use of Geophysical Techniques to Characterize Fluid Flow in a Geothermal Reservoir

4.6.2.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Joint inversion of geophysical data for imaging of groundwater flow has been performed. This seems to have excellent potential for assessing geothermal systems both before and after stimulation and production. I have some questions about the mechanism of the self-potential method, but it seems to have real promise. Imaging of subsurface flow systems would provide extremely valuable data, and the project seems to have made great progress.

- Reviewer does not feel he has sufficient expertise to assess this project.

- Characterizing the structures and fluid flow regime are critical to development of EGS reservoirs. This study contributes to site characterization, monitoring, and reservoir

development through combined geophysical imaging techniques and numerical modeling. A new technique is being developed to measure fluid flux by self-potential data. If successful, this technique could identify 'blind' geothermal systems. Results of this study are guided by and applied to a potential geothermal field site in Colorado.

- This approach which combines seismic, self-potential and resistivity measurements could provide a much better view of subsurface fluid flow than existing ones. The capability to monitor fluid flow will be essential during development and operation of a geothermal site.

- PI was not at the review, so my peer review comments are based only on what I could determine from the presentation posted on the peer review web site. Much of the technology shown here is conventional and routinely applied. Hopefully, some innovative data integration will come out of this. It has a strong educational component.

4.6.2.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Aside from my own ignorance about the fundamentals of the origin of self-potential signals, the approach seems sound. It is well focused, and will provide significant progress to overcoming a number of “barriers”. The use of electric fields at the surface to deduce subsurface fluid flow has great potential. I would hope that additional constraints on the actual fluid flow could be extracted through work on the theory of field generation, as some unknowns seem to creep in due to unknown chargers and redox issues.

- Reviewer does not feel he has sufficient expertise to assess this project

- Data derived from the literature and various geophysical methods are combined with numerical modeling and applied to a specific field site. Field and literature data are used to interpret the overall geologic structure of the area to identify faults responsible for flow. Geophysical measurements are "integrated with geology and geochemistry" to develop a 3-D flow model. (Phrase in quotes because this is lacking.) Because permeability controls fluid flow, it is unclear how geophysical data will be inverted or used to extract the critical parameter of permeability - necessary to calculate fluid flow.

  Flow modeling appears to be quite general. While pore water composition and a reactive transport model are to be developed, there are no measurements of fluid composition and no mineralogy of the reservoir apparent. Without focus on the fluids and minerals, it is difficult to envision how this study will contribute to "understanding precipitation and dissolution reactions in the fracture system" (geophysics is the focus).

If details of the field site's geology including mineralogy and fluid chemistry will be incorporated in the 3-D model, a more realistic assessment of the reservoir will result. Without specifics, this limits the extrapolation of this technique and these results to other areas.

- Well planned so that the technique can be tested against observations in field sites. Combines geophysical inversions with models of fluid transport. Perhaps they have looked at this but a persistent question with complex inversions is the resolution; could some dramatically different model produce similar observations?

- Good scientific approach and organization.

4.6.2.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Fair (2), Outstanding (4), Good (3)

Supporting comments:

- A best poster award for this project was issued at the 2009 SEG meeting. The team seems very well qualified and the progress has been very good. Additional comparison to modeling with the TOUGH family of codes will be done in the future and should provide additional constraints.

- Reviewer does not feel he has sufficient expertise to assess this project

- The project is approx. 30% complete based on the timeline. Based on comments below, this category rates between fair and good. Preliminary data have been gathered for 3-D seismic imaging and inversions of several datasets have occurred. Summary states geology and geochemistry have been integrated with geophysics. However, from these presentations, geology is largely structure and geochemistry has not been covered. The geophysics that is the focus seems largely separate from geologic characterization other than structure.

  The quality of the geophysics' researchers is excellent. Collaborators do not appear to cover the geologic or geochemical aspects of the proposed work. There is an educational component that appears superb with the training of students in a field setting and the acquisition of geophysical data. Two papers in peer-reviewed literature have been submitted, one published in 2010, covering the geophysical techniques. Several presentations have occurred.

- Project already seems to have accomplished much and has generated considerable output in terms of publications and presentations.

- Well qualified performers. They certainly have the resources available.

4.6.2.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Fair (2), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The current team communicates by Skype. The management plan was a bit difficult to assess, due to a paucity of information. Claims are made about connection to ORMAT and NREL, but these connections seem vague to me.
- Reviewer does not feel he has sufficient expertise to assess this project
- Project management is excellent with regularly scheduled (video) meetings. Organizing students in the field takes immense time and planning.
- No comments.
- They seem to have set up an effective communication procedure.

4.6.2.5 Overall

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The use of self-potential, especially when combined with other geophysical data seems to have tremendous potential. Future combination of joint inversions with TOUGH code modeling should provide invaluable advances for EGS development.
- Reviewer does not feel he has sufficient expertise to assess this project
- Results have been presented at international meeting and published in peer-reviewed journals.
- No comments.
- Disappointing that the PI was not at the review. Wasn't it possible to send an alternate? The presentation on the peer review web site indicates that this is a strong project.

4.6.2.6 PI Response

No response.

4.6.3 Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems

Presentation Number: 030
Investigator: Toksoz, Nafi (Massachusetts Institute of Technology)
Objectives: To combine geophysical methods for reservoir and fracture characterization with rock physics measurements made under in-situ conditions (up to 350 °C) for development of geothermal systems; to apply the model to the Cove Fort-Sulphurdale geothermal field in Utah; and to generalize the reservoir characterization model for application to other EGS sites.
Average Overall Score: 3.6/4.0

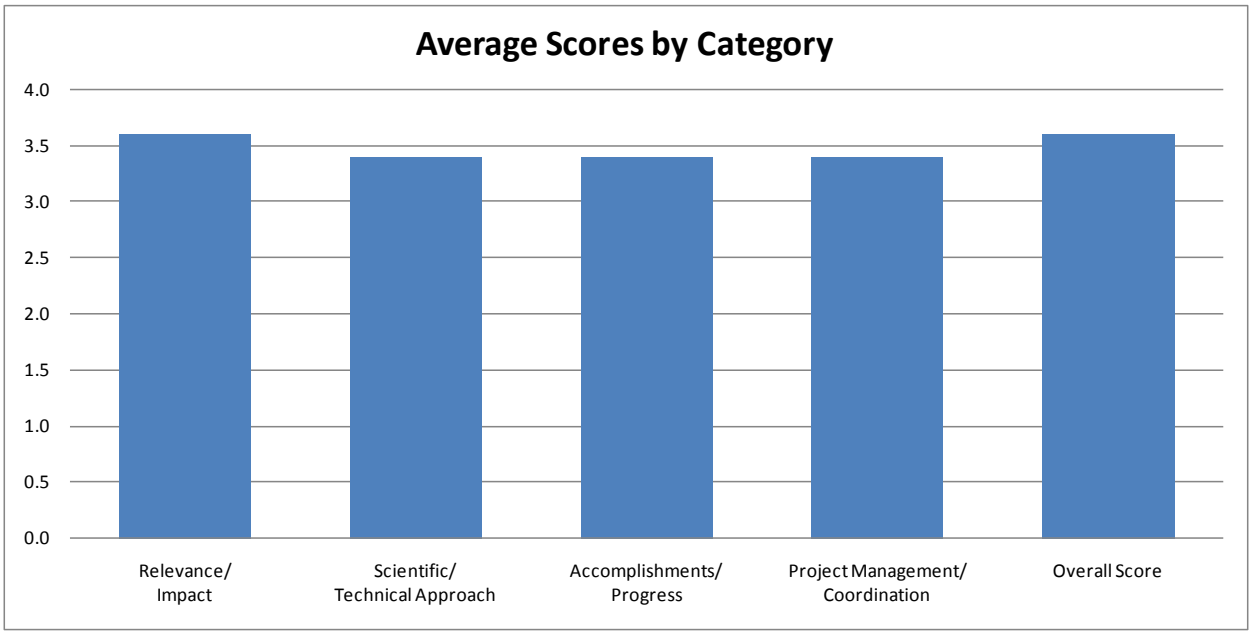


Figure 39: Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems

4.6.3.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- This project has made excellent progress on key reservoir characterization that can be accomplished by seismic tomography. Petrophysical property measurements are highly relevant for converting seismic surveys into usable subsurface thermal images. Fracture imaging did not seem to have been done yet. A significant amount of data had been collected from other sources.

- The project objective is to combine geophysical methods for reservoir and fracture characterization with rock physics measurements made under in-situ conditions (up to 350 °C) for development of geothermal systems. The methods will be tested on a specific reservoir before being extended to other reservoirs.

- This project addresses a significant technical barrier relating to the detection and characterization of fractures, an essential component of EGS, as well as site characterization and reservoir validation. Geophysical methods are used to image controlling parameters such as the fracture distribution, stress regime and reservoir temperature in a field site while direct measurements of rock properties will be made under reservoir P-T conditions. The study is multi-component with well-established field, lab and theoretical contributions.

- Investigates the use of various geophysical techniques (seismic, MT) with laboratory rock physics experiments to characterize a possible geothermal site (Cove Fort). An important field test of the extent to which these measurements accurately characterize a site.

- About 50% completed, so early to judge ultimate impact, but investigators making good progress.

4.6.3.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Good (3), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The seismic tomography done on the collected data was excellent, and provided tangible views of the subsurface. The petrophysical properties section was good for the seismic velocity characterization, but was less well developed, and additional assessment of porosity and permeability should be made on the high-P-T apparatus. The porosity could be important for comparing measured seismic velocities from different core samples. Some of the methods could have been more fully explained.

- Very little information was provided as to the specifics of the conducted research. In particular, I am concerned that a single site validation may not provide enough information to generalize the techniques to other EGS sites.

- The approach combines relevant geophysical data with petrophysical measures of the rocks to characterize fracture locations and apply these data to a field site to generate a reservoir model. Previously acquired geophysical data such as heat flow, gravity, MT, and various types of seismic data have been synthesized and provide a baseline for rock properties as a function of depth and suggest areas to target for field deployment of seismic stations. These data are to be coupled with measures of reservoir rocks to characterize their petrophysical properties.

Properties are dependent on rock composition which needs to be determined. Tools have been developed for measuring in-situ properties. With seismic methods, these field and lab datasets will theoretically allow fracture location, orientations and flow properties to be evaluated. It remains unclear what proportion of the fracture network microearthquakes can detect.

- Although the techniques (Vp/Vs measurements) are not new, there have been significant refinements. In particular, accurate waveform comparison makes possible determination of the mechanism of small seismic fractures in unprecedented detail. Laboratory apparatus has been designed to conduct experiments to calibrate the wave speed measurements.

- Overall good progress. PI needs to become more familiar with the details of the MT survey. Critical that details of the MT survey be included in future reviews, such as how is the static shift accounted for.

4.6.3.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The project has advanced considerably, and the group seems very productive. The successful identification of subsurface geothermal reservoirs as applied to Cove Fort would have obvious applications to any other potential geothermal site. The quality of the work is excellent. A number of papers and conference presentations has been submitted/given.

- This project has reached its mid-point. Its progress is slightly behind schedule, compared to the original timeline, but this should not be a concern. It has lead to a large number of publications. The assessment that 30% of energy released during crack growth is volumetric while 70% is released at the crack tip can lead to a better understanding of induced seismicity.

- Planned tasks and milestones have been met largely. Theoretical tasks are all on target. Previously acquired geological and geophysical data have been analyzed and used to develop tomographic images of the area. A new measurement tool has been developed. Theoretical methods have been developed for fracture and microseismic event characterization.

  Studies have been completed to focus the next study phase of direct measurement of petrophysical properties and microseismic analysis. Lab measurements of rock properties were not presented although they were reported to have been underway. These data need to be incorporated more fully into the current state of the study. Quality of the researchers is excellent and collaborators increase the range of disciplinary experts.

- Quality of team is excellent. Project has already accomplished much and many results have been reported in the scientific literature. I expect that completion of the project will provide a benchmark for the characterization of a possible geothermal site by geophysical methods. Laboratory apparatus has been designed and fabricated. Tests will be conducted during remainder of project.

- PI is very well qualified and accomplished in this field. Good initial results.

4.6.3.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The management plan and project coordination was well constructed and presented. A couple aspects of fraction detection and use of anisotropy seemed behind schedule, but joint inversion work was ahead of schedule.

- The project is on track, has lead to significant findings. I therefore see no reason to question the adequacy of its management and coordination.

- Management appears to be effective. Lab measurements of properties are likely underway at NER but have not yet been incorporated into the study. It is unclear if the data have come from NER.

- Coordination of field observations, modeling and laboratory is well organized and progressing along a realistic schedule. Project management appears to be exemplary.

- Overall good, but PI needs to become more involved in the MT analysis, which, I believe, will be a critical component of this project.

4.6.3.5 Overall

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- This presentation of the use of seismic tomography to image the subsurface has excellent potential application to geothermal reservoir site characterization. When combined with results from the high PT apparatus, thermal structures of the subsurface should be possible. Future work on detection of fractures using microseismic signals will also be a valuable addition. Porosity and permeability measurements of the core samples should be attempted. I wondered why only Coso data on core samples were presented, but hopefully the Cove Fort

samples can be used in the future. These techniques have obvious application to other potential geothermal sites.

- Both the presentation and the documents provided were quite vague as to the specific methods used, making it difficult to assess the overall scientific quality of the project.
- The geophysical and theoretical foundation for the project could enhance reservoir characterization and fracture detection substantially. The study is insightful, overarching and complete. Peer-reviewed papers have been published and presentations made at international meetings.
- No comments.
- Important project for geothermal energy.

4.6.3.6 PI Response

No response.

4.6.4 Fracture Characterization in Enhanced Geothermal Systems by Wellbore and Reservoir Analysis

Presentation Number: 031
Investigator: Horne, Roland (Stanford University)
Objectives: To investigate a new tool (nanosensors) to measure pressure and temperature anywhere in the formation and fracture aperature; and to develop a method to estimate reservoir parameters and characterize fracture networks based on these measurements.
Average Overall Score: 3.2/4.0

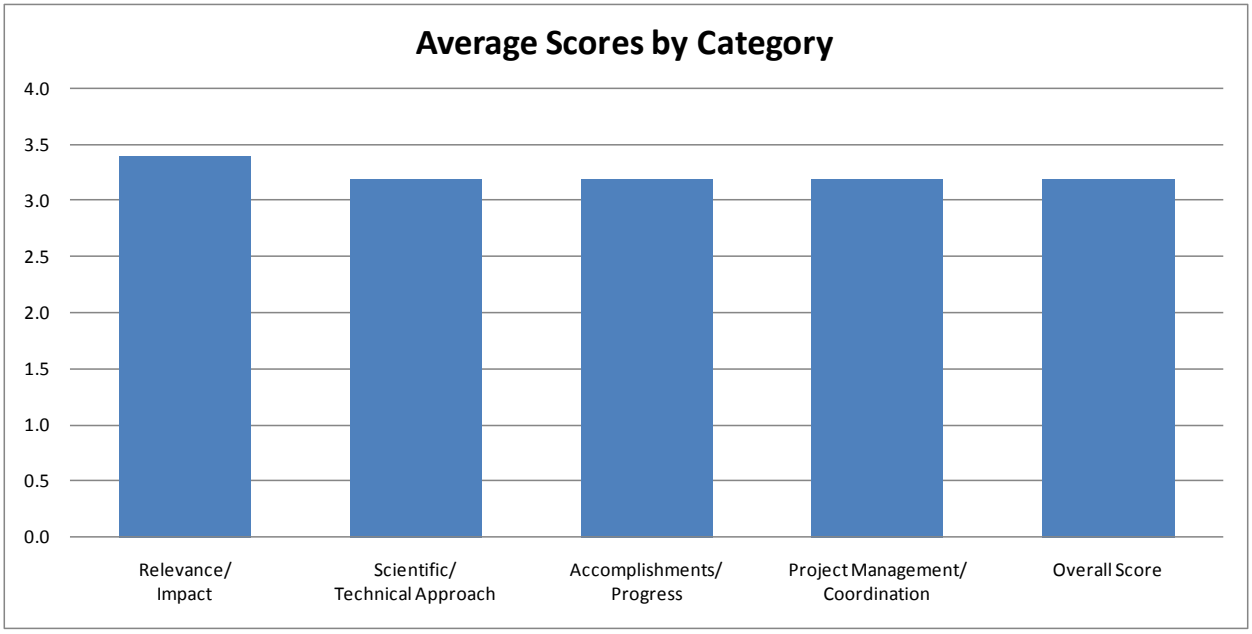


Figure 40: Fracture Characterization in Enhanced Geothermal Systems by Wellbore and Reservoir Analysis

4.6.4.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- Although there seems to be great potential for nanosensors for extraction of some reservoir properties, the progress on this front was less than impressive. The PI also did not provide a report, only a presentation.[5] No information in the downloadable report indicated the timeline of his project. Use of production data or resistivity tomography seemed overly ambitious.

[5] The PI's project summary report was received by GTP, but due to an oversight the report was inadvertently not transmitted to the PeerNet system for the panel's peer reviewers to view.

- This is a very well thought-out, very well executed project which will lead to very significant progress on tracer technology.

- Because the fracture system is a fundamental controlling parameter in EGS, this study addresses a significant technical barrier to understanding the behavior of fractures and characterizing their properties thus supporting site characterization and development. This work relies on development of nanosensors to measure P, T and fracture aperture as a function of EGS conditions to characterize the fracture network. Techniques are being developed to identify the fracture network whereas modeling the fracture network provides a baseline for the transport of the nanotracers.

- Characterizing fractures and how they are altered by production is an essential element of efficient and safe EGS. This project is investigating three methods of characterization. One using nanoparticles is novel and potentially breakthrough. These can sense apertures and temperatures along their travel path, giving information in the interior of the formation, not only at the well bores. Project has made progress on all three methods by examining idealized situation to test the sensitivity and efficacy of the methods.

- Investigators making good progress.

4.6.4.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Part of the problem here may have been just due to poor organization of the presentation. It would seem that maximum linear particle dimension would be the most critical factor to determine whether the particle could get through a fracture (rather than shape). Certainly surface charges could contribute to flow-through capability, but the aggregation of the “nanorice” just looked to me as a natural packing, rather than some influence of charge.

