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

2015 Peer Review Report

U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

Geothermal Technologies Office

2015 Peer Review Report

December 2015

The photo on the cover page is of the Fumarole Area. Photo courtesy of Akutan, 2012.

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2015 Peer Review Report
December 2015

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Geothermal Technologies Office
2015 Peer Review Meeting
December 2015

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1.0 Geothermal Technologies Office Peer Review Process

Peer review is a standard best practice for assessing highly technical, complex projects and programs, and is widely used by industry, government, and academia. Peer review engages objective review and advice from independent experts to provide DOE managers, staff, and researchers with a powerful and effective tool for informing the management, relevance, and productivity of government-funded projects. The 2004 Office of Energy Efficiency and Renewable Energy (EERE) Peer Review Guide[1] defines a peer review as:

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

This definition distinguishes in-progress peer review from other types of review, such as merit review, which is used to evaluate technical proposals for competitive solicitations; "stage gate" reviews, which determine when a project is ready to move to the next phase of development; as well as other review activities such as quarterly milestone reviews or budget reviews.

Peer review is based on the premise that enlisting third-party experts to objectively evaluate the progress and impact of a technical project and/or program adds a valuable layer to technical project management. Peer review is essential in providing robust, documented feedback to EERE leadership to inform program planning. It also provides management with independent validation of the effectiveness and impact of its funded projects and program scopes. Knowledge about the quality and effectiveness of current projects and programs is essential in directing (or redirecting) new and existing efforts.

1.1 Logistics for 2015 Meeting

On May 11–14, 2015, the Geothermal Technologies Office (GTO, or the Office) conducted its bi-annual program peer review in Westminster, Colorado. In addition to providing independent, expert evaluation of the technical progress and merit of GTO-funded projects, the review was a forum for feedback and recommendations on future GTO strategic planning. Further, this event afforded an opportunity for the geothermal community to share ideas and solutions to address the challenges facing the geothermal industry.

During the course of the peer review, GTO-funded projects were evaluated for (1) their impact of research, accomplishments, results and progress and (2) their scientific/technical approach. Projects were also evaluated qualitatively on their strengths, weakness, and opportunities for improvement. Principal Investigators (PIs) came together in sessions organized by topic "tracks" to present the progress and results-to-date of their projects to a panel of independent experts as well as attendees. Dr. Kate Baker served as the overall chairperson, providing guidance to reviewers to ensure consistency, transparency, and independence throughout the review process. Her career has spanned many areas among the geoscience and engineering disciplines, including geotechnical, drilling, and reservoir engineering; geology; geophysics; and formation evaluation. Dr. Baker also served as the overall chairperson for the GTO Peer Review in 2012 and 2013, and is well versed in the EERE peer review process.

The 2015 GTO Peer Review Meeting was organized into the following four tracks, with associated sessions. Please note that, for the purposes of providing a rolled up summary of the sixteen session scores below in this report, several are later combined into eleven total "technology panel" summaries (see Section 4.0).

- **Track 1 – Systems Analysis and Low Temperature Resources:**
    - Systems Analysis, Resources Assessment, Data System Development & Population, Education

[1] *Peer Review Guide*, Office of Energy Efficiency and Renewable Energy (EERE), August 2004

    - Hybrid/Value Added Systems
    - Mineral Recovery
    - Low Temperature Resources
- **Track 2 – Hydrothermal Resource Confirmation (HRC):**
    - Reservoir Fracture Characterization / Fluid Imaging
    - Exploration Validation / Play Fairway Analysis
    - Systems Analysis, Resources Assessment, Data System Development & Population, Education
    - Drilling Systems
    - Geochemistry
- **Track 3 – Enhanced Geothermal Systems (EGS) I:**
    - Tracers / Zonal Isolation / Geochemistry
    - High Temp Tools and Drilling Systems
    - Reservoir Modeling
    - Reservoir Fracture Characterization / Fluid Imaging
- **Track 4 – Enhanced Geothermal Systems (EGS) II:**
    - Innovative Stimulation Techniques
    - Supercritical Carbon Dioxide / Working Fluids
    - Enhanced Geothermal System Demonstrations

Peer reviewers included both unconflicted PIs funded under EERE-GTO programs and experts in geothermal or related technologies who do not receive EERE-GTO project funding.

1.2 Evaluation Methodology

Impact of Research, Accomplishments, Results and Progress

Projects were assessed on the importance of achieving project objectives relative to the broader Geothermal Technologies Office's mission and goals. Projects were evaluated on the extent to which they addressed known, anticipated, and significant technical knowledge gaps, market barriers, or other challenges. Projects were also assessed on the impact the activities and results have on costs, performance, applications, markets, and other factors in geothermal energy development.

Additionally, projects were assessed on the technical accomplishments, results, and progress of the work activities to date and scored on the significance of those results in relation to project objectives and their technical targets/goals. The significance of results centered around two areas:

1. Quality – the quality of accomplishments, results, and progress made towards technical goals/targets and project objectives.
2. Productivity – the level of productivity in work underway considering accomplishments and the value of the accomplishments compared to the costs. This includes achievements against planned goals and objectives, technical targets, awards, or other success measures presented.

Reviewers used a 1 to 10 scoring index, defined as follows:

- **10 – Outstanding.** The project has made substantial progress and impact on the DOE's Geothermal Technologies Office missions and goals. Project has demonstrated outstanding advancement in addressing knowledge gaps and barriers, and has made outstanding progress towards accomplishing project objectives and achieving technical goals/targets. The project has exceptional impact on factors in geothermal energy development.

- **7 to 9 – Good.** The project has made notable progress and impact on the DOE's Geothermal Technologies Office missions and goals. Project has demonstrated significant advancement in addressing knowledge gaps and barriers, and has made significant progress towards accomplishing project objectives and achieving technical goals/targets. The project has considerable impact on factors in geothermal energy development.

- **4 to 6 – Fair.** The project has made modest progress and impact on the DOE's Geothermal Technologies Office missions and goals. Project has demonstrated some advancement in addressing knowledge gaps and barriers, and has made some progress towards accomplishing project objectives and achieving technical goals/targets. The impact is below what could be expected. The project has moderate impact on factors in geothermal energy development.

- **1 to 3 – Poor.** The project has made little or no progress and impact on the DOE's Geothermal Technologies Office missions and goals. Project has demonstrated little to no advancement in addressing knowledge gaps and barriers, and has demonstrated little to no progress towards accomplishing project objects or achieving technical goals/targets. The impact is below what could be expected. The project has marginal impact on factors in geothermal energy development.

Scientific/Technical Approach

Projects were assessed on the quality of the technical approach and rated for the rigor and appropriateness of the employed technical approach—such as work elements, procedures and methods, instrumentation, equipment and staffing—to achieving the project's objectives with the available resources. This criterion covered both the design of the scientific/technical approach and how well the approach was executed in the project tasks.

Reviewers used a 1 to 10 scoring index, defined as follows:

- **10 – Outstanding.** The approach is sharply focused, excellent in design and centered on one or more key technical barriers to achieving the project's objectives. The execution of the approach is outstanding and has little to no room for improvement.

- **7 to 9 – Good.** The approach is well thought out and effective in achieving the project's objectives. The project has good focus, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has minor room for improvement.

- **4 to 6 – Fair.** Some aspects of the project may lead to progress in achieving project objective and overcoming barriers/knowledge gaps but the approach has significant weaknesses and noteworthy areas for improvement.

- **1 to 3 – Poor.** The approach is unlikely to make significant contributions to the objectives and barriers/knowledge gaps. Significant flaws in the approach are identifiable with major areas of improvement.

Overall project scores were computed as a weighted average 60% on the first criteria and 40% on the second criteria as noted in Table 1.1. Projects in the three subprogram areas (EGS, Hydrothermal (HRC), and Low Temperature and Systems Analysis) were weighted identically. The formula listed in Figure 1.1 was used to calculate the overall weighted average score for each project in order to provide a means for comparing a project's final overall score equivalently to other projects.

Table 1.1 Peer review evaluation criteria and weights

Evaluation Criteria	Weighting
Impact of Research, Accomplishments, Results and Progress	60%
Scientific/Technical Approach	40%

$$Weighted\ Average\ Overall\ Score = \left[\left(\frac{\sum_1^n Score\ 1}{n}\right) \times (0.6)\right] + \left[\left(\frac{\sum_1^n Score\ 2}{n}\right) \times (0.4)\right]$$

Figure 1.1 Weighted average overall score calculation

In addition to scoring projects against the two evaluation criterion above, peer reviewers provided an overall narrative assessment of the project. Specifically, reviewers were asked to comment on the overall strengths and weaknesses of and ways to improve the projects. Reviewers entered evaluation scores and feedback into the Program and Peer Review Management Information System (P2RMIS). Detailed reviewer evaluations can be found in the appendices to this main report.

2.0 Geothermal Technologies Office Summary

2.1 Introduction

The mission of the Geothermal Technologies Office is to accelerate the development of domestic geothermal electricity and energy by investing in transformative research, development, and demonstration-scale projects that will catalyze commercial adoption. Successful efforts will promote a stronger, more productive economy; provide valuable, stable, and secure renewable energy to power the U.S.; and support a cleaner environment. To achieve these benefits, the Office's technology portfolio prioritizes two closely related geothermal categories, balancing near-term growth with long-term sector transformation: hydrothermal and EGS. New exploration technologies and tools can reduce the near-term cost and risk associated with developing undiscovered hydrothermal systems, as well as EGS located in or near existing hydrothermal fields. These technologies will also advance the development of greenfield EGS in the long-term. Additionally, the investments in co-produced resources and systems analysis identify opportunities for reducing deployment costs (e.g., developing revenue streams from geothermal brines, streamlining regulatory processes).

The goal of the Geothermal Technologies Office is to make geothermal energy a fully competitive, widely available, and geographically diverse component of the national energy mix. Geothermal Technologies program objectives include technology development that will drive industry deployment of a targeted 30 GW of new undiscovered hydrothermal resources (nearly 10 times the current level of geothermal power deployment) and 100+ GW of EGS. The pathway for achieving these objectives includes developing new exploration tools and techniques to lower the upfront risk of geothermal resource exploration, reducing the Levelized Cost of Electricity (LCOE) of newly developed geothermal systems—including EGS—from current costs of 22.4 cents/kilowatt hour (kWh) to 6 cents/kWh (market prices) by 2030, conducting RD&D on technologies to harness available lower temperature resources more effectively, and developing improved methods to create new EGS reservoirs.

2.2 Geothermal Program Areas

Enhanced Geothermal Systems
The goal of the Enhanced Geothermal Systems (EGS) program is to advance cutting-edge subsurface RD&D that will enable replicable, commercially viable electricity from EGS. EGS are engineered reservoirs, created where there is hot rock but little to no natural permeability or fluid saturation present in the subsurface. To develop an EGS, fluid is injected into the subsurface at low to moderate pressures under a safe, controlled, environmentally responsible and well-engineered stimulation process, causing pre-existing fractures or weaknesses in the rock fabric to open. The pressure increase causes displacements along the fracture planes and zones of rock heterogeneity, which results in increased permeability and allows fluid to circulate throughout the rock. Via a production well, this fluid then transports heat to the surface where electricity can be generated. In the long term, EGS success would potentially enable the utilization of an enormous, geographically diverse energy resource on the order of 100+ GW.

Hydrothermal
The Hydrothermal program is focused on supporting the research and development of technologies necessary to effectively find and access "blind" resources at lower cost, enabling them to be developed and brought online by the private sector. The U.S. Geological Survey's (USGS) 2008 Geothermal Resource Assessment estimated that 30,000 MW (range from a P95 of 7,900 MW to a P5 of 73,000 MW) of undiscovered hydrothermal resources could still be found in the western U.S. alone. However, the technical feasibility of discovering and developing this resource potential depends on innovative approaches to subsurface characterization. Hydrothermal resources are defined by the presence of three key elements associated with geologically active areas: heat, fluid, and permeability (the ability for fluid to flow through rock). However, given the stage of geothermal development in the U.S., most of these remaining resources are now categorized as being either undiscovered or in so-called "blind" systems (i.e., showing little to no surface expression). These blind systems require new and innovative approaches to exploration. The risks and costs associated with successful

geothermal exploration and development in these poorly characterized areas are high, and the sector's inability to consistently drill economically viable wells is therefore a major barrier to near-term capacity expansion.