- The PI has done an outstanding job at leveraging the resources available at Stanford for his project. The experimental procedures are robust and very well executed. They are well leveraged in devising appropriate nanotracers. The extension of the inverse model to 3D seems non-trivial, and I would have wished to hear more about the proposed strategy in the "Next steps" part of the presentation. I understand that the focus of the project is not in developing new numerical tools (which would be quasi impossible in such a short time), but I worry about the quasi-systematic reliance of the GTP on a single numerical tool, TOUGH2. It can be a very efficient approach, but can also lead to a fragile construction.

- The approach and methods are sound, laboratory experiments followed by computational modeling. Lab experiments begin with the basics of morphology, composition, thermal stability, and surface properties of nanomaterials and progress on to more complicated structures and materials. To date, all experiments have used a homogeneous solid material (natural or artificial) to simulate a reservoir. An excellent starting point for evaluating the tracers themselves. These matrix materials have uniform shapes and sizes, in stark contrast to those found in a reservoir. How will these be extrapolated to natural systems?

  Materials tested to date provide a baseline but the chemical and physical heterogeneities in the system need to be explored. Heterogeneous solids (quartz, feldspars, micas) have different wetting angles, morphology (not spheres nor cylinders nor rice), surface and mechanical properties that may alter the effectiveness of the nanomaterials. Higher temperature experiments need to be done (perhaps they are planned but were not discussed). It is unclear what fluid composition is being used. Testing prototypes in fluid compositions more typical of EGS reservoirs as well as typical matrix compositions will add an important dimension to this research.

  This information is augmented by data from well-to-well tests and computational modeling studies. Assumptions and difficulty in analyses are identified and evaluated. New directions in characterizing and modeling the fracture network and tracer paths are being developed. While "mineralization" is identified as a next step, no information exists on how this is to be evaluated.

- Approach is well-designed. Project is at the stage of understanding the processes and their behavior in relatively simple model conditions but I think this is necessary. They are at the stage of having to extend these studies to more complex idealization, refining the approaches and discarding some apparently unpromising avenues (e.g., particles with nanowires). Field studies may be a bit down the road but this is good fundamental work with big potential payoff.

- Good scientific approach and organization. Strongly recommend expanding beyond Berea SS and glass beads.

4.6.4.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Horne's appearance on ABC news (June 2009) seemed to be some sort of honor. He seems to have a good team and good collaborators. He seems to have made good progress on some things. Several aspects of the goals seem overly ambitious. The use of electric potentials for fracture characterization is one example of this. The main result seemed to be that nanoparticles could get through a fracture if they were small enough. This should not be too

surprising. Pressure and temperature sensitive particles COULD have the potential to integrate some peak property along their flow path, but little progress had been made on demonstrating this. Extraction of fracture properties by the inverse procedure of tracer injection and resistivity tomography also seemed overly ambitious.

- At such an early stage of the project, it would be unreasonable to expect a large amount of published work. The group has already produced significant scientific achievements, and has gone well beyond its outreach mission.

- Productivity: No time line was provided, therefore it is unclear as to the extent of progress. To date, experiments have identified nanoparticles for use, provided baseline studies, and supported the recovery of nanoparticles after injection. Various imaging methods have been developed to determine recovery of the particles. SEM imaging confirms the presence of both nanospheres and nanowires in the effluent (of unknown composition) after injection.

  Surface properties of the various minerals need to be investigated to determine the likely transport or 'sticking' of particles: analyze the "rock fine". Progress has been made in fracture network modeling as well as fracture characterization by electrical means. Difficulties remain in fracture modeling. Well-to-well test data has been gathered and modeling the tracer production is underway for the ideal case.

  Quality of the researchers appears excellent for engineering and modeling. Collaborators do not appear to include mineralogists or geochemists from the information presented. No publications nor presentations of research results accompanied this presentation.

- Good progress has been made on all three methods of fracture characterization, particularly the one using nanoparticles. Quality of team is excellent and Stanford provides an environment of related expertise (e.g., on nanoparticles) that this team can draw on. Project has attracted national media attention.

- Well qualified performers. They have some good initial results.

4.6.4.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Unfortunately, no management plan was given, and little information on coordination could be found in his presentation. Given that some results of fracture modeling and particle flow through results were given, some progress has been made.

- The high quality of the achievements reflect the adequacy of the management. The project is in very good position and I don't see any need for changes in its management or coordination strategy.

- Management appears to be sound as most components of the project are moving forward.

- Management is pretty simple and appears to be effective.

- Limited information on this metric, but no red flags.

4.6.4.5 Overall

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- No clear path was available to usable results. Just getting particles through a fracture network would not be enough to characterize efficiency of heat extraction. In general, each of the topics addressed seemed overly ambitious and underdeveloped. Had some idea of the timeline been presented, my review could have been more favorable (say if the project were less than a year duration up to now).

- The project is well designed, well managed and is in track with its schedule. The review was made more difficult by the fact that only the presentation overhead slides were made available on PeerNet.[6]

- A project summary was NOT provided to the review team such that additional information was not available.[7] Collaborators, presentations, publications are missing. While it is difficult to model the subsurface heterogeneities in both the solid and fluid phase, they are essential to understanding the EGS environment.

- No comments.

- Important project for geothermal R&D.

4.6.4.6 PI Response

No response.

[6] See footnote 5.

[7] See footnote 5.

4.6.5 The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs

Presentation Number: 032
Investigator: Moore, Joseph (University of Utah)
Objectives: To develop improved methods for maintaining permeable fracture volumes in EGS reservoirs.
Average Overall Score: 2.8/4.0

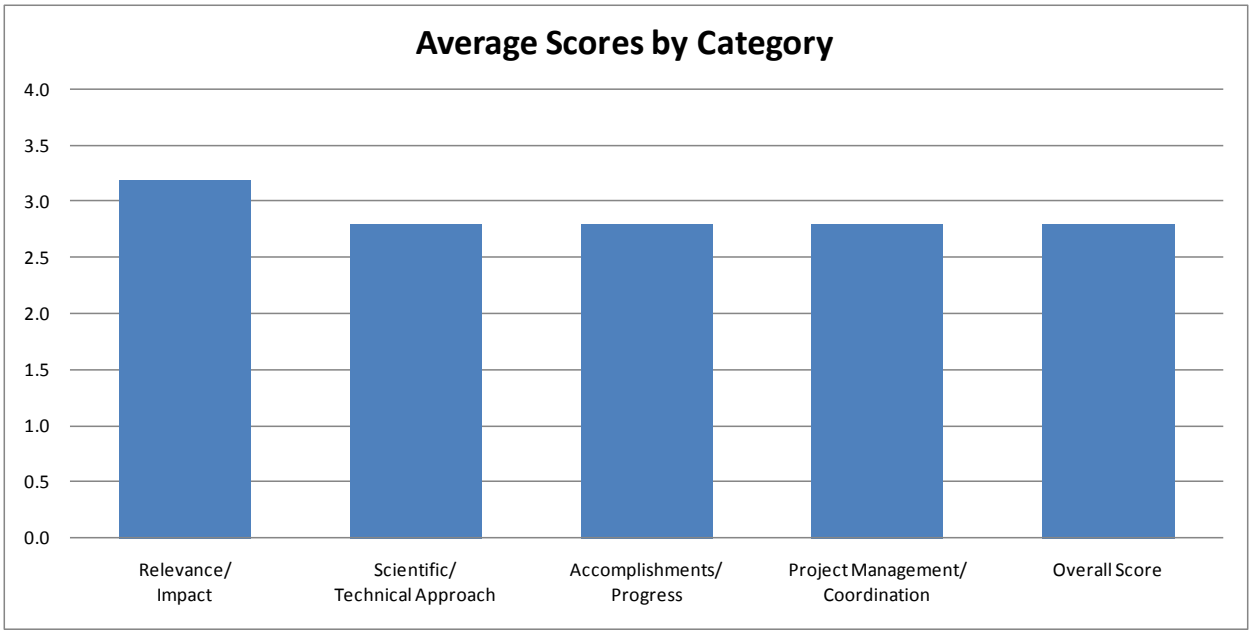


Figure 41: The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs

4.6.5.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Although the goals of the research address significant problems related to EGS development, the progress made for approximately 1.5 years of project duration seemed trivial. From what was presented, vague evidence of surface corrosion of a bauxite proppant (as expected for contact with deionized water) and a few short duration permeability tests were the main results. I would have expected more significant quantitative results. The construction of a high-temperature apparatus could be counted as some progress. Proppants could have great potential for geothermal systems following induced hydrofracture to keep fractures open, but bauxite seems like a poor choice for high-temperature applications, and significant testing with

premium ceramic proppants should have already been conducted. I have some doubt that zonal isolation would work well via proppant injection, but tests still need to be done.

- The project directly contributes to several critical needs of EGS reservoir development: fracture characterization, zonal isolation, controlling fracture propagation and predictive modeling. If proppants are to be used in order to maintain flow path in EGS, understanding their long term behavior is essential. This project also has applications beyond EGS.

- This study focuses on maintaining fracture openings, once created, by the use of proppants. Determining the proppant's thermal-chemical-mechanical stability is essential to understanding their applicability for fracture maintenance (or inhibition) and sustainability in EGS systems. Thus it addresses a significant technical barrier. Dissolution and/or precipitation of proppants and other minerals in the rock can dramatically alter fracture conductivity and connectivity. In addition, mineral dissolution/precipitation near fluid-injection points moves the system far from chemical equilibrium and may promote fluid-mineral interactions that alter the effectiveness of EGS techniques. This study is designed to quantitatively understand these processes. To date, the proposed research is highly relevant but as yet results are unconfirmed. There is potential to contribute to the overall knowledge base of EGS systems.

- Project investigates the effectiveness of proppants in EGS. Because proppants have been widely (and apparently successfully) used in oil production, they may also be necessary to maintain open fractures in EGS (although this seems unclear at this point). Since environmental conditions are more severe in EGS, it is important to determine whether those proppants that have been used in petroleum recovery can also be effective under geothermal conditions and, if not, determine proppants that are.

- Investigators making good progress.

4.6.5.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Fair (2), Good (3), Good (3)

Supporting comments:

- It appeared that only deionized water (DI) was used in tests done to date, but DI plus crushed granite may have also been used. DI spiked with silica was described to be used in ongoing experiments. If brines are a relevant fluid, more experiments should have also been done with such fluids. It is true that DI could be like condensate, but long-term exposure between fluids and rock would be expected to have solutes in nearer to equilibrium with the rock than DI in significant portions of a geothermal system. Expected solute loads should be used in experiments.

- The long term behavior of proppants in EGS is still uncertain. This project will provide valuable insight for their use. The methodology is appropriate, the team has access to high quality experimental facilities, and the level of interactions between academic and industrial partners is appropriate.

- The approach is largely measurement based - selecting rocks, fluids, proppants for measurement at ambient conditions followed by laboratory experiments to determine mineral/rock alteration and its effect on fracture conductivity at elevated P-T conditions. This is to be supplemented by geochemical and geomechanical modeling. Higher T/P experimental techniques at a DOE lab have yet to be developed (but likely DOE staff at the facility would be helpful in developing such techniques).

  It is important to carefully characterize the starting materials for the experiments so that results can be extrapolated to other materials or systems. If bauxite is used, then the chemical makeup and bauxite mineralogy should be determined because the proportions of the hydroxides comprising the bauxite (or silicates composing the granodiorite) may differ.

  In addition, one should do some geochemical modeling first to assess the expected outcome of the experiments. Little information was presented on the geochemical modeling approach. Data exist for these fluid and mineral species, such that reaction paths can be modeled and the most appropriate experiments determined.

  It is unclear why the rock (granodiorite) was sawed - this is not a surface that will exist in the subsurface. This may be useful for mineral characterization and modal analyses (none completed) but not for experiments. While distilled water provides an end member to the reaction problem, it is far from what will be introduced in the subsurface. Other fluid compositions should be tested for applicability to EGS systems.

- The approach, which seems mainly based on laboratory experiments is sound, but seems to be a bit slow off the mark and not very well laid out. The presentation alluded to study of mechanical (not just chemical) properties of proppants but there seems to have been no progress on this front or any clear plan for doing so. This could be a potentially useful and important study, but thus far, it does not seem well-focused.

- Good scientific approach and organization.

4.6.5.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Fair (2), Good (3), Good (3)

Supporting comments:

- I would have expected more significant results to date (as described above). Although the project title alludes to the role of geochemistry and stress on fracture development and proppant behavior, very little work was done on geochemistry, stress, or fracture development. I would have expected that the team and facilities were well matched for the project, but the productivity seems to have been too weak. Geochemical modeling was to have been in progress for one year at time of presentation, but no results were given. It was stated that TOUGHREACT would be used. This model would be appropriate, but after one year on the project it is surprising that no results were available.

- The project is approximately at its middle point and is essentially on track with the original timeline. It has already identified dissolution or precipitation issues with several proppants. It also provides a systematic methodology for the testing of long term properties of proppants in EGS.

- Productivity: PI estimates that the project is 40% complete. Tests materials have been selected and baseline measurements acquired. Petrologic assessment of fluid-proppant interactions via experiments and geochemical modeling are in their initial stages, although no geochemical modeling was presented. Mechanical testing and modeling do not appear to have occurred. No elevated P-T measurements have been made.

  To date, fluid interactions rely on distilled water - useful for an end member scenario but more realistic fluid compositions should be used. Fluid mixtures are important and may cause dramatically different interactions. Crushing of material, e.g. granite, causes enhanced surface energy which drives the chemical reaction (not fluid-mineral interactions) and may not be realistic for subsurface conditions. Geochemical modeling should be underway for assessment of fluid-mineral interactions. Accomplishments appear to be modest based on the information presented.

  Quality: The quality of the current experiments appears sound. More analyses are warranted. Collaborators in geochemical modeling should be included. Two presentations at the GRC resulted.

- Work is of high quality and results are interesting but output seems limited. Project seems to be lagging in reaching its objectives.

- Well qualified performers. They have some good initial results.

4.6.5.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Fair (2), Outstanding (4), Good (3), Fair (2), Good (3)

Supporting comments:

- Although the timeline and management plan seemed appropriate, the achieved results were weak. It is difficult to assess what structural problems exist from the material presented. It was stated that the project was "on schedule", but the presentation did not reflect that.

- The project is very well lead. The degree of collaboration between the industrial and academic partner are appropriate.

- Management appears to be effective and well coordinated. The involvement of students (responsible for geochemical modeling?) may slow results, understandably, and be reflected in the absence of modeling results.

- Although the project is relatively small in terms of the number of people involved it seems to be progressing somewhat slowly. The management plan seems to be well laid out, but, thus far, not effectively executed.

- Limited information on this metric, but no red flags.

4.6.5.5 Overall

Ratings of Five-member Peer Review Panel: Poor (1), Outstanding (4), Good (3), Good (3), Good (3)

Supporting comments:

- As described above, it would be expected that significantly more results would be obtained on experiments and modeling, as well as the use of other proppants. I would think that the PIs could recover from the current lack of progress with a concerted effort. As it stands, there was more fluff than substance.

- This is a very well managed project. The balance between academic and industrial research is good. The outcome of this project are valuable to the GTP, as well as to multiple areas outside of the GTP.

- Because of the lack of modeling and characterization of materials, this project is weakened. Overall, this project rates between a good and fair although only one box could be checked. With improved experiments and integration of modeling, results could be significant.

- No comments.

- Important project for geothermal R&D.

4.6.5.6 PI Response

No response.

4.6.6 Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems

Presentation Number: 033
Investigator: Rose, Peter (University of Utah)
Objectives: To develop through novel high-temperature tracing approaches three technologies for characterizing fracture creation within Enhanced Geothermal Systems (EGS).
Average Overall Score: 3.6/4.0

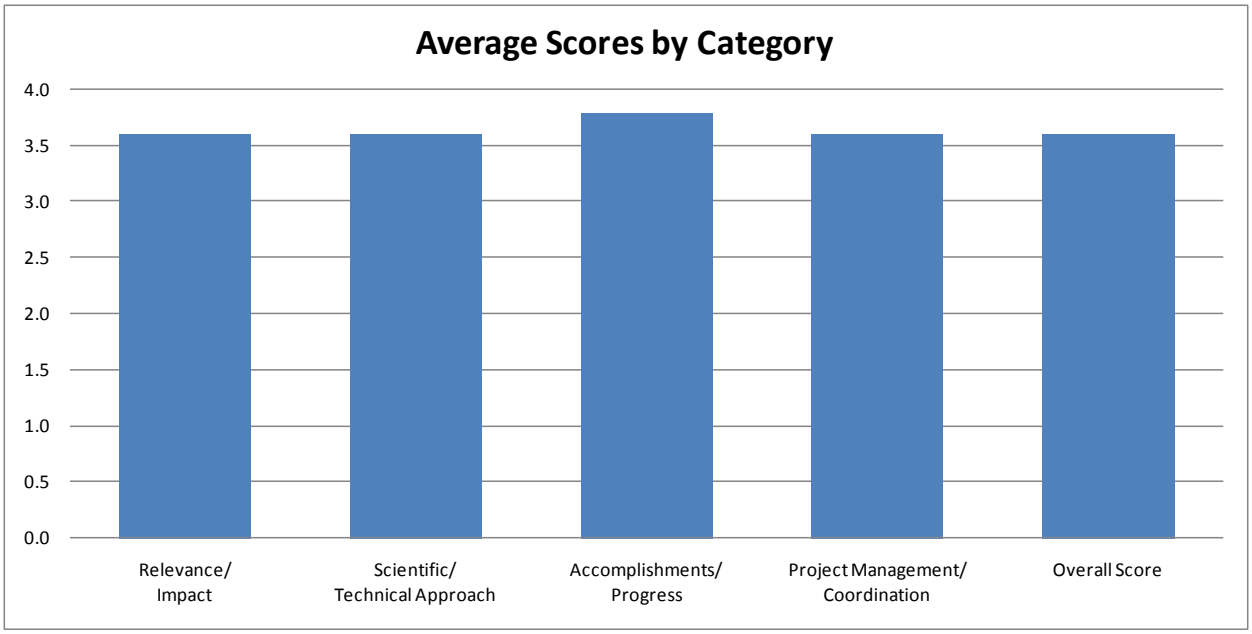


Figure 42: Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems

4.6.6.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The use of tracers has significant potential for characterizing some aspects of fractures in geothermal systems. I was less convinced than the PI as to the ability to extract fracture apertures from tracer tests, unless I misunderstood what he meant by fracture spacing. Through systematic evaluation of multiple tracers, it was concluded that safranin O would be a useful tracer with reasonable thermal stability. If information about fracture surface areas and spacing could be gleaned from tracer injection, then this would have important uses in EGS.