Low Temperature and Coproduced Resources
The Low Temperature and Coproduced Resources program supports targeted RD&D on technologies applicable to geothermal resources below a temperature of 300°F (150°C); as well as opportunities to improve the cost-effectiveness of geothermal production, including high-value material extraction and hybrid power designs that can be co-developed with existing well-field infrastructure and other clean energy technologies. Although low-temperature resources have a lower power conversion efficiency than other geothermal resources—due to the lower temperature fluids—these resources are abundant; highly accessible across the U.S.; and as in the case of co-produced fluids, have much of the necessary infrastructure in place, attributes that lower the effective LCOE. Improving the efficiency of lower temperature geothermal systems, and expanding their utility through value-added commercial opportunities (i.e., Mineral Recovery, Desalination); can enable near-term development of innovative geothermal technologies in more geographically diverse areas of the U.S. The Low Temperature and Coproduced Resources subprogram also supports R&D of the direct use of thermal resources for process and space heating applications.

Systems Analysis
The goal of the Systems Analysis program is to identify and address barriers to geothermal adoption in the U.S., and validate and assess technical progress across the geothermal sector. The Systems Analysis subprogram takes a holistic analytical approach across the program's technology portfolio to evaluate trends, conduct impact analyses, identify best practices, and provide resources and tools that will reduce costs and risk for geothermal developers. The Systems Analysis subprogram primarily conducts analyses in the following areas: the environmental impacts of geothermal; the policy and regulatory barriers to development and deployment; economic modeling and validation of geothermal technologies; and, collecting and disseminating data for public use to spur geothermal development. Lessons learned resulting from these analyses are subsequently incorporated into the program's Multi-Year Program Plan and either validate or refine the program's overall strategic direction. The Systems Analysis subprogram conducts these activities in partnership with the National Labs, Federal agencies, academic institutions, and industry stakeholders.

2.3 Recent Budget History

Table 2.1 below shows the recent budget history for the Geothermal Technologies Office.

Table 2.1 Recent budget history for the Geothermal Technologies Office.

Program Area (Dollars in Thousands)	**FY 2014 Enacted**[2]	**FY 2014 Current**[3]	**FY 2015 Enacted**	**FY 2016 Request**	**FY 2016 vs FY 2015**
Enhanced Geothermal System Demonstrations	27,084	26,536	32,100	45,000	+12,900
Hydrothermal	10,285	9,956	12,500	36,500	+24,000
Low Temperature, Co-Production Demonstration	4,708	4,612	6,000	9,000	+3,000
Systems Analysis, Resources Assessment, Data System Development & Population, Education	3,698	3,698	3,900	5,000	+1,100
Total, Geothermal Technologies	**45,775**	**44,802**	**54,500**	**95,500**	**+41,000**

[2] FY 2014 Enacted funding reflected the contractor foreign travel rescission of $27,000.
[3] Funding reflected the transfer of SBIR/STTR to the Office of Science.

3.0 Program Area Findings and Recommendations of the Peer Reviewers

The Peer Reviewer comments summarized below are directed towards GTO program areas, not their individual projects. For individual projects, a comprehensive list of reviewer comments, PI responses, and individual project scoring evaluations can be found in Appendix I.

Low Temperature Resources and Systems Analysis

Mineral Recovery

- Would be very helpful to come up with a small set of representative brines. This would minimize separate, overlapping efforts and make resulting data more comparable across technologies.

Strategic Materials

- A new NGDS data model was developed. Entitled "Mineral Recovery Brines," the data interchange model was released on April 30, 2015 joining 35 other data models relevant to geothermal energy exploration and development.
- A major milestone for the GDR was reached in July 2014 when a geothermal data provider submitted data in the most structured format prescribed by the National Geothermal Data System (NGDS). This format known as a "Tier 3" submission is organized according to one of thirty-six different data models specific to geothermal energy exploration and development.

Enhanced Geothermal Systems (EGS) Demonstrations

EGS: Overall Comment

- Projects in EGS are centered around a relatively narrow subject described by one reviewer as continuum reservoir simulation or modeling. It would help if GTO DOE supports some studies from researchers with different background other than just continuum reservoir/geomechanics engineering at large scale or even core-scale.

EGS: High Temp Tools and Drilling Systems

- The GTO has been comprehensive with funding and selection of projects in this technology area.
- This technology area does a good job covering projects from advanced high temperature sensors to advanced electronics and packaging. The range of known needs and applications are well covered in this technology area.
- One of the gaps currently missing in the High Temp area is a coding technology.
- Another gap is the production of integrated circuits and microelectromechanical systems (MEMS) tailored for geothermal applications.
- The National Energy Technology Laboratory houses an advanced high temperature high pressure (HTHP) drilling test facility. It has been sitting idle for many years. One reviewer feels that it is worth investigating using this facility for testing HTHP sensors and other drilling components with GTO-supported research projects.
- There seems to be no mention of image logging, reducing the cost, or improving interpretation in geothermal settings.
- This technology area is underfunded. The mix of projects is good and representative of needs, but generally not broad enough to meet the needs of the GTO.
- Should develop better synergy between drilling and instrumentation researchers.
- The GTO should figure out how to address funding issues for high temp applications with a relatively small market.

- The plastics industry should be more engaged to create high temp plastics that can withstand the temperatures, pressures, and chemical environments in these wells.
- This technology area could benefit from a project on well inspection technology capable to go to higher temperatures.
- Enable laboratory interaction to facilitate technology transfer to commercial entities.

EGS: Tracers/Zonal Isolation/Geochemistry

- The GTO is to be complimented on the breadth of research in this technology area. Very bright scientists and engineers doing very appropriate work in this area.
- One of the reviewers mentioned that she has been working on self-sensing, "smart" concrete that could have application in zonal isolation monitoring.
- Five of the six projects/presentations were laboratory-based. There is a need for more field-scale validation or perhaps something smaller than true field scale but bigger than lab tests. The moderator observed that this was part of the intent of the Frontier Observatory for Research in Geothermal Energy (FORGE).

EGS: Reservoir Modeling

- The code comparison study examines whether we are all modeling the same physics correctly, not what is the uncertainty. Modelers have focused on deterministic problems. They need to think about uncertainty quantification, especially when dealing with systems potentially containing a significant nonlinear behavioral element.
- There are scaling issues in this technology area, i.e. how can we continue to improve the laboratory – model linkage for results from one set of data informing another?
- The physics are the key to understanding; it is agnostic to the problem at hand (e.g., EGS, Low Temperature, etc.).
- Uncertainty quantification continues to be a need for better understanding dynamic Thermal-Hydrological-Mechanical-Chemical (THMC) processes in computational simulations.
- A geologic model should be set up first: without proper bounding of reservoir conditions and boundary effects, benefits of modeling are limited.
- The Code Comparison Study should look to include the FORGE sites in the future.

EGS: Demonstrations

- One reviewer felt that there needs to be a funding mechanism for opportunistic demonstration/collaboration as it becomes feasible, something like rapid-response funding – small pots of money to make it possible for principal investigators with tools/methods to get attention of demonstration sites.

EGS: Innovative Stimulation Techniques

- Very important for EGS construction and this technology area has a great project portfolio.
- Unique stimulation methods are bringing step change advancements compared to conventional technologies.
- The FORGE projects have the potential to fill a large gap in working to make EGS technology viable.
- Three good programs are all looking at similar work albeit with different stimulation methods. The detection and modeling should translate across those three programs.
- Would be good to see advanced zonal isolation coupled to advanced hydro-stimulation for a baseline comparison.

EGS: Tracers/Zonal Isolation/Geochemistry

- The gaps that need to be addressed include matching experimentalist with field capabilities.
- The projects that were in the most need of help were the ones that were more self-contained, i.e. had the fewest collaborators.

EGS: Fracture Characterization and Fluid Imaging

- There is much work in fracture characterization but little work applicable to fluid "imaging" in the subsurface.
- Magnetotellurics (MT) is a very fuzzy tool, e.g., hardly producing "images" of fluids in the subsurface.

Hydrothermal Resource Conservation

Hydrothermal: General Comments

- Integrate input from the utilities for areas where they are in need of energy, what they need out of the geothermal industry, and how we can make geothermal accessible to them.
- More public outreach, collaboration, and education are needed in this area.

Hydrothermal: Geochemistry

- Having multi-institutional projects has been huge for this technology area.
- Reviewers observed that work in this area seems national laboratory dominated. There is not a whole lot of diversity of PIs. Interaction with students has been really beneficial to progressing project work. Student intellectual growth is really helped as well.
- Reviewers recommend more academic involvement since most of the work in this area is national laboratory dominated.
- Geochemistry projects should be cross-pollinated, e.g. between this program element and the low temperature mineral recovery one. The data collected by those projects might inform the exploration-focused geochemical R&D effort.
- One reviewer commented that stage-gate reviews do not fit small R&D projects – too cumbersome. There was much agreement with this view.

Hydrothermal: Play Fairway Analysis

- Generally a good distribution of projects, although a lot of focus has been dedicated towards EGS in recent years.
- One reviewer questioned the timing of the Play Fairway reviews as most of them had only finished collecting the basic data. The reviewer felt that giving them ratings at this time had relatively little value.

4.0 Summary of Project Scoring for Each Technology Area

As part of the GTO 2015 Peer Review, 110 projects in 12 technology panels were reviewed by approximately 50 reviewers. Using the methodology described in Section 1.2, the weighted average score was calculated for each project. The weighted average score for all projects averaged 7.2 (on a scale of 1 to 10). Table 4.1 shows the overall performance of each technology panel, as well as the overall weighted average score for all projects reviewed.

Table 4.1 Overall performance of the Technology Panels

Technology Panel	Impact / Results 60%	Sci / Tech Approach 40%	Weighted Average
Hybrid/Value Added Systems	**7.8**	**7.5**	**7.7**
Low Temperature, Co-Production Demonstration	**8.1**	**8.0**	**8.1**
Mineral Recovery	**6.9**	**7.0**	**7.0**
Systems Analysis, Resources Assessment, Data System Development & Population, Education	**7.6**	**7.4**	**7.5**
Enhanced Geothermal System Demonstrations	**7.5**	**7.4**	**7.5**
High Temp Tools, Drilling Systems	**7.5**	**7.4**	**7.5**
Reservoir Fracture Characterization / Fluid Imaging	**7.2**	**7.4**	**7.3**
Reservoir Modeling	**7.3**	**7.8**	**7.5**
Supercritical Carbon Dioxide/Working Fluids	**6.8**	**6.1**	**6.5**
Exploration Validation / Play Fairway Analysis	**6.0**	**6.2**	**6.1**
Tracers / Zonal Isolation / Geochemistry	**7.4**	**7.3**	**7.4**
Innovative Stimulation Techniques	**7.6**	**7.4**	**7.5**
Overall Review Average	**7.2**	**7.2**	**7.2**

The following subsections summarize the scoring results by individual projects in the 12 technology areas that were reviewed. For individual projects, a comprehensive list of reviewer comments, PI responses, and individual project scoring evaluations can be found in Appendix I.

4.1 Hybrid/Value Added Systems

Table 4.1.1 summarizes the projects and scores for the Hybrid/Value Added Systems technology panel. This technology panel had 7 projects reviewed. The 7 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had average, maximum, and minimum values of 7.7, 8.3 and 7.1 respectively.