- This project deals with a large number of important problems for the GTP, related to tracers, from the identification of proper tracers, the design of numerical tools to estimate fracture

connectivity from tracer tests, and that of measurement tools. This project contributes to addressing key obstacles in the GTP, and provides valuable tools for other applications.

- This research addresses the significant technical barrier relating to measurement of the fluid-rock interfacial surface area - the area that controls heat exchange. This parameter is essential for understanding the productivity of EGS systems and developing the resources most effectively. This study provides methods to measure fracture surface area of injectors and producers and areas near the bore hole via interwell testing using tracers. In addition, a new borehole tool is being developed to enable direct measurements of fluid flow in fractures resulting from stimulation.

  The project demonstrates excellent progress toward goals and objectives - summarized as three primary tasks. As stated it is 37% complete. Each task has many subcomponents, all requiring significant effort. Design and fabrication of a new column reactor to simulate EGS is complete and measurement tools for tracers and effluent have been developed. Successful initial testing of the tracers and experimental setup has been completed. A number of experiments have been conducted with numerous tracers and an ideal tracer identified. Computational modeling is underway.

- Heat exchange in an EGS occurs on the fracture surfaces, and thus, estimating this area is a critical issue for the viability of a site. This project attempts to identify tracers that indicate fracture surface area. The project is also developing a down-hole instrument that is apparently better than current spinner tools for determining fracture flow.

- Investigators are making good progress.

4.6.6.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- Multiple tracers have been evaluated for use in EGS. A flow reactor was constructed in an appropriate way. I have some doubt that applications in real geothermal systems will be as straightforward as suggested in the presentation, due to the complexity of multiple interconnected pathways for fluid flow. The down-hole flow meter design seemed to be an appropriate design.

- This is a very rich project dealing with tracer technology at multiple levels: identification of tracers with optimal sorbtion properties, design of a borehole fluorimeter/flowmeter for measuring fracture flow, and design of an algorithm for the numerical approximation of fracture surface area from tracers. The approach is appropriate.

- The approach is well-designed following a systematic plan from laboratory experiments though model calibration and field testing. Initially, experimental tools and techniques have been developed and tested. Lab experiments are integrated with computational experiments as a means of data inversion. Each of the approaches is carefully designed, monitored and evaluated. Experiments provide the basis for the next stage of measurements that are feedback into the experiments and field tests. The continued evaluation of outcomes that are integrated into future experiments is a successful strategy for maximizing results. All steps appear to be rigorous.

  Little information was presented on the experimental starting materials other than the tracer. Fluid compositions for experiments with tracers should include those typical of EGS reservoirs to determine the effect of fluid chemistry on tracer behavior. No information was presented on the solid matrix used in the experiments to 'simulate' a geothermal reservoir. These data are critical in order to extrapolate to the natural system. Additional flow reactor tests to higher temperature are needed.

- The scientific approach is excellent: identifying candidate tracers, testing their behavior in a designed and fabricated laboratory system and mathematical modeling before proceeding to field testing.

- Good scientific approach and organization.

4.6.6.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The PI has made excellent progress assessing tracers, constructing a flow reactor, and designing a down-hole flow meter. The presentation graphs were not of good quality, as various curves were stacked on top of each other, making it difficult to understand some of the results. Collaboration with Pruess at LBNL is a valuable part of this project.

- This project had led to the identification of tracers with optimal properties, the development of a model to calculate fracture surface in injection/backflow tests based upon the kinetics of the thermal decay of tracers. They also designed a borehole fluorimeter/flowmeter for measuring fracture flow following a hydraulic stimulation experiment. Project is essentially on track with the proposed timeline. I am surprised by the lack of publications, considering the magnitude of the work performed.

- Productivity to date is excellent. Tasks 1 and 2 appear to be largely complete. The new laboratory flow reactor and measurement techniques/apparatus have been developed and

testing completed. Numerous tests with various candidate tracers have identified the most promising tracer (with thermal and chemical stability) and will be used in an upcoming field test. Computational modeling has been developed to invert the tracer data to interwell fracture surface area. This modeling is then extended to provide surface area calculations from injection and backflow tests. A new, novel, borehole flowmeter is being developed for down-hole use.

Upscaling of the lab results to field test is an important step for demonstrating the utility of this approach. Quality of the collaborators for modeling is excellent. Characterization of solids could be improved. No publications/presentations have yet resulted from this work. These are encouraged.

- Project has made good progress in identifying possible tracers and testing them in laboratory experiments in an apparatus they have fabricated. Design of the down-hole tool is also progressing despite a major change in design. Project seems to be on a trajectory to provide tracers and a tool for field testing.

- Well qualified performers. They have some good initial results.

4.6.6.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The project seemed well managed and designed. I have some concern about the field tests of the tracers: they seem to be planned, but apparently no field tests have been done to date. This is a critical issue for the remainder of the project. It seems that the down-hole meter had to be redesigned compared to the original plan, but the PI seems to have made appropriate and flexible decisions.

- Despite its breadth and complexity, the project is essentially on track. It is noted that the project involves collaboration with LBNL and LANL for the numerical modeling, and with multiple test sites operated by several industrial or institutional partners. The balance in fundamental, experimental, and numerical work and their integration is excellent. The technological design work and accomplishment is also very good.

- Based on the progress to date, management of the project is highly effective and well structured. Coordination between collaborators is evident in the multi-faceted approach to testing, experimenting and future directions.

- Project management seems straightforward and work seems well-coordinated with related computational work at LBNL. Plans are in place for review of the down-hole instrument.

Presentation mentions interaction with a number of field projects for use of the products, but this is for the future and understandably a bit vague at this point.

- Limited information on this metric, but no red flags.

4.6.6.5 Overall

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- Not only does this project address the use of tracers in EGS, but it has also evaluated numerous candidate tracers. I have some hesitation about the ease of interpretation of field tests of these tracers. It is intended that the fracture area available for heat exchange could be evaluated in field tests, but my guess is that this will be inconclusive. Perhaps the use of multiple tracers with known characteristics, as well as the use of heat exchange measurements from push-pull tests could extract some useful information, especially when combined with modeling with LBNL.

- This is a very well managed, very successful project.

- The project is well conceived and executed with its many components. All interact in a positive feedback to assure success.

- No comments.

- Important project for geothermal R&D.

4.6.6.6 PI Response

No response.

4.6.7 Tracer Methods for Characterizing Fracture Stimulation in Enhanced Geothermal Systems (EGS)

Presentation Number: 034
Investigator: Pruess, Karsten (Lawrence Berkeley National Laboratory)
Objectives: To design and analyze laboratory and field experiments that would (a) identify tracers with sorption properties favorable for EGS applications, (b) apply reversibly sorbing tracers to determine the fracture-matrix interface area available for heat transfer, and (c) explore the feasibility of obtaining fracture-matrix interface area from non-isothermal, single-well injection-withdrawal (SWIW) tests.
Average Overall Score: 3.8/4.0

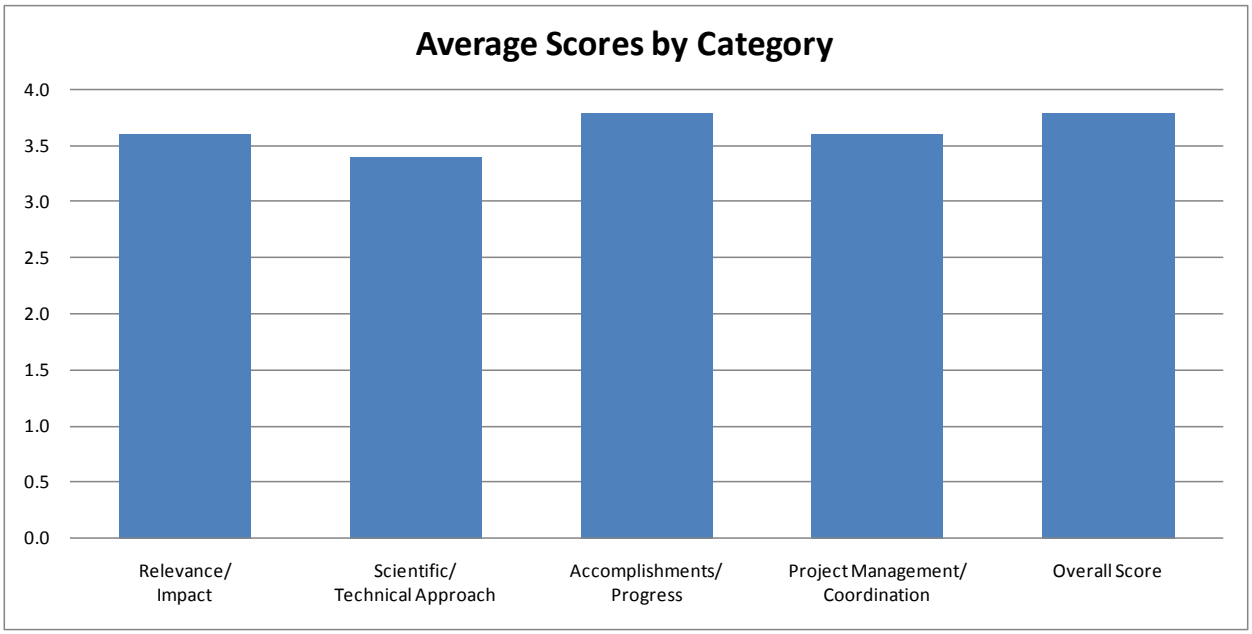


Figure 43: Tracer Methods for Characterizing Fracture Stimulation in Enhanced Geothermal Systems (EGS)

4.6.7.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The project (with a very small amount of funding) has excellent potential for site characterization using thermal and tracer response to single-well injection-withdrawal tests. The aim is to measure the surface area for heat exchange in a reservoir. Such characterization is fundamental to the success of EGS technologies.

- The project provides a low cost, simple but elegant approach to reservoir characterization using water as a tracer in single well injection-withdrawal test. One may argue with the claim that

heat conduction depends "only on thermal parameters of rocks and fluids", and is not affected by tortuosity effects. This may not be true when the crack opening is large enough. Also, the characterization of the heat transfer coefficient at the interfaces may not be very accurate.

- Characterizing the surface area of a fracture that is available to heat transfer by fluids is critical to the performance of EGS. Surface area is extremely difficult to measure by any number of tested techniques. This research suggests that surface area characterization procedures can be done using temperature with the additional benefit that heat exchange mimics the essential heat exchange process required in EGS systems. While the project is currently in the developmental stages, it has significant potential if the conceptual model can move onto a more real world scenario.

- Well-calibrated tracers will be important for characterizing subsurface fracture systems in selecting possible sites and inferring their changes during production. In addition to looking at sorbing tracers, the project is investigating the novel possibility that using temperature itself as an indicator appears to be advantageous.

- Investigators making good progress.

4.6.7.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- I particularly liked the section on equivalence between the reversibly-sorbing solutes and heat. As noted, this provides an additional method (heat) in addition to tracers to assess surface areas accessible for heat exchange in geothermal reservoirs. There was particular weakness in the description of boundary conditions and geometry for the model and results to extract the surface area. The relevance of a dispersion-free particle tracking method was poorly explained, and of doubtful importance. There are some ambiguities when moving from the simple fracture model to real field examples of complex fracture arrays that should have been discussed.

- The idea of using temperature as a tracer in reservoir characterization is both simple and elegant. The preliminary numerical and analytical results are very encouraging. At this stage, the project has only focused on analytical and numerical work. Field or lab tests are necessary to validate the approach. My only worry is that it reinforces even further the reliance of the GTP on a single numerical tool, a cost-efficient but potentially fragile approach.

- The approach relies on mathematical modeling using well-calibrated models. Verification and validation of the modeling approach will be provided by field tests. Assumptions are largely

known and stated. Effects of differing fluid and rock compositions (H_2O, CO_2, NaCl, cation/anion composition; amount of ferromagnesian phases) on heat exchange have not yet been addressed nor shown to be insignificant, as assumed, but may have important impacts. Conceptual model is limited to single fracture such that intersecting fractures have yet to be modeled.

- Thus far project has focused on numerical simulation of ideal situations in order to gain an understanding of behavior. Undoubtedly field and even laboratory systems will be more complex but intelligent interpretation of these requires a thorough understanding of less complex systems.

- Overall good progress. Strongly recommend looking at heterogeneous earth, not just homogeneous medium.

4.6.7.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- Although there were some geometric ambiguities of some of the modeling results (mentioned above), this project had a lot of "bang for the buck", given the nice exposition of the equivalence of tracer and thermal methods under some assumptions.

- The project is at a very early stage and has a fairly small budget, compared to others in this session. However, it has already lead to significant scientific accomplishments, and one conference proceedings paper.

- Productivity of the research is excellent, especially with respect to the low cost of the project. Results from a simplistic conceptual model had excellent agreement with the analytical solution supporting the approach as did the equivalence of solute and heat transfer. First order calculations support the hypothesis that temperature recovery is related to fracture-matrix surface area as measured by tracers. This paves the way for further, more refined, calculations. With additional parameters, this method has potential. Quality of the team and facilities is outstanding. A proceeding publication resulted from this work.

- This project has been very productive for its small scope and resources. The project undoubtedly benefits from an environment at LBNL that provides excellent resources and experience in numerical computation.

- Well qualified performers. They have some good initial results.

4.6.7.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The project management plan was not really given. Coordination with University of Utah was clear and relevant. It seems that the project is to end in 2010, and was only of 2 year duration. It should be extended if possible to an additional year, especially as relevant to support the tracer work of Rose.
- This is a small yet well managed project. The quality of the management is demonstrated by the good scientific productivity in such a short time.
- Management is minimal due to the small size of the project. Interactions and collaborations are on-going and effective.
- Project is small and well managed.
- Limited information on this metric, but no red flags.

4.6.7.5 Overall

Ratings of Five-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- This project will help advance theoretical understanding of characterization of rock surface areas usable for heat extraction in geothermal reservoirs. More complex geometries should be assessed and limitation of the comparison of solutes and thermal methods should be explored.
- This well managed project has progressed very quickly towards goals of significant importance for the GTP.
- Significant progress has been made to provide a new technique for measuring fluid-rock interface surface area, a critical parameter in the development and utilization of EGS. In light of the small budget, this is an exceptional study with far-reaching results.
- No comments.
- Important project for geothermal R&D.

4.6.7.6 PI Response

No response.

4.6.8 Chemical Signatures of and Precursors to Fractures Using Fluid Inclusion Stratigraphy

Presentation Number: 035
Investigator: Dilley, Lorie (Hattenburg, Dilley and Linnell, LLC)
Objectives: To develop a method to identify fracture systems in wells using fluid inclusion gas analysis of drill chips.
Average Overall Score: 2.2/4.0

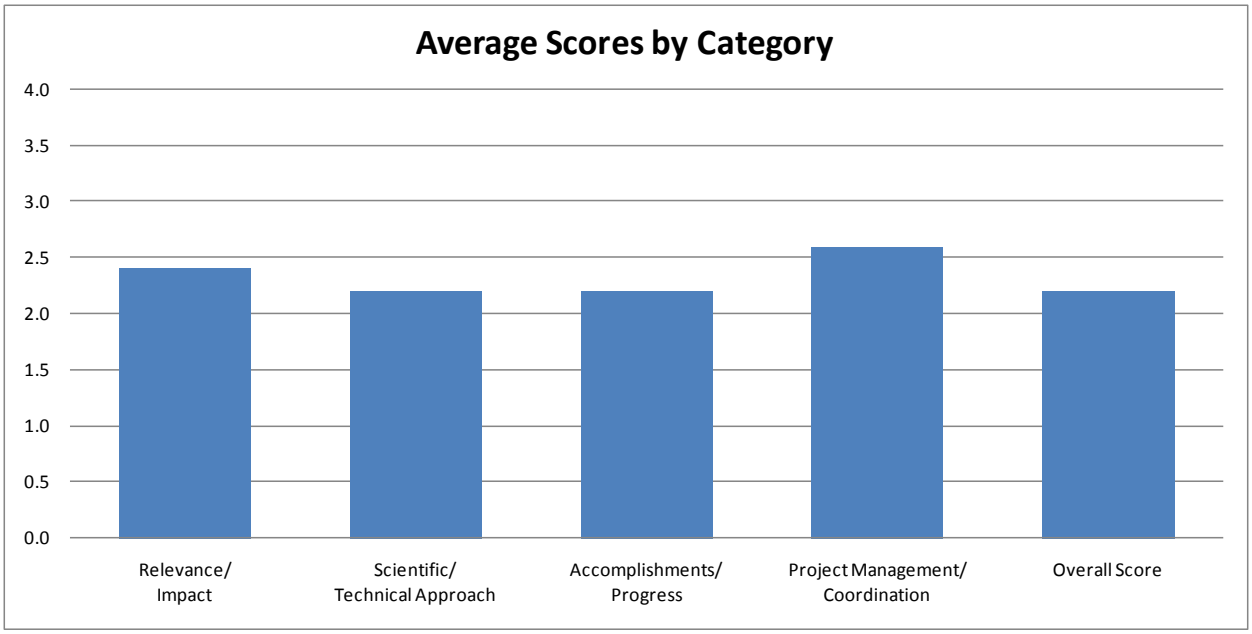


Figure 44: Chemical Signatures of and Precursors to Fractures Using Fluid Inclusion Stratigraphy

4.6.8.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Poor (1), Good (3), Good (3), Fair (2), Good (3)

Supporting comments:

- Although the fluid inclusion stratigraphy (FIS) results presented are intriguing and potentially of great value for understanding geothermal systems, the number of questions and concerns raised by Dilley's presentation and report weigh negatively on this project. The presentation and analysis of the multi-variate data were totally inadequate. Repeated comments that the statistics of gas concentrations (from FIS) were correlated with fracture density were utterly unconvincing. I would recommend that the PIs share the data collected with interested parties who would be more qualified to do the analysis and statistics.
- This project may provide a very low-cost way to identify open fracture systems by peaks in the fluid inclusion stratigraphy (FIS) signature during drilling. It is in line with the GTP goals.

- This research proposes to use fluid compositions and the abundance of fluids, extracted from trapped inclusions, to fingerprint the open fracture interval in geothermal systems. While this method has been used to target petroleum sources, it has not been applied to geothermal systems. Consequently, if successful, the project has potential to advance exploration techniques for geothermal target zones and could be highly useful. This work could provide a new, relatively inexpensive and fast technique for reservoir areas to target and enhance.

- The use of inclusion fluid stratigraphy to identify fracture zones and, possibly, fluid type in the reservoir could be a useful technique but thus far there seems to be considerable uncertainty in the interpretation of the results and a lack of quantitative assessment of the method.

- Investigator appears to have made good progress.

4.6.8.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Fair (2), Fair (2), Fair (2), Fair (2), Good (3)

Supporting comments:

- FIS analyses of chips from drilling with a reported (as small as) 10-foot spacing were presented. The gas concentration units were never given. Plots were "average" plus "two times standard deviation" versus depth according to the verbal presentation. Given that the standard deviation was often as large as the average, the plots could be apparently dominated by noise or analytical uncertainty, a wholly unjustified method of presentation. Comparison to geology and mineralogy of segments along the core were apparently planned, but no results of such a comparison were given. Local mineralogy may have in fact been more important than "open fractures". It may have been that the fluid inclusion data were dominated by the local mineralogy, but this cannot be known from the results. The "open" fractures and "lost circulation" were based on inadequate observational data and questionable relationships to N2 and CO_2 ratios. Permeability of actual core samples should have been made for "ground truthing", but this was not done. The time of sealing of fluid inclusions and their formation time were implicitly assumed to be recent, which may not be true at all. The time of formation of the fluid inclusions is critically important for this study, but documentation of this seems impossible. Whether gas concentrations were above or below fractures was supposed to mean something, but no convincing statistical analysis was presented. For the multi-variate analysis, I would suggest that the PIs look into the open source free software "R" (http://www.r-project.org). I'm not even sure who did the actual gas analyses for this FIS. Was it done by the PIs, or was this outsourced?

- The methodology is not entirely clear from the provided documents. In particular, the rationale for focusing on specific chemical signatures while ignoring others is not entirely clear to me. The correlation between peaks in the FIS and open fracture systems is also not clear. The method has not yet demonstrated its ability to reliably predict open fracture system locations. In particular, it seems that in order to identify the location of fracture systems, one needs to

selectively filter through a very large number of measurements. This filtering does not seem systematic. Maybe the project would benefit from a deeper collaboration with statisticians.

- To acquire fluid chemistry, cores are sampled and the samples sent out to industry for analysis in a mass spectrometer (a bulk technique that averages the sample). Data returns to the PI for analysis. This approach is standard. Methods and procedures for fluid chemistry analysis are patented and, thus, unavailable. Sensitivity, errors are not listed.

  Plots are made of fluid compositions and amount per stratigraphic interval and used for interpretation. These plots are to be related to mineralogy of the corresponding zone. To date, there has been relatively little data analysis. A few plots were presented that contained many of the fluid species but all plots were qualitative (no numbers were attached). The amount of data returned might be immense, but the PI needs to explore other/new methods to interrogate the data and to display the results (the key data). For example, try plotting different scales, different components, multiple components, try tools for visual analysis of large datasets, and above all - keep quantitative data quantitative until you know the absolute values are not important.

  In addition, it is unclear why sealed fractures (those with fluid inclusions) in the wall rock adjacent to open fractures are key to current "open" fractures. The hypothesis needs to be tested and shown to be valid. How many generations of sealed fractures are present in the samples? Do the various "closed" fractures/fluid inclusion generations have the same chemical signature? How does averaging affect the overall result? Fluid inclusions are stable. These inclusions could be from the time the melt crystallized and not representative of the geothermal system. Fluid inclusions are stable - once they form, they remain. There are 3.6 billion year, three-phase fluid inclusions that remain in Archean ironstones. A significant amount of work needs to go into rigorous data analysis before this technique will be viable, but it holds promise.

- The approach seems largely one of empirical correlations of chemical signatures with fractures observed in boreholes. The project would be improved by more effort to achieve a better fundamental understanding of the mechanisms and their magnitudes. Although the approach generates a large amount of data, its interpretation seems unclear.

- Overall good approach and organization. PI needs to include more quantitative information on slides - - fracture numbers, permeability, etc. Too many qualitative indicators, when quantitative information should be available and would be more helpful.

4.6.8.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Poor (1), Fair (2), Fair (2), Good (3), Good (3)

Supporting comments:

- The results themselves are interesting, but the underlying assumptions and the presentation of the data without rigorous statistical analysis render the accomplishment “poor”. See comments on #2 above.

- In my opinion, Phase I has not yet demonstrated the method's ability to reliably predict open fracture system locations. Phase II consists of performing a large number of measurements. It is not entirely clear to me how increasing the already colossal amount of data will improve the predictive abilities of the method. I would suggest that the project focus on improving the robustness of the prediction with a small amount of data before performing more measurements.

- a. Productivity: Phase 1 had five subtasks.
  1. Literature review was completed although not presented.
  2. Simple statistics are used to determine which chemical species is highest in known fractures. Some statistics have been done but no units were given - there are orders of magnitude changes in some of the species but it is unclear what this means. Specific FIS could not be positively linked to fracture zones.
  3. Minerals assemblages and changes to FIS are to be evaluated but no information was presented relating mineralogy to FIS.
  4. Fractures and non-fractured regions in epithermal systems are to be compared, again, no data were presented.
  5. Additional core sampling identified, this has been done. Perhaps this information was reported earlier but it was not contained in the review materials nor answered in the questioning.

  The project is stated to be 80% complete. Phase 2, 3 are additional sampling and analyses. Goals were to identify chemical species in active geothermal systems; evaluate FIS signatures based on mineral assemblages in the fracture and determine specific chemical signatures in rock above open fractures. It remains unclear how there can be an FIS signature in "open" fractures - they are open, hence they cannot contain fluid inclusions.

  Significant data analysis remains to be done. Quality of the resources and people appears to be adequate. Collaborations might include someone well versed in working with large datasets. One proceedings paper has resulted.

- Use of resources seems to be good, and much work has been done but its interpretation seems still uncertain. Productivity appears adequate although I would have expected that a project this far along (roughly 80%) had produced more papers or presentations.

- Appears to be some interesting initial results.

4.6.8.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Poor (1), Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- No project management plan or organization was given, so it was impossible to evaluate this item.
- The project management seems appropriate. Although it may be late at this stage of the project, I would recommend that the investigators seek deeper involvement of statisticians.
- Project management has been carried out effectively. Cores have been sampled, analyses performed and interactions with other team members have occurred.
- Project management and planning is adequate though it seemed to lack specific targets about the feasibility and usefulness and/or advantages of this method.
- Limited information on this metric, but no red flags.

4.6.8.5 Overall

Ratings of Five-member Peer Review Panel: Poor (1), Fair (2), Fair (2), Good (3), Good (3)

Supporting comments:

- See comments above. I hope DOE can extract the usable data from this study and make it available (gas concentration versus depth for all boreholes analyzed) to investigators who may be able to make sense of the measurements.
- While I would not rule out the idea of using Fluid Inclusion Stratigraphy to identify open fracture systems, I would not consider that this project has proved or is on track to prove the viability of this approach.
- Because the success of the project relies heavily on the quality of data analyses which has largely been minimal, the project needs attention. No mineralogic analysis nor direct observation of cores being sampled has occurred but is critical for making the case and may bring to light new lines of evidence to support the hypothesis. This project has significant potential but is currently unconvincing. Conclusions need to be supported by data. No peer reviewed publications have resulted, as of yet, with the exception of conference proceedings.
- A good project that has produced much data and some interesting results but I think it needs to be a bit more vigorous in its approach to assessing and understanding the method.
- Useful project for geothermal energy.

4.6.8.6 PI Response

No response.

5.0 Conclusions and Recommendations

The Geothermal Technologies Program recognizes the vital role of peer review in ensuring the integrity, productivity and relevance of funded projects. Reviews have long been used in DOE's Geothermal Program to help establish program priorities, alert staff to potential problems, provide advice and feedback to principal investigators and their research staffs, and to disseminate information about the Program and its results. The guidance provided by such reviews has had a significant part to play in the success of DOE's geothermal energy research program over some four decades. In recent years, more rigor has been brought into these reviews through the establishment of a formal process with carefully selected peer reviewers. The current Peer Review followed guidance developed by the DOE Energy Efficiency and Renewable Energy Program based on best practices for peer review in government and academic research.

During this Peer Review meeting, 35 projects, the majority initiated between 2007 and 2009, were subjected to a full, formal review by three to five objective and qualified reviewers. Reviewers were carefully selected by GTP staff from a list of candidates on the basis of the expertise needed to review their assigned projects effectively while ensuring no conflict of interest. Many of the reviewed projects aimed at solving problems associated with the development of Enhanced Geothermal Systems, reflecting the program priorities at the time of funding. With a greatly enhanced geothermal budget, due in part to the availability of American Recovery and Reinvestment Act of 2009 (ARRA) funds, the geothermal program has now expanded to include new areas of research and demonstration as well as strengthened work in traditional areas. As a result, many new projects, funded during the last year, have not made enough progress to warrant a full review at this time. A total of 168 of these recently funded projects was presented in overview fashion in order to alert the public to the new breadth of the Program, and to bring together researchers, the geothermal community at large and the GTP staff for three days of intensive communication concerning them.

The majority of the 35 projects receiving full formal review were judged by the reviewers to be relevant to program goals, making significant progress, well managed and worthy investments of federal funds. Those few projects that received lower ratings have been called to the attention of the GTP staff as a result of this review, and corrective actions are underway.

A total of 337 people participated in the meeting as presenter, researcher, reviewer, organizer, or spectator. Thus, this Peer Review meeting was one of the best attended of such meetings in the history of the Geothermal Technologies Program. The meeting was deemed to be a success by all participants, and a great deal of enthusiasm for the Program was evident in the lively participation in the technical sessions as well as in side meetings and conversations.

An obvious conclusion from this meeting is the necessity for subjecting all funded geothermal research projects to periodic peer review. Indeed, peer review has long been recognized as necessary in all scientific endeavors as well as in publication of research results. Peer review of projects benefits the Program by obtaining outside objective and informed evaluations on the relevance of funded projects to

the Program's goals and objectives, the effectiveness of project management, and the progress made toward the funded project's objectives. For principal investigators, the peer review provides feedback from experts on executing their projects and often includes suggestions for resolving problems or enhancing the value of their efforts. Peer review advances geothermal science and technology by improving individual research, and by challenging and enhancing the focus of GTP-sponsored research on objectives that are important for the development of geothermal technology. It is strongly recommended by the personnel involved in the current Peer Review that such reviews continue on a regular basis in the Geothermal Technologies Program.

6.0 APPENDICES

6.1 Peer Reviewer Evaluation Form

Relevance/Impact of the Research

Assess the importance of achieving the project's objectives relative to the broader Geothermal Program mission of conducting research, development and demonstration projects to establish Enhanced Geothermal Systems (EGS) as a major contributor for electricity generation. Evaluate the extent to which project activities address known, anticipated, and significant technical or market barriers. In the case of longer term basic research, with as-yet unconfirmed results, consider the degree to which the project advances the underlying science and technology and adds to the knowledge base.

4 – Outstanding. The project/program has made excellent progress toward DOE goals and objectives.

3 – Good. The project/program demonstrates significant progress toward DOE goals and objectives.

2 – Fair. The project/program demonstrates a modest amount of progress toward DOE goals and objectives, but the overall rate of accomplishments has been slow.

1 – Poor. The project/program demonstrates little or no progress toward DOE goals and objectives.

Please provide supporting comments:

Scientific/Technical Approach

Rate the rigor and appropriateness of the technical approach (work elements, procedures and methods, etc.) to achieving the project objectives with the available resources. Cover both the design of the technical approach and how well the approach has been executed in project tasks.

4 – Outstanding. The approach is sharply focused, well-designed and focused on one or more key technical barriers to the development of geothermal technologies.

3 – Good. The approach is generally well thought out and effective. Most aspects of the project/program will contribute to significant progress in overcoming barriers.

2 – Fair. Some aspects of the project may lead to progress in overcoming some barriers but the approach has significant weaknesses.

1 – Poor. The approach is unlikely to make significant contributions to overcoming the barriers.

Please provide supporting comments:

Accomplishments, Expected Outcomes and Progress

Assess the overall quality of the research team, equipment and facilities and any accomplishments to date. Factors to consider include:

a) Productivity -- the level of productivity in work underway considering accomplishments and the value of the accomplishments compared to costs. This includes achievement against planned goals and objectives, technical targets, awards, or other success measures typical for the type of activity.

b) Quality -- the composition and quality of the resources engaged, including people and facilities. Considered are the team members' honors and awards, their relevant experience, and the balance of appropriate skills (including collaborators).

4 – Outstanding. The composition and quality of the resources applied to the project are outstanding and results have been outstanding in relation to the resources expended.

3 – Good. The composition and quality of the resources applied to the project are good and results have been good in relation to the resources expended.

2 – Fair. The composition and quality of the resources applied to the project are fair and results have been fair in relation to the resources expended, but there is room for improvement.

1 – Poor. The composition and quality of the resources applied to the project are poor and/or the results have been poor in relation to the resources expended; there is significant room for improvement.

Please provide supporting comments:

Project Management/Coordination

Assess how well technical, policy, business, and spend plans for the project are carried out, and evaluate prospective future efforts in these areas. Verify that the project includes decision points where the project can either be ended or redirected, and whether these decision points are appropriately placed in the research plan.

4 – Outstanding. Management of this project has been exceptionally effective and/or the plans for management are very well-structured and include all the appropriate management checks and controls necessary.

3 – Good. Management of this project has been very effective and/or the plans for management are well-structured and include all the appropriate management checks and controls necessary, but minor improvements are possible.

2 – Fair. Management of this project has been weak and at least partially ineffective and/or the plans for management are not well-structured and are missing some appropriate management checks and controls.

1 – Poor. Management of this project has been ineffective and has impaired its success, and/or the plans for management are poorly structured and are missing critical management checks and controls.

Overall

Please provide your general overall rating of the project, followed by comments. In addition, please separately highlight any factors or considerations which have not been adequately covered by the prior criteria above.

4 – Outstanding. A world-class project in nearly all respects.

3 – Good. A strong project deserving of priority attention.

2 – Fair. A weak project or one with some significant deficiencies requiring management attention.

1 – Poor. A project with serious deficiencies which warrants careful re-evaluation

Please provide supporting comments:

Average score for all 4 criteria:

6.2 Instructions to Peer Reviewers and Presenters

Peer Reviewers:

Objective review and advice from peers (peer review)provides managers, staff, or researchers, a powerful and effective tool for enhancing the management, relevance, effectiveness, and productivity of all of the Office of Energy Efficiency and Renewable Energy (EERE) research, development, demonstration, deployment and supporting business management programs.
– EERE Peer Review Guidance

Overall Leadership of the Peer Review

Phillip Michael Wright (Mike) (pmwslc@aol.com) chairs the Geothermal Peer Review and will provide overall guidance to assure quality and an outcome that is helpful to DOE Geothermal Programs and projects. He and the peer reviewers are to operate independently of the Department of Energy, relying solely on their own expertise and judgment.

Hildigunnur Thorsteinsson (Hildigunnur.Thorsteinsson@ee.doe.gov) is DOE's technical lead for the Peer Review and will arrange support and assistance that will expedite the work of the peer reviewer panels.

Peer Reviewers

The peer reviewers are the heart of the peer review, bringing independent technical expertise to the process.

There are at least three reviewers per panel (technical track), one of whom will be designated as the panel chair. The panel will hear presentations by principal investigators for each project, engage in discussions with the presenter, and draw conclusions as individual peer reviewers as to the quality and progress of each project presented. Conclusions are independently derived by each individual peer reviewer – there is no requirement for consensus, because DOE seeks forthright evaluation from each individual expert reviewer.

Persons attending the peer review presentations, apart from the project's presenter and the peer review panel members, are not participants and shall speak only if invited to do so by the panel. The panel chair shall helpfully guide the panel in its work. P. Michael Wright is the overall peer review chair and panels may consult him as they wish.