Figure 4.1.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

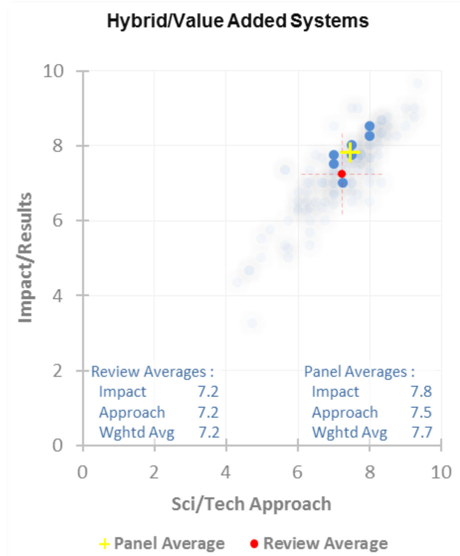

Figure 4.1.1

Table 4.1.1 Hybrid/Value Added Systems projects scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Development of New Biphasic Metal Organic Working Fluids for Geothermal Systems - Pete McGrail, Pacific Northwest National Laboratory	8.5	8.0	**8.3**
Geothermal risk reduction via geothermal/solar hybrid power plants - Craig Turchi, National Renewable Energy Lab & Dan Wendt, Idaho National Lab	8.3	8.0	**8.2**
Geothermal Power Generation and CO2 Capture Co-Production - David. J. Heldebrant, Pacific Northwest National Laboratory	8.0	7.5	**7.8**
Forward Osmosis Purification of Co-Produced Water - Greg Mines, Idaho National Lab	7.8	7.5	**7.7**
Low-Enthalpy Geothermal Desalination - Craig Turchi, National Renewable Energy Laboratory	7.8	7.0	**7.5**
Freeform Heat Exchangers for Binary Geothermal Power Plants - Adrian Sabau, Oak Ridge National Laboratory	7.5	7.0	**7.3**
Integrating Compressed Air Energy Storage and Geothermal for Grid-Scale Renewables Integration - Peter McGrail, Pacific Northwest National Laboratory	7.0	7.3	**7.1**
Panel Average	**7.8**	**7.5**	**7.7**
Review Average	**7.2**	**7.2**	**7.2**

4.2 Low Temperature Resources and Co-Production Demonstration

Table 4.2.1 summarizes the projects and scores for the Low Temperature Resources and Co-Production Demonstration technology panel. This technology panel had 2 projects reviewed. The 2 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had average, maximum, and minimum values of 8.1, 8.5 and 7.7 respectively.

Figure 4.2.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

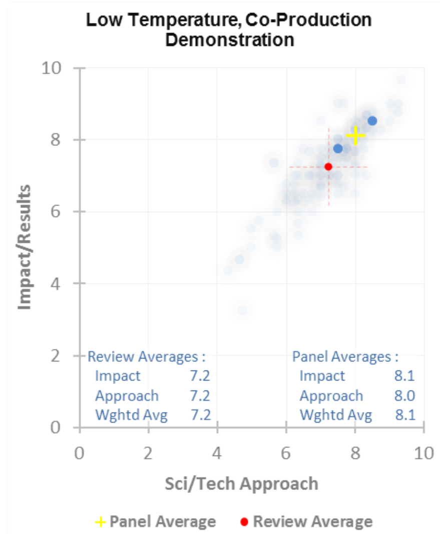

Figure 4.2.1

Table 4.2.1 Low Temperature Resources and Co-Production Demonstration project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Recovery Act: Electric Power Generation from Low to Intermediate Temperature Resources - William D. Gosnold, University of North Dakota	8.5	8.5	**8.5**
Low Temperature Project Analysis - Greg Mines & Tom Williams, Idaho National Laboratory/National Renewable Energy Laboratory	7.8	7.5	**7.7**
Panel Average	**8.1**	**8.0**	**8.1**
Review Average	**7.2**	**7.2**	**7.2**

4.3 Mineral Recovery

Table 4.3.1 summarizes the projects and scores for the Mineral Recovery technology panel. This technology panel had 8 projects reviewed. The 8 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.0, 9.1 and 5.6 respectively.

Figure 4.3.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

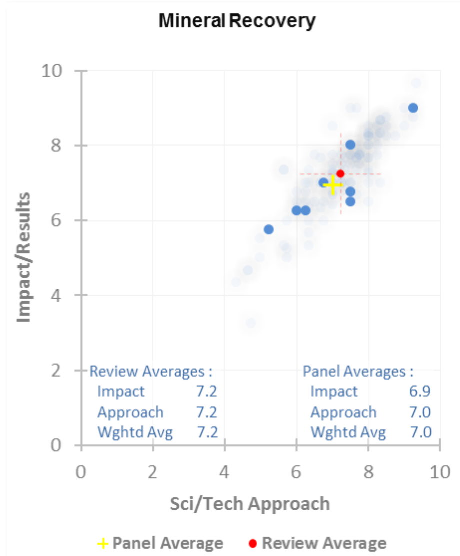

Figure 4.3.1

Table 4.3.1 Mineral Recovery project scores

Project **- Principal investigator, Organization**	**Impact / Results** (60% weight)	**Sci / Tech Approach** (40% weight)	**Weighted Average**
Magnetic Partitioning Nanofluid for Rare Earth Extraction from Geothermal Fluids - Peter McGrail, Pacific Northwest National Laboratory	9.0	9.3	**9.1**
Geothermal Thermoelectric Generation (G-TEG) with Integrated Temperature Driven Membrane Distillation and Novel Manganese Oxide for Lithium Extraction - Jay Renew, Southern Research Institute	8.0	7.5	**7.8**
Recovery of Rare Earths, Precious Metals and Other Critical Materials from Geothermal Waters with Advanced Sorbent Structures - Raymond Addleman, Pacific Northwest National Laboratory	6.8	7.5	**7.1**
Environmentally friendly economical sequestration of rare earth metals from geothermal waters - Dean Stull, Tusaar Corp.	7.0	6.8	**6.9**
Chelating Resins for Selective Separation and Recovery of Rare Earth Elements from Low Temperature Geothermal Water - Athanasios Karamalidis, Carnegie Mellon University	6.5	7.5	**6.9**
Engineering Thermophilic Microorganisms to Selectively Extract Strategic Metals from Low Temperature Geothermal Brines - Caroline Ajo-Franklin, Lawrence Berkley National Laboratory	6.3	6.3	**6.3**
Selective Recovery of Metals From Geothermal Brines - Susanna Ventura, SRI International	6.3	6.0	**6.2**
Maximizing REE Recovery in Geothermal Systems - Robert Zierenberg, University of California - Davis	5.8	5.3	**5.6**
Panel Average	**6.9**	**7.0**	**7.0**
Review Average	**7.2**	**7.2**	**7.2**

4.4 Systems Analysis, Resources Assessment, Data System Development & Population, Education

Table 4.4.1 summarizes the projects and scores for the Systems Analysis, Resources Assessment, Data System Development & Population, Education technology panel. This technology panel had 11 projects reviewed. The 11 projects were scored by an average of 3 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.5, 9.5 and 5.3 respectively.