What you Should Do

- Before Review Meeting
  - Peruse the web site so that you are generally familiar with all aspects of the peer review
  - Prepare and submit your written materials (CV, Conflict of Interest, Hotel reservations)

- Obtain and log into the ORISE system and become familiar with ORISE data input procedure

- At Review Meeting
  - Confine presentations to 20 minutes
  - Hold significant questions until after each presentation; Enforce
  - 10 Minutes of Q/A – Briefly from each peer reviewer in turn
  - Participate in feedback and questions to PI/Presenters

- After the Review Meeting
  - Submit final evaluations within 1 week via PeerNet. If you are unable to complete your reviews in PeerNet, please submit them in Word format to geotech2010@orise.orau.gov
  - Submit requests for reimbursement

Presenters

Instructions to presenters are attached in a document entitled "2010 Geothermal Technologies Program Peer Review Guidelines for Preparing and Submitting Project Summaries" and presented in file: Project_Summary_Guidelines.pdf

Schedule-At-A-Glance

2010 U.S. Department of Energy Geothermal Peer Review - Pre-Meetings, Crystal City Hyatt, May 17, 2010

	Lower Level				3rd Floor			
	Conference Theater	Washington A	Washington B	Regency C/D	Kennedy	Jefferson	Lincoln	Roosevelt
Monday, May 17th								
12:00			National Geothermal Data System, Resource Assessment and Classification - Lunch					
1:00	National Geothermal Data System, Resource Assessment & Classification - Project Coordination							
2:00		Ground Source Heat Pump Operational Data Collection Planning Meeting						
3:00								
4:00								
5:00			Reception					
5:30								
6:00								

Schedule-At-A-Glance
2010 U.S. Department of Energy Geothermal Peer Review, Crystal City Hyatt, May 18-20, 2010

Tuesday, May 18th

8:00 Breakfast in Regency Foyer, Lower Level
9:00 Welcome in Regency A/B, Lower Level
9:15 Steve Chalk - Chief Operating Officer & Acting Deputy Assistant Secretary for Renewable Energy, Energy Efficiency and Renewable Energy
9:30 Jay Nathwani - Acting Program Manager, Geothermal Technologies Program
9:45 Lauren Boyd - Technology Development Manager, Geothermal Technologies Program
10:00 Tim Reinhardt - Technology Development Manager, Geothermal Technologies Program
10:15 Break
10:45 Hidda Thorsteinsson - Technology Development Manager, Geothermal Technologies Program
11:00 Arlene Anderson -Team Lead, Strategic Planning, Analysis and Geothermal Informatics
11:15 Tina Kaarsberg - Geothermal Heat Pump Lead and Senior Policy Analyst
11:30 Hidda Thorsteinsson - Technology Development Manager, Geothermal Technologies Program
11:45 Lunch, Served in Regency C/D, Lower Level. Speaker: Walt Snyder - Professor of Stratigraphy & Sedimentology, Boise State University

	Lower Level				3rd Floor			
	Conference Theater	**Washington A**	**Washington B**	**Regency C/D**	**Kennedy**	**Jefferson**	**Lincoln**	**Roosevelt**
1:00	EGS, Low Temperature, Exploration and Demonstration Projects	High Temperature Tools and Drilling	Seismicity and Reservoir Fracture Characterization	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Specialized Materials and Fluids and Power Plants	Reservoir Characterization
2:00	Break							
2:15 4:00 5:00	EGS, Low Temperature, Exploration and Demonstration Projects	High Temperature Tools and Drilling	Seismicity and Reservoir Fracture Characterization	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Specialized Materials and Fluids and Power Plants	Reservoir Characterization

Wednesday, May 19th

7:30	Breakfast in Regency Foyer, Lower Level							
8:00 9:00	EGS, Low Temperature, Exploration and Demonstration Projects	High Temperature Tools and Sensors, Downhole Pumps and Drilling	Seismicity and Seismic	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Specialized Materials and Fluids and Power Plants	Reservoir / Low Temperature Demonstration Projects
10:00	Break							
10:15	EGS, Low Temperature, Exploration and Demonstration Projects	High Temperature Tools and Sensors, Downhole Pumps and Drilling	Seismicity and Seismic	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Chemistry, Reservoir and Integrated Models	Low Temperature Demonstration Projects
11:45	Lunch, Served in Regency C/D, Lower Level. Speaker: Henry Kelly - Principal Deputy Assistant Secretary, Energy Efficiency and Renewable Energy							
1:00	*Seismicity Working Group - Side Meeting*	High Temperature Tools and Sensors, Downhole Pumps and Drilling	Tracers and Exploration Technologies	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Chemistry, Reservoir and Integrated Models	Low Temperature Demonstration Projects
2:00	Break							
3:00 4:00 5:00	*Seismicity Working Group - Side Meeting*	High Temperature Tools and Sensors, Downhole Pumps and Drilling	Tracers and Exploration Technologies	GSHP Demonstration Projects	Analysis, Data System and Education	Validation of Innovative Exploration Technologies	Chemistry, Reservoir and Integrated Models	Low Temperature Demonstration Projects

Schedule-At-A-Glance
2010 U.S. Department of Energy Geothermal Peer Review, Crystal City Hyatt, May 18-20, 2010

	Lower Level				3rd Floor			
	Conference Theater	**Washington A**	**Washington B**	**Regency C/D**	**Kennedy**	**Jefferson**	**Lincoln**	**Roosevelt**
Thursday, May 20th								
7:30	Breakfast in Regency Foyer, Lower Level							
8:00				GSHP Demonstration Projects			Chemistry, Reservoir and Integrated Models	
9:00						*Low Temperature Geothermal Roadmapping Planning - Side Meeting*		
10:00	Break							
10:15				GSHP Demonstration Projects		*Low Temperature Geothermal Roadmapping Planning - Side Meeting*		**Prince William**
10:30								*Reservoir Modeling Working Group - Side Meeting*
11:00								
12:00								
1:00								
2:00								

6.3.2 Detailed Agenda

2010 Geothermal Peer Review, Hyatt Crystal City, Conference/Theater Room, Lower Level

Tuesday, May 18

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Full Review	Engineered Geothermal Systems Demonstration Projects	Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Walters, Geysers Power Company, LLC
18-May	1:15 - 1:30				
18-May	1:30 - 1:45	Full Review	Engineered Geothermal Systems Demonstration Projects	Feasibility of EGS Development at Bradys Hot Springs, NV	Drakos, ORMAT Nevada, Inc.
18-May	1:45 - 2:00				
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Full Review	Engineered Geothermal Systems Demonstration Projects	Concept Testing and Development at the Raft River Geothermal Field, ID	Moore, University of Utah
18-May	2:30 - 2:45				
18-May	2:45 - 3:00	Full Review	Engineered Geothermal Systems Demonstration Projects	Desert Peak East EGS Project	Drakos, ORMAT Nevada, Inc.
18-May	3:00 - 3:15				
18-May	3:15 - 3:30	Full Review	Engineered Geothermal Systems Demonstration Projects	Creation of an Enhanced Geothermal System through Hydraulic and Thermal Stimulation	Rose, University of Utah
18-May	3:30 - 3:45				
Wednesday, May 19					
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
19-May	8:00 - 8:15	Full Review	Low-temperature, Exploration Demonstration Projects	Geothermal Testing Facilities in an Oil Field - Rocky Mountain Oil Field Testing Center	Johnson, RMOTC
19-May	8:15 - 8:30				
19-May	8:30 - 8:45	Full Review	Low-temperature, Exploration Demonstration Projects	Electric Power Generation Using Geothermal Fluid Co-produced from Oil & Gas	Karl, Chena Hot Springs Resort
19-May	8:45 - 9:00				
19-May	9:00 - 9:15	Full Review	Low-temperature, Exploration Demonstration Projects	GRED Drilling Award - GRED III Phase II	Karl, Chena Hot Springs Resort
19-May	9:15 - 9:30				
19-May	9:30 - 9:45	Full Review	Low-temperature, Exploration Demonstration Projects	Klamath and Lake Counties Agricultural Industrial Park	Riley, South Central Oregon Economic Development District
19-May	9:45 - 10:00				
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Overview	Engineered Geothermal Systems Demonstration Projects	Newberry Volcano EGS Demonstration	Petty, AltaRock Energy, Inc.
19-May	10:30 - 10:45	Overview	Engineered Geothermal Systems Demonstration Projects	Southwest Alaska Regional Geothermal Energy Project - Implementation of a Demonstration EGS Project in Naknek, AK	Friedman, Naknek Electric Association
19-May	10:45 - 11:00	Overview	Engineered Geothermal Systems Demonstration Projects	New York Canyon Stimulation	Raemy, TGP Development Company, LLC
19-May	11:00 - 11:15	**Q&A**			
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			

2010 Geothermal Peer Review, Hyatt Crystal City Washington A, Lower Level

Tuesday, May 18th

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Full Review	High-temperature Tools and Drilling	Detecting Fractures Using Technology at High-temperatures and Depths - Geothermal Ultrasonic Fracture Imager (GUFI)	Patterson, Baker Hughes Oilfield Operations Incorporated
18-May	1:15 - 1:30				
18-May	1:30 - 1:45	Full Review	High-temperature Tools and Drilling	Development and Demonstration of an Electric Submersible Pump at High Temperatures	Hooker, Composite Technology Development, Inc.
18-May	1:45 - 2:00				
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Full Review	High-temperature Tools and Drilling	Development of Tools for Measuring Temperature, Flow, Pressure, and Seismicity of EGS Reservoirs	Tilak, GE Global Research
18-May	2:30 - 2:45				
18-May	2:45 - 3:00	Full Review	High-temperature Tools and Drilling	High-temperature ESP Monitoring	Booker, Schlumberger Technology Corp
18-May	3:00 - 3:15				
18-May	3:15 - 3:30	Full Review	High-temperature Tools and Drilling	Extending the Temperature Range of Electric Submersible Pumps to 338 °C - Hotline V High-temperature ESP	Dowling, Schlumberger Technology Corp
18-May	3:30 - 3:45				
18-May	3:45 - 4:00	Full Review	High-temperature Tools and Drilling	Fielding of HT Seismic Tools and Evaluation of HT FPGA Module	Henfling, SNL
18-May	4:00 - 4:15				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Multi-parameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems	Knobloch, GE Global Research
19-May	8:15 - 8:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	High-temperature, High-volume Lifting for Enhanced Geothermal Systems	Turnquist, GE Global Research
19-May	8:30 - 8:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells	Tilak, GE Global Research
19-May	8:45 - 9:00	**Q&A**			
19-May	9:00 - 9:15	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	OM300: Geothermal MWD Tools Navigation Instrument	MacGugan & Ohme, Honeywell International Inc.
19-May	9:15 - 9:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Micro-hole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Oglesby, Impact Technologies LLC
19-May	9:30 - 9:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Technology Development and Field Trials of EGS Drilling Systems	Bauer, SNL
19-May	9:45 - 10:00	**Q&A**			
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Base Technologies and Tools for Supercritical Reservoirs	Henfling, SNL
19-May	10:30 - 10:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Advanced Drilling Systems for EGS	Hall, Novatek, Inc
19-May	10:45 - 11:00	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Pertubation Sensing	Freifield, LBNL
19-May	11:00 - 11:15	**Q&A**			
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Feasibility and Design for a High-temperature Down-hole Tool	Akkurt, ORNL
19-May	1:15 - 1:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Multi-purpose Acoustic Sensor for Down-hole Fluid Monitoring	Pantea, LANL
19-May	1:30 - 1:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Wear-resistant NanoComposite Stainless Steel Coatings and Bits for Geothermal Drilling	Peter, ORNL

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	1:45 - 2:00	**Q&A**			
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Harsh Environment Silicon Carbide Sensor Technology for Geothermal Instrumentation	Pisano, The Regents of the University of California
19-May	2:30 - 2:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Complete Fiber/Copper Cable Solution for Long-term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Lowell, DRAKA CABLETEQ USA, INC.
19-May	2:45 - 3:00	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	Development of a Hydrothermal Spallation Drilling System for EGS	Potter, Potter Drilling, Inc.
19-May	3:00 - 3:15	**Q&A**			
19-May	3:15 - 3:30	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	High-temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Hooker, Composite Technology Development, Inc.
19-May	3:30 - 3:45	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	High-temperature Perforating System for Enhanced Geothermal Applications	Smart, Schlumberger Technology Corp
19-May	3:45 - 4:00	Overview	High-temperature Tools and Sensors, Down-hole Pumps and Drilling	High-temperature 300 °C Directional Drilling System	Macpherson, Baker Hughes Oilfield Operations Incorporated
19-May	4:00 - 4:15	**Q&A**			

2010 Geothermal Peer Review, Hyatt Crystal City, Washington B, Lower Level

Tuesday, May 18

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Overview	Seismicity and Reservoir Fracture Characterization	Fluid Imaging of Enhanced Geothermal Systems	Newman, LBNL
18-May	1:15 - 1:30	Overview	Seismicity and Reservoir Fracture Characterization	Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems	Gritto, Array Information Technology
18-May	1:30 - 1:45	Overview	Seismicity and Reservoir Fracture Characterization	Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems Reservoirs	Huang, LANL
18-May	1:45 - 2:00	Q&A			
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Overview	Seismicity and Reservoir Fracture Characterization	Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Templeton, LLNL
18-May	2:30 - 2:45	Overview	Seismicity and Reservoir Fracture Characterization	Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments	Ghassemi, Texas A&M University
18-May	2:45 - 3:00	Overview	Seismicity and Reservoir Fracture Characterization	Fracture Network and Fluid Flow Imaging for EGS Applications from Multi-dimensional Electrical Resistivity Structure	Wannamaker, University of Utah
18-May	3:00 - 3:15	**Q&A**			
18-May	3:15 - 3:30	Overview	Seismicity and Reservoir Fracture Characterization	Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-exposed, High-velocity Rocks	Hardage, University of Texas at Austin
18-May	3:30 - 3:45	Overview	Seismicity and Reservoir Fracture Characterization	Characterizing Fractures in Geysers Geothermal Field from Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	Aminzadeh, University of Southern California
18-May	3:45 - 4:00	Overview	Seismicity and Reservoir Fracture Characterization	Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions	O'Connell, William Lettis & Associates, Inc.
18-May	4:00 - 4:15	**Q&A**			

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Full Review	Seismicity and Seismic	Microearthquake Technology for EGS Fracture Characterization	Foulger, Foulger Consulting
19-May	8:15 - 8:30				
19-May	8:30 - 8:45	Full Review	Seismicity and Seismic	Seismic Fracture Characterization Methodologies For Enhanced Geothermal Systems	Queen, Hi-Q Geophysical Inc.
19-May	8:45 - 9:00				
19-May	9:00 - 9:15	Full Review	Seismicity and Seismic	Microseismic Study with LBNL	Majer, Lake County
19-May	9:15 - 9:30				
19-May	9:30 - 9:45	Full Review	Seismicity and Seismic	Development of an Updated Induced Seismicity Protocol for the application of Microearthquake Monitoring for characterizing Enhanced Geothermal Systems	Majer, LBL
19-May	9:45 - 10:00				
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Full Review	Seismicity and Seismic	Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System Reservoir	Fehler, Massachusetts Institute of Technology
19-May	10:30 - 10:45				
19-May	10:45 - 11:00	Full Review	Seismicity and Seismic	Well Monitoring Systems for EGS	Normann, Perma Works and Frequency Management International
19-May	11:00 - 11:15				
19-May	11:15 - 11:30	Full Review	Seismicity and Seismic	Analysis of Geothermal Reservoir Stimulation using Geo-mechanics-based Stochastic Analysis of Injection-induced Seismicity	Ghassemi, Texas A&M University
19-May	11:30 - 11:45				
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Tracers and Exploration Technologies	Using Thermally-degrading, Partitioning and Non-reactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Watson, BNL; Reimus; Vermeul, PNNL
19-May	1:15 - 1:30	Overview	Tracers and Exploration Technologies	Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-based Geothermal Reservoirs	Hull, INL
19-May	1:30 - 1:45	Overview	Tracers and Exploration Technologies	Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments	Becker, California State University, Long Beach Foundation
19-May	1:45 - 2:00	**Q&A**			

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	Tracers and Exploration Technologies	Integrated Chemical Geothermometry System for Geothermal Exploration	Spycher, LBNL
19-May	2:30 - 2:45	Overview	Tracers and Exploration Technologies	Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Kennedy, LBNL
19-May	2:45 - 3:00	Overview	Tracers and Exploration Technologies	Novel Multi-dimensional Tracers for Geothermal Inter-well Diagnostics	Tang, Power, Environmental and Energy Research Institute
19-May	3:00 - 3:15	**Q&A**			
19-May	3:15 - 3:30	Overview	Tracers and Exploration Technologies	Quantum Dot Tracers for Use in Enhanced Geothermal Systems	Rose, University of Utah
19-May	3:30 - 3:45	Overview	Tracers and Exploration Technologies	Characterizing Structural Controls of EGS-candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	Faulds, Board of Regents, NSHE, on behalf of UNR
19-May	3:45 - 4:00	Overview	Tracers and Exploration Technologies	Development of Exploration Methods for Enhanced Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation	Iovenitti, Altarock Energy, Inc.
19-May	4:00 - 4:15	Overview	Tracers and Exploration Technologies	Advanced 3-D Geophysical Imaging Technologies for Geothermal Resource Identification	Newman, LBNL & Fehler, MIT
19-May	4:15 - 4:30	Overview	Tracers and Exploration Technologies	Fracture Evolution Following Hydraulic Stimulation within an EGS Reservoir	Rose, University of Utah
19-May	4:30 - 4:45	**Q&A**			

2010 Geothermal Peer Review, Hyatt Crystal City, Regency C and D, Lower Level

Tuesday, May 18

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Overview	Ground-source Heat Pump Demonstration Projects	Two-175 Ton (350 Tons total) Chiller Geothermal Heat Pumps for Recently Commissioned LEED Platinum Building	Hoffman, Johnson Controls, Inc.
18-May	1:15 - 1:30	Overview	Ground-source Heat Pump Demonstration Projects	National Certification Standard for the Geothermal Heat Pump Industry	Kelly, Geothermal Heat Pump Consortium
18-May	1:30 - 1:45	Overview	Ground-source Heat Pump Demonstration Projects	Measuring the Costs & Economic, Social & Environmental Benefits of Nationwide Geothermal Heat Pump Deployment & The Potential Employment, Energy & Environmental Impacts of Direct Use Applications	Battocletti, Bob Lawrence & Associates, Inc.
18-May	1:45 - 2:00	**Q&A**			
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Overview	Ground-source Heat Pump Demonstration Projects	Geothermal Academy: Focus Center for Data Collection, Analysis and Dissemination	Nakagawa, Colorado School of Mines
18-May	2:30 - 2:45	Overview	Ground-source Heat Pump Demonstration Projects	Finite Volume Based Computer Program for Ground Source Heat Pump Systems	Menart, Wright State University
18-May	2:45 - 3:00	Overview	Ground-source Heat Pump Demonstration Projects	Development of a Software Design Tool for Hybrid Solar-geothermal Heat Pump Systems in Heating- and Cooling- dominated Buildings	Yavuzturk, University of Hartford
18-May	3:00 - 3:15	**Q&A**			
18-May	3:15 - 3:30	Overview	Ground-source Heat Pump Demonstration Projects	Development of Design and Simulation Tool for Hybrid Geothermal Heat Pump System	Ellis, Climatemaster & Liu, ORNL
18-May	3:30 - 3:45	Overview	Ground-source Heat Pump Demonstration Projects	Hybrid Geothermal Heat Pump Systems Research	Hackel, Energy Center of Wisconsin
18-May	3:45 - 4:00	Overview	Ground-source Heat Pump Demonstration Projects	Cedarville School District Retrofit of Heating and Cooling Systems with Geothermal Heat Pumps and Ground Source Water Loops	Ferguson, Cedarville School District 44
18-May	4:00 - 4:15	Overview	Ground-source Heat Pump Demonstration Projects	Large -scale GSHP as Alternative Energy for American Farmers: Technical Demonstration & Business Approach	Xu, The Curators of the University of Missouri
18-May	4:15 - 4:30	**Q&A**			
18-May	4:30 - 4:45				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Overview	Ground-source Heat Pump Demonstration Projects	Analysis of Energy, Environmental and Life-cycle Cost Reduction Potential of Ground Source Heat Pump in Hot and Humid Climate	Tao, Florida International University Board of Trustees
19-May	8:15 - 8:30	Overview	Ground-source Heat Pump Demonstration Projects	Analysis and Tools to Spur Increased Deployment of "Waste Heat" Rejection/Recycling Hybrid GHP Systems in Hot, Arid or Semiarid Climates Like Texas	Masada, The University of Texas at Austin
19-May	8:30 - 8:45	Overview	Ground-source Heat Pump Demonstration Projects	Geothermal Retrofit of Illinois National Guard State Headquarters Building	Lee, Department of Military Affairs
19-May	8:45 - 9:00	**Q&A**			
19-May	9:00 - 9:15	Overview	Ground-source Heat Pump Demonstration Projects	A Demonstration System for Capturing Geothermal Energy from Mine Waters beneath Butte, MT	Gilmore, Montana Tech of The University of Montana
19-May	9:15 - 9:30	Overview	Ground-source Heat Pump Demonstration Projects	RiverHeath, Appleton, WI	Geall, RiverHeath LLC
19-May	9:30 - 9:45	Overview	Ground-source Heat Pump Demonstration Projects	District Energy SW 40th Street Thermal Plant	Amancherla, District Energy Corporation
19-May	9:45 - 10:00	**Q&A**			

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Overview	Ground-source Heat Pump Demonstration Projects	Optimal Ground Source Heat Pump System Design	Ozbek, Environ International Corporation
19-May	10:30 - 10:45	Overview	Ground-source Heat Pump Demonstration Projects	Flathead Electric Cooperative Facility Geothermal Heat Pump System Upgrade	Talley, Flathead Electric Cooperative
19-May	10:45 - 11:00	Overview	Ground-source Heat Pump Demonstration Projects	Forest County Geothermal Energy Project	Elliott & Farnham, Forrest County
19-May	11:00 - 11:15	Overview	Ground-source Heat Pump Demonstration Projects	Retrofit of the Local 150 of International Operating Engineers Headquarters Campus	Cheiftez, Indie Energy Systems Company, LLC
19-May	11:00 - 11:15	**Q&A**			
19-May	11:15 - 11:30				
19-May	11:30 - 11:45				
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Ground-source Heat Pump Demonstration Projects	Education and Collection Facility Ground Source Heat Pump Demonstration Project	Noel, Denver Museum of Nature & Science
19-May	1:15 - 1:30	Overview	Ground-source Heat Pump Demonstration Projects	Wilders Grove Solid Waste Service Center	Battle, City of Raleigh
19-May	1:30 - 1:45	Overview	Ground-source Heat Pump Demonstration Projects	Oak Ridge City Center Technology Demonstration Project	Thrash, Oak Ridge City Center, LLC
19-May	1:45 - 2:00	**Q&A**			
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	Ground-source Heat Pump Demonstration Projects	Lake Elizabeth Micro-utility	Isaac, SKYCHASER ENERGY, INC.
19-May	2:30 - 2:45	Overview	Ground-source Heat Pump Demonstration Projects	Colorado State Capitol Building Geothermal Program	Shephard, Colorado Department of Personnel and Administration
19-May	2:45 - 3:00	Overview	Ground-source Heat Pump Demonstration Projects	City of Eagan - Civic Ice Arena Renovation	Lutz, City of Eagan
19-May	3:00 - 3:15	**Q&A**			
19-May	3:15 - 3:30	Overview	Ground-source Heat Pump Demonstration Projects	District Wide Geothermal Heating Conversion	Chatterton, Blaine County School District #61
19-May	3:30 - 3:45	Overview	Ground-source Heat Pump Demonstration Projects	Tennessee Energy Efficient Schools Initiative Ground Source Heat Pump Program	Graham, Tennessee Department of Education
19-May	3:45 - 4:00	Overview	Ground-source Heat Pump Demonstration Projects	Improved Design Tools for Surface Water and Standing Column Well Heat Pump Systems	Spitler, Oklahoma State University
19-May	4:00 - 4:15	**Q&A**			
19-May	4:15 - 4:30				
Thursday, May 20					
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
20-May	8:00 - 8:15	Overview	Ground-source Heat Pump Demonstration Projects	CNCC Craig Campus Geothermal Project	Boyd, Colorado Northwestern Community College
20-May	8:15 - 8:30	Overview	Ground-source Heat Pump Demonstration Projects	1010 Avenue of the Arts - New School & Performing Arts Theater	Colman, 1001 South 15th Street Associates LLC
20-May	8:30 - 8:45	Overview	Ground-source Heat Pump Demonstration Projects	**Middlesex Community College's Geothermal Project (MA)	**Klein, Middlesex Com. College
20-May	8:45 - 9:00	**Q&A**			

Day	Time	Presentation	Technical Track	Subject	Presenter
20-May	9:00 - 9:15	Overview	Ground-source Heat Pump Demonstration Projects	North Village Ground Source Heat Pumps	Redderson, Furman University
20-May	9:15 - 9:30	Overview	Ground-source Heat Pump Demonstration Projects	Pioneering Heat Pump Project	Aschliman, Indiana Institute of Technology
20-May	9:30 - 9:45	Overview	Ground-source Heat Pump Demonstration Projects	Human Health Science Building Geothermal Heat Pump Systems	Leidel, Oakland University
20-May	9:45 - 10:00	**Q&A**			
20-May	10:00 - 10:15	**BREAK**			
20-May	10:15 - 10:30	Overview	Ground-source Heat Pump Demonstration Projects	Geothermal Heat Pump System for the New 500-bed 200,000 SF Apartment-style Student Housing Project at the University at Albany's Main Campus	Lnu, University of Albany
20-May	10:30 - 10:45	Overview	Ground-source Heat Pump Demonstration Projects	BSU GHP District Heating and Cooling System (Phase I)	Lowe, Ball State University
20-May	10:45 - 11:00	Overview	Ground-source Heat Pump Demonstration Projects	Heat Pump Feasibility Study	Beiswanger, Deamen College
20-May	11:00 - 11:15	**Q&A**			

2010 Geothermal Peer Review, Hyatt Crystal City, Kennedy Room, 3rd Floor

Tuesday, May 18

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Overview	Analysis, Data System and Education	Geothermal Resources and Transmission Planning	Hurlbut, NREL
18-May	1:15 - 1:30	Overview	Analysis, Data System and Education	Economic Impact Analysis for EGS	Gowda & Levy, University of Utah
18-May	1:30 - 1:45	Overview	Analysis, Data System and Education	National Geothermal Data System Architecture Design, Testing and Maintenance	Snyder, Boise State University
18-May	1:45 - 2:00	Q&A			
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Overview	Analysis, Data System and Education	National Geothermal Data Systems Data Acquisition and Access	Snyder, Boise State University
18-May	2:30 - 2:45	Overview	Analysis, Data System and Education	Geothermal Data Aggregation: Submission of Information into the National Geothermal Data System	Blackwell, Southern Methodist University
18-May	2:45 - 3:00	Overview	Analysis, Data System and Education	State Geological Survey Contributions to the National Geothermal Data System	Allison, Arizona State Geological Survey
18-May	3:00 - 3:15	Q&A			
18-May	3:15 - 3:30	Overview	Analysis, Data System and Education	Estimation & Analysis of Life-cycle Costs of Baseline Enhanced Geothermal Systems	Turaga, ADI Analytics, LLC
18-May	3:30 - 3:45	Overview	Analysis, Data System and Education	National Geothermal Resource Assessment and Classification	Williams, U.S. Geologic Survey
18-May	3:45 - 4:00	Overview	Analysis, Data System and Education	2009 Geothermal, Co-production, and GSHP Supply Curve	Augustine, NREL
18-May	4:00 - 4:15	Q&A			
18-May	4:15 - 4:30				
18-May	4:30 - 4:45				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Full Review	Analysis, Data System and Education	Geothermal Electricity Technology Evaluation Model (GETEM) Development	Mines, INL
19-May	8:15 - 8:30				
19-May	8:30 - 8:45	Full Review	Analysis, Data System and Education	Student Competition	Visser, NREL
19-May	8:45 - 9:00				
19-May	9:00 - 9:15	Full Review	Analysis, Data System and Education	Geothermal Power Generation Plant	Lund, Oregon Institute of Technology
19-May	9:15 - 9:30				
19-May	9:30 - 9:45	Full Review	Analysis, Data System and Education	Systems Engineering	Lowry, SNL
19-May	9:45 - 10:00				
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Full Review	Analysis, Data System and Education	Life-cycle Analysis of EGS/Freshwater Requirements and Water Quality Impacts of EGS	Wang, ANL
19-May	10:30 - 10:45				
19-May	10:45 - 11:00				
19-May	11:00 - 11:15				
19-May	11:00 - 11:15				
19-May	11:15 - 11:30				
19-May	11:30 - 11:45				
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Analysis, Data System and Education	Baseline System Costs for 50 MW Enhanced Geothermal System -- A Function of: Working Fluid, Technology, and Location, Location, Location	Dunn, Gas Equipment Engineering Corporation
19-May	1:15 - 1:30	Overview	Analysis, Data System and Education	Decision Analysis for Enhanced Geothermal Systems	Einstein, Massachusetts Institute of Technology
19-May	1:30 - 1:45	Overview	Analysis, Data System and Education	Energy Returned on Investment of Enhanced Geothermal Systems	Mansure, Art Mansure
19-May	1:45 - 2:00	Q&A			
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	Analysis, Data System and Education	Analysis of Low-temperature Utilization of Geothermal Resources	Anderson, West Virginia University Research Corporation
19-May	2:30 - 2:45	Overview	Analysis, Data System and Education	Expanding Geothermal Resource Utilization in Nevada Through Directed Research and Public Outreach	Faulds/Calvin, University of Nevada at Reno

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	2:45 - 3:00	Overview	Analysis, Data System and Education	Geothermal Workforce Education Development and Retention	Anderson, W VA University/Calvin, University of Nevada, Reno (UNR)
19-May	3:00 - 3:15	Q&A			
19-May	3:15 - 3:30	Overview	Analysis, Data System and Education	Geothermal Policymakers' Guidebook, State-by-State Developers' Checklist, and Geothermal Developers' Financing Handbook	Young, NREL
19-May	3:30 - 3:45	Overview	Analysis, Data System and Education	Exploration: Best Practices and Success Rates	Young, NREL
19-May	3:45 - 4:00	Overview	Analysis, Data System and Education	Jobs and Economic Development Modeling	Young, NREL
19-May	4:00 - 4:15	Q&A			

2010 Geothermal Peer Review, Hyatt Crystal City Jefferson Room, 3rd Floor

Tuesday, May 18th

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Overview	Validation of Innovative Exploration Technologies	Effectiveness of Shallow Temperature Surveys to Target a Geothermal Reservoir at Previously Explored Site at McGee Mountain, NV	Zehner, Geothermal Technical Partners, Inc.
18-May	1:15 - 1:30	Overview	Validation of Innovative Exploration Technologies	Unalaska Geothermal Energy (AK)	Fulton, City of Unalaska
18-May	1:30 - 1:45	Overview	Validation of Innovative Exploration Technologies	Away from the Range Front: Intra-basin Geothermal Exploration	Melosh, GeoGlobal Energy LLC
18-May	1:45 - 2:00	**Q&A**			
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Overview	Validation of Innovative Exploration Technologies	Crump Geyser: High Precision Geophysics and Detailed Structural Exploration and Slim Well Drilling	Casteel & Niggeman, Nevada Geothermal Power Company
18-May	2:30 - 2:45	Overview	Validation of Innovative Exploration Technologies	El Paso County Geothermal Electric Generation Project Ft. Bliss	Lear, El Paso County
18-May	2:45 - 3:00	Overview	Validation of Innovative Exploration Technologies	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, NV	Benoit, Magma Energy Corp.
18-May	3:00 - 3:15	**Q&A**			
18-May	3:15 - 3:30	Overview	Validation of Innovative Exploration Technologies	Conducting a 3-D Converted Shear Wave Project to Reduce Exploration Risk at Wister, CA	Matlick, ORMAT Nevada,Inc.
18-May	3:30 - 3:45	Overview	Validation of Innovative Exploration Technologies	Application of a New Structural Model and Exploration Technologies to Define a Blind Geothermal System: A Viable Alternative to Grid-drilling for Geothermal Exploration: McCoy, Churchill County, NV	Benoit, Magma Energy Corp.
18-May	3:45 - 4:00	Overview	Validation of Innovative Exploration Technologies	Black Warrior: Sub-soil Gas and Fluid Inclusion Exploration and Slim Well Drilling	Casteel, Nevada Geothermal Power Company
18-May	4:00 - 4:15	**Q&A**			
18-May	4:15 - 4:30				
18-May	4:30 - 4:45				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Overview	Validation of Innovative Exploration Technologies	Use of Remote Sensing Data to Locate High Temperature Ground Anomalies in Colorado	Robinson, Flint Geothermal LLC
19-May	8:15 - 8:30	Overview	Validation of Innovative Exploration Technologies	Validation of Innovative Exploration Technologies for Newberry Volcano	Waibel, Newberry Geothermal Holdings, LLC
19-May	8:30 - 8:45	Overview	Validation of Innovative Exploration Technologies	Validation of Innovative Exploration Technologies at the Colado, NV, Geothermal Prospect	Combs, Vulcan Power Company
19-May	8:45 - 9:00	**Q&A**			
19-May	9:00 - 9:15	Overview	Validation of Innovative Exploration Technologies	Merging High-resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, OR	Walsh, ORMAT Nevada, Inc.
19-May	9:15 - 9:30	Overview	Validation of Innovative Exploration Technologies	Blind Geothermal System Exploration in Active Volcanic Environments; Multi-phase Geophysical and Geochemical Surveys in Overt and Subtle Volcanic Systems, Hawai'i & Maui	Martini, ORMAT Nevada, Inc.
19-May	9:30 - 9:45	Overview	Validation of Innovative Exploration Technologies	Advanced Seismic data Analysis Program (The “Hot Pot Project”)	Moore, OSKI Energy LLC
19-May	9:45 - 10:00	**Q&A**			
19-May	10:00 - 10:15	**BREAK**			

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	10:15 - 10:30	Overview	Validation of Innovative Exploration Technologies	Application of 2-D VSP Imaging Technology to the Targeting of Exploration and Development Wells in a Basin and Range Geothermal System, Humboldt House-Rye Patch Geothermal Area	Ellis, Presco Energy, Inc.
19-May	10:30 - 10:45	Overview	Validation of Innovative Exploration Technologies	Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, NM	Kaufman, Pueblo of Jemez
19-May	10:45 - 11:00	Overview	Validation of Innovative Exploration Technologies	Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Jackson & Pohll, Pyramid Lake Paiute Tribe
19-May	11:00 - 11:15				
19-May	11:00 - 11:15				
19-May	11:15 - 11:30				
19-May	11:30 - 11:45				
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Validation of Innovative Exploration Technologies	Finding Large Aperture Fractures in Geothermal Resource Areas Using a Three-component Long-offset Surface Seismic Survey	Teplow, US Geothermal, Inc.
19-May	1:15 - 1:30	Overview	Validation of Innovative Exploration Technologies	New River Geothermal Research Project, Imperial County, CA	Johnson, Ram Power, Inc.
19-May	1:30 - 1:45	Overview	Validation of Innovative Exploration Technologies	Alum Innovative Exploration Project	Ronne, Sierra Geothermal Power, Inc.
19-May	1:45 - 2:00	**Q&A**			
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	Validation of Innovative Exploration Technologies	Silver Peak Innovative Exploration Project	Ronne, Sierra Geothermal Power, Inc.
19-May	2:30 - 2:45	Overview	Validation of Innovative Exploration Technologies	Pilgrim Hot Springs, Ak	Holdmann, University of Alaska Fairbanks
19-May	2:45 - 3:00	Overview	Validation of Innovative Exploration Technologies	Detachment Faulting and Geothermal Resources - Pearly Hot Springs, NV	Stockli, University of Kansas Center for Research Inc.
19-May	3:00 - 3:15	Overview	Validation of Innovative Exploration Technologies	Snake River Geothermal Drilling Project: Innovative Approaches to Geothermal Exploration	Shervais, Utah State University
19-May	3:15 - 3:30	**Q&A**			

2010 Geothermal Peer Review, Hyatt Crystal City Lincoln Room, 3rd Floor

Tuesday, May 18th

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Overview	Specialized Materials and Fluids and Power Plants	Evaluate Thermal Spray Coatings as a Pressure Seal	Henfling, SNL
18-May	1:15 - 1:30	Overview	Specialized Materials and Fluids and Power Plants	Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids	Harrison, Simbol Mining Corp.
18-May	1:30 - 1:45	Overview	Specialized Materials and Fluids and Power Plants	Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Jody, ANL
18-May	1:45 - 2:00	**Q&A**			
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Overview	Specialized Materials and Fluids and Power Plants	Geopolymer Sealing Materials	Butcher, BNL
18-May	2:30 - 2:45	Overview	Specialized Materials and Fluids and Power Plants	High-temperature, High-pressure Devices for Zonal Isolation in Geothermal Wells	Fabian, Composite Technology Development, Inc.
18-May	2:45 - 3:00	Overview	Specialized Materials and Fluids and Power Plants	High-potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	Klockow, GE Global Research
18-May	3:00 - 3:15	**Q&A**			
18-May	3:15 - 3:30	Overview	Specialized Materials and Fluids and Power Plants	Temporary Bridging Agents for Use in Drilling and Completion of EGS	Watters, CSI Technologies, LLC
18-May	3:30 - 3:45	Overview	Specialized Materials and Fluids and Power Plants	Development Of An Improved Cement For Geothermal Wells	Trabits, Trabits Group, LLC
18-May	3:45 - 4:00	Overview	Specialized Materials and Fluids and Power Plants	Air-cooled Condensers in Next-generation Conversion Systems	Mines, INL
18-May	4:00 - 4:15	**Q&A**			
18-May	4:15 - 4:30				
18-May	4:30 - 4:45				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Overview	Specialized Materials and Fluids and Power Plants	Ionic Liquids for Utilization of Geothermal Energy	Brennecke, Notre Dame University
19-May	8:15 - 8:30	Overview	Specialized Materials and Fluids and Power Plants	Hybrid- and Advanced-air Cooling	Kutscher & Bharathan, NREL
19-May	8:30 - 8:45	Overview	Specialized Materials and Fluids and Power Plants	Working Fluids and Their Effect on Geothermal Turbines	Sabau, ORNL
19-May	8:45 - 9:00	**Q&A**			
19-May	9:00 - 9:15	Overview	Specialized Materials and Fluids and Power Plants	Metal Organic Heat Carriers for Enhanced Geothermal Systems	McGrail, PNNL
19-May	9:15 - 9:30	Overview	Specialized Materials and Fluids and Power Plants	Optimization of Hybrid-water/Air-cooled condenser in an Enhanced Turbine Geothermal ORC system	Wu, United Technologies Research Center
19-May	9:30 - 9:45	Overview	Specialized Materials and Fluids and Power Plants	Tailored Working Fluids for Enhanced Binary Geothermal Power Plants	Mahmoud, United Technologies Research Center
19-May	9:45 - 10:00	**Q&A**			
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Overview	Chemistry, Reservoir and Integrated Models	Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems	Gutierrez, Colorado School of Mines
19-May	10:30 - 10:45	Overview	Chemistry, Reservoir and Integrated Models	Development of Advanced THMC Modeling Capabilities for Enhanced Geothermal Systems	Wu, Colorado School of Mines
19-May	10:45 - 11:00	Overview	Chemistry, Reservoir and Integrated Models	Enhanced Geothermal Systems with CO2 as Heat Transmission Fluid	Pruess, LBNL
19-May	11:00 - 11:15	Overview	Chemistry, Reservoir and Integrated Models	Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems.	Pritchett, Science Applications International Corporation
19-May	11:00 - 11:15	**Q&A**			
19-May	11:15 - 11:30				
19-May	11:30 - 11:45				