Figure 4.4.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

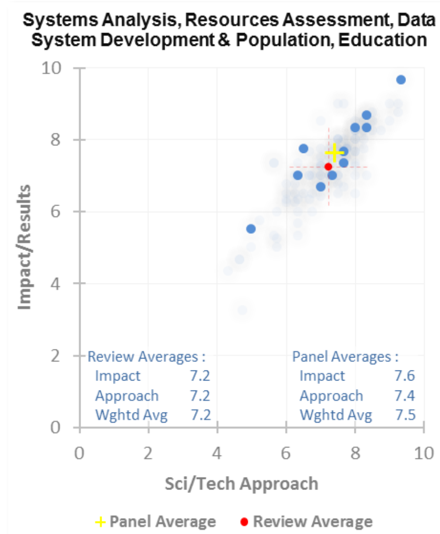

Figure 4.4.1

Table 4.4.1 Systems Analysis, Resources Assessment, Data System Development & Population, Education project scores

Project **- Principal investigator, Organization**	**Impact / Results** (60% weight)	**Sci / Tech Approach** (40% weight)	**Weighted Average**
Regulatory Roadmap - Katherine Young, National Renewable Energy Laboratory	9.7	9.3	**9.5**
National Geothermal Resource Assessment and Classification - Colin Williams, U.S. Geological Survey	8.7	8.3	**8.5**
Geothermal Prospector - Dan Getman, National Renewable Energy Laboratory	8.3	8.3	**8.3**
The Value of Geothermal Power for Integration of Intermittent Generation - Thomas Edmunds, Lawrence Livermore National Laboratory	8.3	8.0	**8.2**
Projected Deployment of Geothermal Technologies Subject to Water Availability Constraints - Jordan Macknick, National Renewable Energy Laboratory	7.7	7.7	**7.7**
GT-Mod - Tom Lowry, Sandia National Laboratories	7.3	7.7	**7.5**
Resource Reporting Methodology Analysis and Development of Geothermal Resource Reporting Metric for GTO's Hydrothermal Program - Patrick Dobson & Kate Young, National Renewable Energy Laboratory / Lawrence Berkley National Laboratory	7.8	6.5	**7.3**
Strategic Analysis - Chad Augustine, National Renewable Energy Laboratory	7.0	7.3	**7.1**
Geothermal Resource Potential and Supply Curve Improvement - Chad Augustine, National Renewable Energy Laboratory	6.7	7.0	**6.8**
GETEM - Greg Mines, Idaho National Laboratory	7.0	6.3	**6.7**
Hydrothermal Reservoir Productivity - Greg Mines, Idaho National Laboratory	5.5	5.0	**5.3**
Panel Average	**7.6**	**7.4**	**7.5**
Review Average	**7.2**	**7.2**	**7.2**

4.5 Enhanced Geothermal System Demonstrations

Table 4.5.1 summarizes the projects and scores for the Enhanced Geothermal System technology panel. This technology review area had 12 projects reviewed. The 12 projects were scored by an average of 3 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.5, 8.5 and 6.1 respectively.

Figure 4.5.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

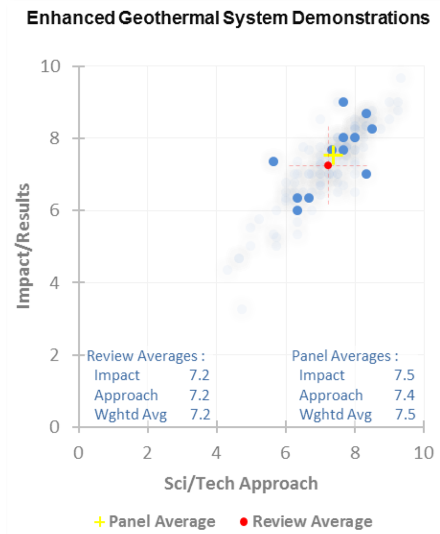

Figure 4.5.1

Table 4.5.1 Enhanced Geothermal Systems Demonstrations project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Concept Testing and Development at the Raft River Geothermal Field, Idaho - Joseph Moore, University of Utah	8.7	8.3	**8.5**
Archive of Fenton Hill Data; Creation and Testing of Data Sets for Simulation and Testing - Sharad Kelkar, Los Alamos National Laboratory	9.0	7.7	**8.5**
Poroelastic Tomography by Adjoint Inverse Modeling of Data from Seismology, Geodesy, and Hydrology - Kurt Feigl, University of Wisconsin-Madison	8.3	8.5	**8.4**
Monitoring EGS Stimulation and Reservoir Dynamics with InSAR and MEQ - Nicholas Davatzes, Temple University	8.0	8.0	**8.0**
Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California - Mark Walters, Calpine - Geysers Power Company LLC -	8.0	7.7	**7.9**
Geysers Calpine Modeling - Jonny Rutqvist, Lawrence Berkley National Laboratory	7.7	7.7	**7.7**
Evaluation of Stimulation at Newberry Volcano EGS Demo Site Through Natural Isotopic Reactive Tracers and Geochemical Investigation - Eric Sonnenthal, Lawrence Berkley National Laboratory	7.0	8.3	**7.5**
Feasibility of EGS Development at Bradys Hot Springs, Nevada - Peter Drakos, Ormat Nevada, Inc.	7.7	7.3	**7.5**
Recovery Act: Newberry Volcano EGS Demonstration - Susan Petty, AltaRock Energy, Inc.	7.3	5.7	**6.7**
Bradys and Desert Peak Numerical Modeling - Sharad Kelkar, Los Alamos National Laboratory	6.3	6.7	**6.5**
EGS Reservoir Stimulations and Long-Term Performance Modeling - Mitch Plummer, Idaho National Laboratory	6.3	6.3	**6.3**
Joint Active and Passive Seismic Imaging of EGS Reservoirs - Lianjie Huang, Los Alamos National Laboratory	6.0	6.3	**6.1**
Panel Average	**7.5**	**7.4**	**7.5**
Review Average	**7.2**	**7.2**	**7.2**