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Chemistry, Reservoir and Integrated Models	Coupled THMC Model and Experiments for Optimization of Enhanced Geothermal System Development and Production	Sonnenthal, LBNL
19-May	1:15 - 1:30	Overview	Chemistry, Reservoir and Integrated Models	Chemical Impact of Elevated CO2 on Geothermal Energy Production	Carroll, LLNL
19-May	1:30 - 1:45	Overview	Chemistry, Reservoir and Integrated Models	THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity	Ellsworth, Pennsylvania State University
19-May	1:45 - 2:00	**Q&A**			
19-May	2:00 - 2:15	**BREAK**			
19-May	2:15 - 2:30	Overview	Chemistry, Reservoir and Integrated Models	Carbonation Mechanism of Reservoir Rock by Supercritical Carbon Dioxide	Butcher, BNL
19-May	2:30 - 2:45	Overview	Chemistry, Reservoir and Integrated Models	Experiment-based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	Petro, Symyx Technologies, Inc.
19-May	2:45 - 3:00	Overview	Chemistry, Reservoir and Integrated Models	A New Analytic-adaptive Model for EGS Assessment, Development and Management Support	Danko, Board of Regents, NSHE, on behalf of UNR
19-May	3:00 - 3:15	**Q&A**			
19-May	3:15 - 3:30	Overview	Chemistry, Reservoir and Integrated Models	Development of Chemical Model to Predict the Interactions between Supercritical Carbon Dioxide and Reservoir Rock in EGS Reservoirs	Lu, University of Utah
19-May	3:30 - 3:45	Overview	Chemistry, Reservoir and Integrated Models	Waveguide-based Ultrasonic and Far-field Electromagnetic Sensors for Down-hole Reservoir Characterization	Sheen, ANL
19-May	3:45 - 4:00	**Q&A**			
Thursday, May 20					
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
20-May	8:00 - 8:15	Overview	Chemistry, Reservoir and Integrated Models	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	Saar, Regents of the University of Minnesota
20-May	8:15 - 8:30	Overview	Chemistry, Reservoir and Integrated Models	Properties of CO2-rich Pore Fluids and Their Effect on Porosity Evolution in EGS Rocks	Cole, ORNL
20-May	8:30 - 8:45	Overview	Chemistry, Reservoir and Integrated Models	FRACSTIM/I: An Integrated Fracture Stimulation and Reservoir Flow and Transport Simulator	Podgorney, INL
20-May	8:45 - 9:00	Q&A			
20-May	9:00 - 9:15	Overview	Chemistry, Reservoir and Integrated Models	Predicting Stimulation-response Relationships for Enhanced Geothermal Reservoirs	Carrigan, LLNL
20-May	9:15 - 9:30	Overview	Chemistry, Reservoir and Integrated Models	Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation	Grubelich, SNL
20-May	9:30 - 9:45	Overview	Chemistry, Reservoir and Integrated Models	Synchrotron X-ray Studies of Supercritical Carbon Dioxide/ Reservoir Rock Interfaces	You, ANL
20-May	9:45 - 10:00	**Q&A**			

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Tuesday, May 18th

Day	Time	Presentation	Technical Track	Subject	Presenter
18-May	9:00 - 10:15	**Plenary Session**			
18-May	10:15 - 10:30	**BREAK**			
18-May	10:30 - 11:45	**Plenary Session**			
18-May	11:45 - 1:00	**LUNCH Speaker: Walt Snyder - Prof of Stratigraphy & Sedimentology, Boise State University**			
Day	**Time**	**Presentation**	**Technical Track**	**Subject**	**Presenter**
18-May	1:00 - 1:15	Full Review	Reservoir Characterization	Fracture Characterization in Enhanced Geothermal Systems by Wellbore and Reservoir Analysis	Horne, Stanford University
18-May	1:15 - 1:30				
18-May	1:30 - 1:45	Full Review	Reservoir Characterization	Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs	Ghassemi, Texas A&M University
18-May	1:45 - 2:00				
18-May	2:00 - 2:15	**BREAK**			
18-May	2:15 - 2:30	Full Review	Reservoir Characterization	Use of Geophysical Techniques to Characterize Fluid Flow in a Geothermal Reservoir	Revil, Colorado School of Mines
18-May	2:30 - 2:45				
18-May	2:45 - 3:00	Full Review	Reservoir Characterization	Detection and Characterization of Natural and Induced Fractures for the Development of Enhanced Geothermal Systems	Toksoz, Massachusetts Institute of Technology
18-May	3:00 - 3:15				
18-May	3:15 - 3:30	Full Review	Reservoir Characterization	Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems	Pruess, LBNL
18-May	3:30 - 3:45				
18-May	3:45 - 4:00	Full Review	Reservoir Characterization	The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs	Moore, University of Utah
18-May	4:00 - 4:15				
18-May	4:15 - 4:30				
18-May	4:30 - 4:45				

Wednesday, May 19

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	8:00 - 8:15	Full Review	Reservoir Characterization	Use of Tracers to Characterize Fractures in Enhanced Geothermal Systems	Rose, University of Utah
19-May	8:15 - 8:30				
19-May	8:30 - 8:45	Full Review	Reservoir Characterization	Chemical Signatures of and Precursors to Fractures Using Fluid Inclusion Stratigraphy	Dilley, Hattenburg, Dilley and Linnell, LLC
19-May	8:45 - 9:00				
19-May	9:00 - 9:15	Overview	Reservoir Characterization	Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced geothermal Systems	Pruess, LBL
19-May	9:15 - 9:30	Overview	Low-temperature Demonstration Projects	Purchase and Installation of a Geothermal Power Plant to Generate Electricity Using Geothermal Water Resources	Brown, City of Klamath Falls
19-May	9:30 - 9:45	Overview	Low-temperature Demonstration Projects	Beowawe Binary Bottoming Cycle	McDonald, Beowawe Power, LLC
19-May	9:45 - 10:00	**Q&A**			
19-May	10:00 - 10:15	**BREAK**			
19-May	10:15 - 10:30	Overview	Low-temperature Demonstration Projects	Demonstration of a Variable Phase Turbine Power System for Low-temperature Geothermal Resources	Hays, Energent Corporation
19-May	10:30 - 10:45	Overview	Low-temperature Demonstration Projects	Novel Energy Conversion Equipment for Low-temperature Geothermal Resources	Kohler, Johnson Controls, Inc.
19-May	10:45 - 11:00	Overview	Low-temperature Demonstration Projects	Demonstrating the Commercial Feasibility of Geopressured-Geothermal Power Development at the Sweet Lake Field, Cameron Parish, LA	Jordan, Louisiana Tank, Inc.
19-May	11:00 - 11:15	**Q&A**			
19-May	11:15 - 11:30				
19-May	11:30 - 11:45				
19-May	11:45 - 1:00	**LUNCH Speaker: Henry Kelly - Principal Deputy Assistant Secretary, EERE, U.S. DOE**			
19-May	1:00 - 1:15	Overview	Low-temperature Demonstration Projects	Develop NREL Center for Low Temperature Research/Project Data Collection	Williams, NREL
19-May	1:15 - 1:30	Overview	Low-temperature Demonstration Projects	Osmotic Heat Engine for Energy Production from Low-temperature Geothermal Resources	McGinnis, Oasys Water
19-May	1:30 - 1:45	Overview	Low-temperature Demonstration Projects	Rural Electric Cooperative Geothermal Development	Silveria, Surprise Valley Electrification Corporation
19-May	1:45 - 2:00	**Q&A**			
19-May	2:00 - 2:15	**BREAK**			

Day	Time	Presentation	Technical Track	Subject	Presenter
19-May	2:15 - 2:30	Overview	Low-temperature Demonstration Projects	Dixie Valley Bottoming Binary Project	McDonald, Terra-Gen Sierra Holdings, LLC
19-May	2:30 - 2:45	Overview	Low-temperature Demonstration Projects	Technical Demonstration and Economic Validation of Geothermally-produced Electricity from Co-produced Water at Existing Oil/Gas Wells in Texas	Alcorn, Universal GeoPower LLC
19-May	2:45 - 3:00	Overview	Low-temperature Demonstration Projects	Electric Power Generation from Co-produced Fluids from Oil and Gas Wells	Gosnold, University of North Dakota
19-May	3:00 - 3:15	Overview	Low-temperature Demonstration Projects	Electric Power Generation from Low- to Intermediate-temperature Resources	Gosnold, University of North Dakota
19-May	3:15 - 3:30	**Q&A**			

6.4 Participating Peer Reviewers

Peer reviewers were selected based on their expertise, recognized leadership and accomplishments in their fields, and their ability to objectively review and evaluate the projects in their technical track. Short biographies revealing their professional training, experience and accomplishments are provided below.

6.4.1 Phillip M. Wright (Mike), Peer Review Chairperson, Enhanced Geothermal Systems Peer Reviewer and Analysis, Data Systems and Education Peer Reviewer

Dr. Wright served as the 2010 chairperson for the Geothermal Technologies Program Peer Review. Dr. Wright received his Ph.D. degree in Geophysics from the University of Utah in 1966, with honors. He began his work in geophysics in 1966 and continues to work as a consultant to the geothermal community. He served as: Director of Biological and Geological Science, Energy and Environmental Sciences Division, Idaho National Laboratory from 2002 to 2004; as a Scientific Fellow and Director of the Subsurface Science Initiative with INL from 2000 to 2004; as Deputy Director in the Energy & Geoscience Institute and Research Professor, University of Utah, from 1995 to 2000; as Associate Director (1977 to 1984) and then Vice President (1984 to 1995) of the Earth Sciences Laboratory at the University of Utah Research Institute; and as Chief Geophysicist for Kennecott Copper Corporation's U.S. operations.

Dr. Wright has served as President of the Geothermal Resources Council (GRC), the President of the Geothermal Energy Association (GEA) and the President of the International Geothermal Energy Association (IGA). He has published over 100 papers and articles in leading geophysics and geology publications and has presented testimony before Congress on geothermal energy issues.

6.4.2 Douglas Blankenship, Enhanced Geothermal Systems Peer Reviewer

Mr. Blankenship received his M.S. degree in Civil (Geological) Engineering from the University of California, Berkeley. Since 2006, Mr. Blankenship has served as the Manager of the Geothermal Research Department at Sandia National Laboratories. He was a Senior/Principal member of Sandia's staff from 1989 to 1992, and again from 2003 to 2006. Mr. Blankenship worked for RESPEC, Inc., a private firm where he served as Project Engineer/Senior Consultant from 1981 to 1989, and again from 1992 to 2003. His current work at Sandia is focused on providing R&D support and solutions for drilling, completion and monitoring in geothermal and other high-temperature environments. Of particular interest is the development of high-temperature tools (for drilling, logging and monitoring), drill-string vibrations, rock-bit interactions, advanced drilling methods, numerical modeling and other issues related to the development of wells and reservoirs in high-temperature, hard-rock environments. In his capacity as manager Mr. Blankenship is responsible for program development activities, program and personnel management, direct support to project activities, extensive customer and stakeholder interactions (both private and public), workplace safety, and other typical managerial functions. Recent technical activities include the development and demonstration of a high-temperature, diagnostics-while-drilling system designed to monitor drilling dynamics in real-time.

6.4.3 John Ziagos, Enhanced Geothermal Systems Peer Reviewer and Seismicity and Seismic Peer Reviewer

Dr. Ziagos received his Ph.D. degree in Geophysics, Terrestrial Heat Flow Studies and Geothermal Energy from Southern Methodist University in 1982 under Dr. David Blackwell. Since 2008, he has served as Senior Science Advisor on a three-year Change of Station assignment from Lawrence Livermore National Laboratory (LLNL) to the National Nuclear Security Administration's Non-proliferation and Verification R&D Program (NA-22). Specifically, in this capacity he is responsible for maintaining the highest quality scientific (seismology) content for the Ground-based Nuclear Explosion Monitoring R&D (GNEMR&D) Program. From 1990 to 2008, while at LLNL, Dr. Ziagos rose to the position of Deputy Department Head of the Atmosphere, Earth and Energy Department in 2005. He led professional scientists, engineers, and technicians in support of the Energy and Environment Directorate research portfolio including energy technology, carbon management, climate change and National security. Prior to that promotion, Dr. Ziagos led the negotiations with DOE, state and federal regulators and public interests groups to the signing of the first Record of Decision in the DOE complex in his role as Superfund manager for LLNL. Prior to working at LLNL, from 1987 to 1990 he served as Vice President of Geothermal Resources International/GEO East Mesa where he managed construction of a new 50 MWe geothermal power plant, including utility and regulatory agency negotiations and development of a 36 production/injection well-field. He started his geothermal career in 1974 at the U.S. Geological Survey measuring geothermal heat flow in the Basin and Range province. Honors include a Lawrence Livermore National Laboratory Geosciences Distinguished Achievement Award (1993); a Department of Energy Geothermal Energy Fellowship (1977-1980); and a U.S. Geologic Survey Special Achievement Award (1977).

6.4.4 Richard Campbell, Low-temperature Peer Reviewer

Mr. Campbell received his M.S. degree in Chemical Engineering from the California Institute of Technology. He is currently Vice President of Engineering Technology for CH2M HILL. Previous career highlights include serving as Manager of the Technical and Engineering Services Division of TIC—The Industrial Company and President of The Ben Holt Co. He has had numerous Process Engineering and Project Management roles for both steam and binary cycle power plants. Geothermal projects he has worked on include Stillwater, Mahanagdong, Dieng, Steamboat, Mammoth, Pleasant Bayou, and The Geysers. Mr. Campbell has authored or co-authored numerous technical papers and articles for professional journals. Other distinctions include serving as President of the Geothermal Resources Council, Chairman of the Southern California Section of the American Institute of Chemical Engineers, Director of the International Geothermal Energy Association, receiving the GRC 2000 Aidlin Award for Outstanding Contribution to the Development of Geothermal Energy, and receiving the GRC 2009 Ben Holt Award for Outstanding Achievements in the Field of Geothermal Power Plant Design and Construction.

6.4.5 Pablo Gutierrez, Low-temperature Peer Reviewer

Mr. Gutierrez received his B.S. degree in Mechanical Engineering from the California State University, Fresno. He is the Geothermal Program Lead for the California Energy Commission (CEC) Energy Research and Development Division where he manages program development, technical reviews, project

management, strategic planning, legislative and policy analysis and contract management. Prior to joining the CEC in 1999, Mr. Gutierrez was a Water Resources Control Engineer for the California EPA State Water Resources control Board (1988 to 1999) where he managed construction projects; conducted technical assessments; tracked legislative, regulatory and policy developments; and conducted environmental assessments and reviews.

6.4.6 Colin Harvey, Low-temperature Peer Reviewer

Dr. Colin Harvey is one of New Zealand's most experienced geothermal scientists. He holds a Ph.D. degree in low-temperature geochemistry from Indiana University and has extensive geothermal project management experience in New Zealand and over 20 countries worldwide. He has lectured extensively at Indiana University (Associate Professor 1995 & 2001-2) and at the NZ Geothermal Institute through sabbaticals in both geology and geochemistry. His current role as Personal Assistant to the CEO of GNS Science includes participation on the advisory board of the National Energy Research Institute and involvement in shaping national policy with key New Zealand Government agencies (Ministries of Research Science and Technology, Economic Development, Trade and Industry and the Environment). His geothermal resource experience includes peer review panel roles for the Ohaaki and Kawerau geothermal fields in New Zealand. His international experience includes projects undertaken for the United Nations, World Bank and the Asian Development Bank. He is Past President, NZ Geothermal Association and currently Treasurer for the world geothermal body, the International Geothermal Association.

6.4.7 Paul Kasameyer, Low-temperature Peer Reviewer

Dr. Kasameyer received his Ph.D. degree from MIT in Earth and Planetary Sciences in 1974. His research interests include use of geophysical methods to solve interesting problems: geophysical exploration, heat and mass flow in porous media, geothermal systems, well-bore geophysics, seismic hazard analysis, body dynamics and inertial navigation. His career includes 29 years as a geophysicist at the Lawrence Livermore National Laboratory working for, and leading, the lab's geothermal program. Dr. Kasameyer also led and supported other research and applied projects such as nuclear test containment, seismic hazard prediction, and the critical examination of evidence for non-Newtonian gravity and analysis of rocket dynamics. As a consultant, he developed and implemented navigation algorithms for personal location devices. He has authored or co-authored many articles in professional journals on the topic of geothermal energy and geophysics. Honors include membership in the American Geophysical Union, Society of Exploration Geophysicists, Sigma Xi and receipt of the U. S. Department of Energy Office of Geothermal Technology "Ring of Fire" Award in 2003.

6.4.8 Duncan Foley, Analysis, Data Systems and Education Peer Reviewer

Dr. Foley received his Ph.D. degree in Geology from Ohio State University in 1978, with an emphasis on volcanology. From 1986 to the present, he has served as Assistant Professor, Associate Professor, Professor and Chair of the Geology Department at Pacific Lutheran University. From 1978 to 1986, Dr. Foley served as Geologist and Project Manager for the Earth Science Laboratory of the University of Utah Research Institute, where his tasks included program management for U.S. Department of Energy (DOE) funded low- and moderate-temperature geothermal resource assessment programs conducted by

state geological surveys and universities in western and Great Plains states. Dr. Foley's writing includes four books, journal articles and technical papers.