4.6 High Temp Tools and Drilling Systems

Table 4.6.1 summarizes the projects and scores for the High Temp Tools and Drilling Systems technology panel. This technology review area had 16 projects reviewed. The 16 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.5, 9.0 and 5.9 respectively.

Figure 4.6.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

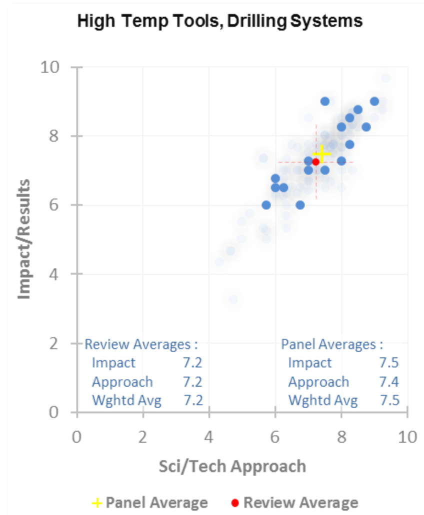

Figure 4.6.1

Table 4.6.1 High Temp Tools and Drilling Systems project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Development of a 300°C, 200 level, 3C Fiber Optic Downhole Seismic Receiver Array for Surveying and Monitoring of Geothermal Reservoirs - Dr. Bjorn Paulsson, Paulsson, Inc.	9.0	9.0	**9.0**
Drilling Technologies Evaluation - Douglas Blankenship, Sandia National Laboratories	8.8	8.5	**8.7**
Recovery Act: High Temperature 300C Directional Drilling System, including drill bit, steerable motor, and drilling fluid, for Enhanced Geothermal Systems - Kamalesh Chatterjee, Baker Hughes Oilfield Operations Incorporated	8.3	8.8	**8.5**
Elastomeric Material Evaluation and Development - Erica Redline & Toshi Sugama, Sandia National Laboratories/Brookhaven National Laboratory	8.5	8.3	**8.4**
Well Monitoring Systems for EGS - Randy Norman, Perma Works	9.0	7.5	**8.4**
High Temperature Downhole Motor - David Raymond, Sandia National Laboratories	8.3	8.0	**8.2**
Multifunctional Corrosion-resistant Foamed Cement Composites - Toshi Sugama, Brookhaven National Laboratory	7.8	8.3	**8.0**
Directional Measurement-While-Drilling System for Geothermal Applications - Kamalesh Chatterjee, Baker Hughes Oilfield Operations Incorporated	7.3	8.0	**7.6**
Enhanced High Temperature/High Speed Data Link for Logging Cables - Grzegorz Cieslewski, Sandia National Laboratories	7.0	7.5	**7.2**
High Temperature Chemical Sensing Tool for Distributed Mapping of Fracture Flow in EGS - Grzegorz Cieslewski, Sandia National Laboratories	7.3	7.0	**7.2**
Advanced Percussive Drilling Technology for Geothermal Exploration and Development - Dale Wolfer, Atlas Copco Secoroc LLC	7.0	7.0	**7.0**
Evaluation of High Temperature Components for Use in Geothermal Tools - Avery Cashion, Sandia National Laboratories	6.8	6.0	**6.5**
SURGE: Geothermal Drilling and Completions: Petroleum Practices Technology Transfer - Charlie Visser, National Renewable Energy Laboratory	6.5	6.3	**6.4**

Table 4.6.1 High Temp Tools and Drilling Systems project scores - continued

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Testing and Calibration of HT Wide-bandwidth Seismic Sensors for EGS Applications and Collaboration with IPGT Program - Ernest L. Majer, Lawrence Berkley National Laboratory	6.5	6.0	**6.3**
Deployment of Integrated Wide Bandgap Sensor, HT Packaging, and Data Communication System - Grzegorz Cieslewski, Sandia National Laboratories	6.0	6.8	**6.3**
Recovery Act: Development Of An Improved Cement For Geothermal Wells - George Trabits, Trabits Group, LLC	6.0	5.8	**5.9**
Panel Average	**7.5**	**7.4**	**7.5**
Review Average	**7.2**	**7.2**	**7.2**

4.7 Reservoir Fracture Characterization/Fluid Imaging

Table 4.7.1 summarizes the projects and scores for the Reservoir Fracture Characterization/Fluid Imaging technology panel. This technology review area had 19 projects reviewed. The 19 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.3, 9.0 and 4.7 respectively.