6.4.9 Gerald Nix, Analysis, Data Systems and Education Peer Reviewer

In 1969, Dr. Nix received his Ph.D. degree in Chemical Engineering and Mathematics from the University of Minnesota. Dr. Nix' career included serving in various roles including researcher, branch manager and technology manager for the National Renewable Energy Laboratory from 1980 through 2007. His responsibilities included management of up to 50 people and projects/programs to $30 million. Technical activities included energy storage, solar thermal, ocean thermal energy conversion, wind energy, fuel cells, and geothermal energy. From 1969 to 1980, Dr. Nix was consultant to the Engineering Department of E.I. DuPont de Nemours where he provided expertise in the general areas of heat and mass transfer, with additional experience in reaction engineering and mixing. His job was to solve problems that others could not in areas ranging from pure research to manufacturing. He also has academic experience as an adjunct professor at the Delaware Technical and Community College (physics), the University of Delaware (chemical engineering) and the Colorado School of Mines (chemical engineering).

6.4.10 George Cooper, High-temperature Tools and Drilling Peer Reviewer

Dr. Cooper received his Ph.D. degree from the University of Cambridge in 1967 where his thesis was "The Fracture of Fiber-Reinforced Materials". In July 1988, Dr. Cooper was appointed as a Full Professor with tenure at UC Berkeley to head the Petroleum Engineering Program and to teach and carry out research in Petroleum Engineering, initially in the Department of Materials Science and Mineral Engineering and, since 2000, in the Department of Civil and Environmental Engineering. In the summer of 2003, he was appointed as "Professor in the Graduate School". This position (semi retired) allows him to continue with research but he has no lecturing responsibilities. In this position he is currently consulting with NASA on various projects concerned with the drilling of exploration boreholes on Mars and other planetary bodies, including project review and selection activities. From 1981 to1988, Dr. Cooper was Manager of the Department of Drilling and Rock Mechanics of Schlumberger Cambridge Research, then Assistant Manager for Technical Marketing at Sedco, a Schlumberger company. In 1982, Dr. Cooper was responsible for establishing a new laboratory to carry out research and development for Schlumberger's Petroleum Drilling and Production Services group. He became Manager of the Drilling Mechanics Department (later expanded to include Rock Mechanics also), one of three Departments in the Laboratory. From 1981 to 1982, Dr. Cooper served as Research and Development Coordinator and then Director of Technical Services for Castolin, a multi-national manufacturer and seller of welding equipment and consumables including wear-resistant coatings for use inter alia, in mining, rock drilling and oilfield equipment. Dr. Cooper has over 100 publications and ten patents in the fields of composite materials, rock excavation and drilling technologies. Fifteen publications are concerned with drilling on Mars. He has acted as an expert witness in trials both in the USA and UK.

6.4.11 Daniel Hand, High-temperature Tools and Drilling Peer Reviewer

Mr. Hand is a Sustainable Engineering Development Expert, combining business and engineering to develop indigenous resources. He is a Licensed Professional Engineer (27 years) LEED Accredited, with an M.S

degree in Mechanical Engineering from the University of Arizona in Tucson. From 2009 to the present, he has served as President and Owner of Sustainable Engineering, a project development firm working with rural cooperatives to develop small renewable energy projects: geothermal, hydro, solar, and wind. His firm is currently developing a 2 MW geothermal electric power with geothermal energy direct use. Prior to establishing Sustainable Engineering, Mr. Hand was a Vice President at AltaRock Energy responsible for securing geothermal energy projects. He has also served as a Project Development Manager for Chevron (2001 to 2007), Lead Energy Engineer for Johnson Controls (1997 to 2001), Engineering Manager for NORESCO (1995 to 1997), and Engineering Resources Manager for Honeywell (1994 to 1995). From 1988 to 1994, Mr. Hand was Assistant Professor in the Department of Mechanical Engineering at West Point (3 years) and a senior staff officer. From 1978 to 1986, he was Engineer Officer in Army Units at Ft Bragg, NC; Korea; and Ft McClellan where he led groups ranging from 35 to 200 engineers. He is experienced in: Sustainability, Leading, Developing Business, Resource Development, Project Design & Management, Energy Efficiency, Negotiations, Teaching, and Government Funding.

6.4.12 David Lombard, High-temperature Tools and Drilling Peer Reviewer

Dr. Lombard earned a B.A. in Physics and Mathematics from Northeastern University in 1953, an M.S. in Physics from the Pennsylvania State University in 1955, and a Ph. D. in Physics from the Pennsylvania State University in 1959. He served as a Senior Physicist with the Lawrence Livermore Laboratory from 1959 to 1970, working primarily on the Plowshare Program, devoted to the peaceful uses of nuclear explosives. Much of his research involved the measurement of shock waves in solid materials. In 1970, Dr. Lombard moved to Arvada, Colorado, where he represented Atcor, Inc., a company in the nuclear services industry. In 1972, he accepted a position with Subcom, Inc. which performed consulting work on underwater explosion research for the U.S. Navy in Crystal City, Virginia. In 1974, Dr. Lombard was appointed as a program manager in the National Science Foundation in Washington DC. He had a leading role in establishing the NSF's "Research Applied to National Needs" program in geothermal energy, an alternative energy source. He moved with the program into the Energy Research and Development Administration, which subsequently became a part of the U.S. Department of Energy. There his responsibilities included managing research in Hot Dry Rock, Geopressured Geothermal Energy, Advanced Drilling Research, Power Plant issues, Geothermal Heat Pumps and Direct Heat Applications. He also served as Acting Director of the Geothermal Energy Division. After 23 years of federal service, he retired in 1997.

6.4.13 Yuri Fialko, Seismicity and Seismic Peer Reviewer

Dr. Fialko earned his Ph.D. degree in Geosciences from Princeton University in 1998. Since 2001, he has served as an Assistant Professor, Associate Professor and now a Full Professor at the Scripps Institution of Oceanography, University of California at San Diego. Dr. Fialko's publications include multiple journal articles and he also serves as a reviewer for: Science, Nature, Journal of Geophysical Research, Geology, Geophysical Research Letters, Journal of Geothermal and Volcanological Research, Pure and Applied Geophysics, Earth and Planetary Science Letters, IEEE Transactions of Geoscience and Remote Sensing, Journal of Mathematical Engineering, Journal of Structural Geology, and the IASPEI International Handbook of Earthquake and Engineering Seismology. He is an active member of the American

Geophysical Union since 1994, serving on the Program Committee for AGU's Fall meeting in 2003 and 2004. He Chaired the GeoEarthScope InSAR Working Group from 2006 to 2008.

6.4.14 Jonathan Lees, Seismicity and Seismic Peer Reviewer

Dr. Lees received his Ph.D. degree in Geophysics from the University of Washington, Seattle, in 1989. Since 2000 he has served as an Associate Professor, Associate Chair and finally Full Professor of the Department of Geological Sciences at the University of North Carolina, Chapel Hill. Prior to joining UNC Dr. Lees was an Assistant Professor and then an Associate Professor at Yale University's Department of Geology and Geophysics, Kline Geology Laboratory, from 1990 to 2000. Between 1984 and 1990, Dr. Lees worked for the Institute for Crustal Studies, UC Santa Barbara (1989 to 1990); and the University of Washington, Seattle Geophysics Program (1984 to 1989). From 1979 to 1984, Dr. Lees served as an Exploration Geophysicist for Shell Oil Company. Honors and awards include a Certificate of Recognition from the North Carolina State Museum of Natural Sciences; Award for Contributions in Geology, Geothermal Program Office; Japan-Science and Technology Agency Fellowship; David A. Johnston Memorial Scholarship (Geophysics); and President, University of Washington Geophysical Society. He has been published extensively in refereed journals and technical proceedings.

6.4.15 Wayne Pennington, Seismicity and Seismic Peer Reviewer

Dr. Pennington earned his Ph.D. degree from the University of Wisconsin, Madison, in Geophysics and Geology in 1979. He is currently Chair of the Department and a Full Professor in the Department of Geophysical Engineering at Michigan Technological University, where he has worked since 1994. In 2009, Dr. Pennington was also named as a Jefferson Science Fellow Senior Engineering Advisor for the U.S. Agency for International Development (USAID). Prior to joining Michigan Tech, Dr. Pennington spent 9 years with Marathon Oil, advancing to the title of Advanced Senior Geophysicist. From 1979 to 1985, Dr. Pennington was an Assistant Professor in the Department of Geological Sciences at the University of Texas at Austin. Dr. Pennington's major research areas include in situ properties of rock under varying conditions of stress and fluid saturation and their dependence on scale of measurement. This general interest is manifested in three specific applications: tectonic (natural) earthquakes; oil and gas exploration and development; and, most recently, ice quakes and glacier mechanics. Awards and honors include a Faculty Excellence Award and being named the Union Oil Faculty Fellow. Dr. Pennington is the President-Elect of the American Geological Institute (AGI) and the Director, Board of Chairs of Earth and Space Science Departments of the American Geophysical Union. Dr. Pennington is a former First Vice President of the Society of Exploration Geophysics, former Chairman of the Society of Exploration Geophysicists (SEG) Development and Production Committee, SEG representative to the AGI and SEG Representative to AGI's Government Affairs Program Advisory Committee. He is an author and contributor to numerous journal articles, book chapters, and technical papers. Dr. Pennington has also served as an Associate Editor of the Society of Petroleum Engineers, an Editorial Board Member for The Leading Edge (SEG), and an Associate Editor for Geophysics. In 1986, he was General Chairman of the Annual Meeting of the Seismological Society of America, in 1992 Chairman of the SEG Development and Production Forum, and in 2002 Co-Chair of the Forum on Seismic Petrophysics.

6.4.16 Edward Bolton, Reservoir Characterization Peer Reviewer

Dr. Bolton received his Ph.D. degree in Geophysics and Space Physics from the University of California Los Angeles in 1985. Dr. Bolton's interests include numerical simulation of flow, reactions, and transport in heterogeneous porous media; creation of conceptual and numerical models of fluid-rock interaction with dynamic permeability; numerical modeling and computational fluid dynamics; finite difference, global-Galerkin, spectral-transform, and particle tracking methods; experimental fluid mechanics; nonlinear thermal convection and stability analysis; wavelet analysis of time series and climate; landform evolution and erosion modeling; and flow visualization of common fluid instabilities. Since 1986, he has worked for Yale University, mainly in the Department of Geology and Geophysics where he is now a Senior Research Scientist. From 1985 to 1986, Dr. Bolton conducted postdoctoral research with the Groupe de Physique des Solides, Ecole Normale Supérieure in Paris, France on the application of dynamical systems theory to convective systems and experimental studies of shear flow instabilities in an oscillating fluid plane with Prof. B. Perrin, J. Maurer and S. Fauve. Dr. Bolton is the author of numerous journal articles and technical papers published in refereed journals and is also the author of several computer programs including KINFLOW and Meta-KINFLOW. He is also active in professional organizations including serving for the last six years as Associate Editor of the American Journal of Science, and co-organizing the 2006 Yale Forum: "Carbon Sequestration: Is it Feasible?". Dr. Bolton contributed to the development of the Yale Climate and Energy Institute in 2008 and organizes monthly discussions on carbon sequestration with Yale experts in law, management, policy, forestry, environmental studies, chemical engineering, chemistry, geology, geophysics and sustainability.

6.4.17 Blaise Bourdin, Reservoir Characterization Peer Reviewer

Dr. Bourdin received his Doctorat de l'Université Paris – Nord (Ph.D. degree) in Applied Mathematics in 1998. Dr. Bourdin is the co-author of a book entitled "The Variational Approach to Fracture" and has also authored numerous journal articles, technical papers and presentations on topics in applied mathematics and engineering. Since 2002, he has served on the faculty of Louisiana State University (LSU), where he rose to the positions of Associate Professor in the Department of Mathematics and Adjunct Faculty in the Center for Computation and Technology.

6.4.18 Barbara Dutrow, Reservoir Characterization Peer Reviewer

Dr. Dutrow earned her Ph.D. degree in Geological Sciences from Southern Methodist University in 1985. Since 1985 she has taught and conducted research, primarily at Louisiana State University, where she has achieved the status of Adolphe G. Gueymard Distinguished Professor. Since 1993, Ms. Dutrow has also held the distinction of being an Affiliate or Visiting Scientist with Los Alamos National Laboratory. Dr. Dutrow has also served as a Visiting Scientist/Professor at the University of Arizona, the University of Iowa, and as an Alexander Humboldt Fellow at the Institut für Mineralogie Ruhr Universität, in the former West Germany. During the 1980s, she was also a Consulting Geologist for Mobil Exploration and Producing Services. She has been called as an expert witness in several cases involving mineralogy and geochemistry. Dr. Dutrow has been honored with a number of awards and fellowships in Professional societies including being elected Councilor to the Geological Society of America (GSA) for 2010 to 2014, and election as a Fellow of the GSA in 2007. She served as President of The Mineralogical Society of

America in 2007 and was elected to fellowship in 1995. The South Central Federation of Mineralogical Societies awarded her its Distinguished Achievement Honorary Award for 2005 to 2007. She is an active member of GSA, the American Geophysical Union, the Geochemical Society and many other professional organizations, serving on nominating committees, conference boards, advisory committees, editorial boards and peer/merit review panels. Her scientific interests include metamorphic petrology combining field, experimental and theoretical approaches to unraveling the history of metamorphic terranes. Themes include deciphering the geologic evolution of specific metamorphic terranes; combining heat and mass transport modeling studies with kinetic modeling of mineral textures to interpret metamorphic rock textures; crystal chemistry of specific minerals as a guide to formation conditions and how formation conditions influence crystal chemistry; fluids in the crust and their affect on mineral stability and chemistry; geothermal systems and complexity; mineralogy and the environment; and the use of scientific visualization and the very large datasets to teach geology. Dr. Dutrow has numerous publications in refereed journals, contributions to books, research reports and keynote presentations in her field.

6.4.19 John Rudnicki, Reservoir Characterization Peer Reviewer

Dr. Rudnicki earned his Ph.D. degree in Solid Mechanics from Brown University in 1977. Since 1981, he has taught and conducted research at Northwestern University in Illinois where he was elevated to the position of Full Professor of Civil and Environmental Engineering in 1990 and of Mechanical Engineering in 1991. Prior to Northwestern University, Dr. Rudnicki was an Assistant Professor at the University of Illinois Urbana-Champaign (1978 to 1981) and a post-doctoral fellow at the California Institute of Technology (1977 to 1978). He has been honored as a Fellow of the American Society of Mechanical Engineers, was named to the Honor Roll for Faculty and Administrators by the Northwestern Associated Student Government, received the Brown Engineering Alumni Medal in 2008, and the Maurice A. Biot Medal from the Engineering Mechanics Division of the American Society of Civil Engineers in 2006. Dr. Rudnicki has been active in professional organizations serving on editorial boards for leading professional journals and serving on several advisory boards, peer review panels and scientific committees. His consulting services have been sought by Exxon-Mobil, Advantek International, Amoco Netherlands, Snap-On Tools, Sandia National Laboratories, Science Applications International Corporation, Los Alamos National Laboratory, and Amoco Oil Company.

6.4.20 Ben Sternberg, Reservoir Characterization Peer Reviewer

Dr. Sternberg earned his Ph.D. degree in Geophysics with a minor in Electrical Engineering from the University of Wisconsin, Madison in 1977. Since 1986, he has taught and conducted research at the University of Arizona in Tucson, where he is currently Professor and Director of the Laboratory for Advanced Subsurface Imaging (LASI), after also serving as Department Head from 1989 to 1998. Prior to joining the University of Arizona, faculty Dr. Sternberg was Manager of Controlled Source Electrical Methods for Phoenix Geophysics (1984 to 1986), Manager of Computer Services and Geophysics and Chief Geophysicist for Barringer Resources (1983-1984), and a Research Scientist and Supervisor of Electrical Methods for Conoco (1977 to 1983). Honors include having Sternberg peak included on the map of Antarctica to honor of Dr. Sternberg's research contributions. Dr. Sternberg has also been

honored with appointments to the National Academy of Sciences National Research Council Committees on Seeing into the Earth, Environmental and Engineering Geophysics, 1995-1998; and Research Needs for High-level Waste at Department of Energy Sites, 2000-2001. Dr. Sternberg was elected president of the Near-Surface Geophysics (NSG) Section of the Society of Exploration Geophysics (SEG). SEG is the world's largest exploration geophysics society and NSG is the section concerned with environmental and engineering applications (1994-1995). He was appointed chairman of the Technical Academic Review Group (TARG) for Department of Energy (DOE) to review DOE geophysics projects (1993-1995). Dr. Sternberg has published more than 150 technical papers and articles in his field, and he has received patents on three different inventions since 2003.

6.5 Peer Review Staff Organizations and Personnel

Department of Energy (DOE)
DOE is providing overall financial and technical support for the peer review process. It will be the recipient of the results of the peer review and will employ those results to refine projects and programs to enhance progress toward geothermal program objectives. Geothermal staff include:

- Hildigunnur Thorsteinsson (Hildigunnur.Thorsteinsson@ee.doe.gov)
- Lauren Boyd (Lauren.Boyd@ee.doe.gov)

Antares Group and New West Technologies
Responsible for coordinating the elements of the peer review meeting itself, including timeline of events, announcements and information packages for distribution to participants, by DOE, moderating and recording the review panels, and initial preparation of draft report. Antares staff includes

- Kevin DeGroat (kdegroat@antares.org)
- Kurt Riegel (kurt.riegel@gmail.com)
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- Sarah Francis (sfrancis@nwttech.com)
- Rete Browning (rbrowning@nwttech.com)
- Richard Marks (rmarks@nwttech.com)

Courtesy Associates
Responsible for meeting logistics including reimbursements, hotel and accommodations arrangements, meeting room setup, and onsite support of the meeting. Staff includes:

- Regina Mohr (rmohr@courtesyassoc.com)
- Tonya Stanback (tstanback@courtesyassoc.com)

Oak Ridge Institute for Science and Education (ORISE)
Responsible for its web based PeerNet system, arranging for input of PI data and presentations, ORISE workstations for use at the meeting, and tabulation of results.

- Lee-Ann Talley (lee-ann.talley@orise.orau.gov)
- Leslie Shapard (Leslie.Shapard@orise.orau.gov)
- Margaret Lyday (Margaret.Lyday@orise.orau.gov)