Figure 4.7.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

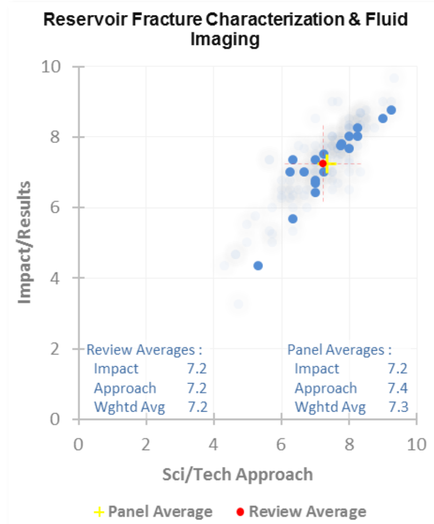

Figure 4.7.1

Table 4.7.1 Reservoir Fracture Characterization / Fluid Imaging project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Application of Neutron Imaging and Scattering to Fluid Flow and Fracture in EGS Environments - Yarom Polsky & Philip Bingham, Oak Ridge National Laboratory	8.8	9.3	**9.0**
Viability of Sustainable, Self-Propping Shear Zones in EGS: Measurement of Reaction Rates at Elevated Temperatures - Susan Carroll, Lawrence Livermore National Laboratory	8.5	9.0	**8.7**
Novel Geothermal Development of Deep Sedimentary systems in the US - Joe Moore, University of Utah	8.3	8.3	**8.3**
Sustainability of Shear-Induced Permeability for EGS Reservoirs - Tim Kneafsey, Lawrence Berkley National Laboratory	8.0	8.3	**8.1**
Seismic Analysis of Spatio-Temporal Fracture Generation During EGS Resource Development - Dr. Roland Gritto, Array Information Technology	8.0	8.0	**8.0**
Leveraging a Fundamental Understanding of Fracture Flow, Dynamic Permeability Enhancement, and Induced Seismicity to Improve Geothermal Energy Production - Dr. Chris Marone, The Pennsylvania State University	7.8	7.8	**7.8**
Imaging Fault Zones Using a Novel Elastic Reverse-Time Migration Imaging Technique - Lianjie Huang, Los Alamos National Laboratory	7.7	8.0	**7.8**
Laboratory-Scale Characterization of EGS Reservoirs - Dr. Ahmad Ghassemi, The Board of Regents of the University of Oklahoma	7.8	7.8	**7.8**
Surface and Subsurface Geodesy Combined with Active Borehole Experimentation for the Advanced Characterization of EGS Reservoirs - Dr. Derek Elsworth, The Pennsylvania State University	7.5	7.3	**7.4**
Stochastic Joint Inversion for Integrated Data Interpretation in Geothermal Exploration - Rob Mellors, Lawrence Livermore National Laboratory	7.3	7.0	**7.2**
Novel use of 4D Monitoring Techniques to Improve Reservoir Longevity and Productivity in Enhanced Geothermal Systems - Kelly Rose, National Energy Technology Laboratory	7.0	7.3	**7.1**
SURGE: Completing Horizontal Geothermal Wells - Chad Augustine, National Renewable Energy Laboratory	7.3	6.3	**6.9**
SURGE: Sedimentary Geothermal Feasibility Study - Chad Augustine, National Renewable Energy Laboratory	7.0	6.7	**6.9**

Table 4.7.1 Reservoir Fracture Characterization / Fluid Imaging project scores - continued

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Phase I Project: Fiber Optic Distributed Temperature Sensing for Periodic Hydraulic Tests - Dr. Matthew Becker, California State University Long Beach	6.8	7.0	**6.9**
Time-lapse joint inversion of GEOphysical Data and its application to gEothermal prospecting - GEODE - Dr. Andre Revil, Colorado School of Mines	6.7	7.0	**6.8**
Laboratory Evaluation of EGS Shear Stimulation - Stephen Bauer, Sandia National Laboratories	7.0	6.3	**6.7**
Quantifying EGS Reservoir Complexity with an Integrated Geophysical Approach - Improved Resolution Ambient Seismic Noise Interferometry - Ileana Tibuleac, Board of Regents, NSHE, obo University of Nevada, Reno	6.4	7.0	**6.6**
Identifying High Potential Well Targets with 3D Seismic, and Mineralogy - Robert Mellors, Lawrence Livermore National Laboratory	5.7	6.3	**5.9**
Geothermal Resource Development with Zero Mass Withdrawal, Engineered Convection, and Wellbore Energy Conversion - Richard Hughes, LA State University	4.3	5.3	**4.7**
Panel Average	**7.2**	**7.4**	**7.3**
Review Average	**7.2**	**7.2**	**7.2**

4.8 Reservoir Modeling

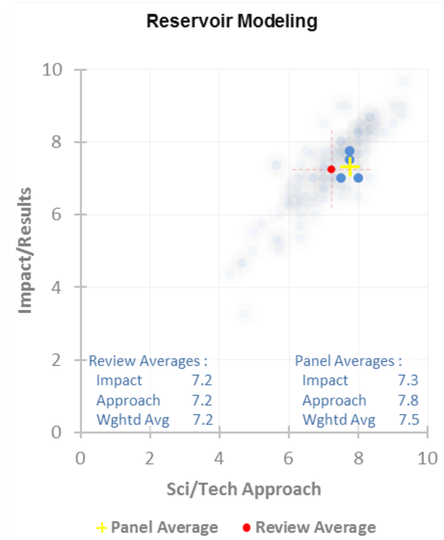

Figure 4.8.1

Table 4.8.1 summarizes the projects and scores for the Reservoir Modeling technology panel. This technology review area had 4 projects reviewed. The 4 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.5, 7.8 and 7.2 respectively.

Figure 4.8.1 shows scoring for individual projects and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

Table 4.8.1 Reservoir Modeling project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
ARRA THMC Modeling - Eric Sonnenthal, Lawrence Berkley National Laboratory	7.8	7.8	**7.8**
Recovery Act: THMC Modeling of EGS Reservoirs - Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity - Dr. Derek Elsworth, Pennsylvania State University	7.5	7.8	**7.6**
Support of the DOE GTO Model Comparison Activity - Mark White, Pacific Northwest National Laboratory	7.0	8.0	**7.4**
Recovery Act: Development of a Geomechanical Framework for the Analysis of MEQ in EGS Experiments (GEYSERS). Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis - Dr. Ahmad Ghassemi, The Board of Regents of the University of Oklahoma	7.0	7.5	**7.2**
Panel Average	**7.3**	**7.8**	**7.5**
Review Average	**7.2**	**7.2**	**7.2**

4.9 Supercritical Carbon Dioxide/Working Fluids

Table 4.9.1 summarizes the projects and scores for the Supercritical Carbon Dioxide/Working Fluids technology panel. This technology review area had 3 projects reviewed. The 3 projects were scored by an average of 3 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 6.5, 8.2 and 4.7 respectively.

Figure 4.9.1 shows scoring for individual project and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

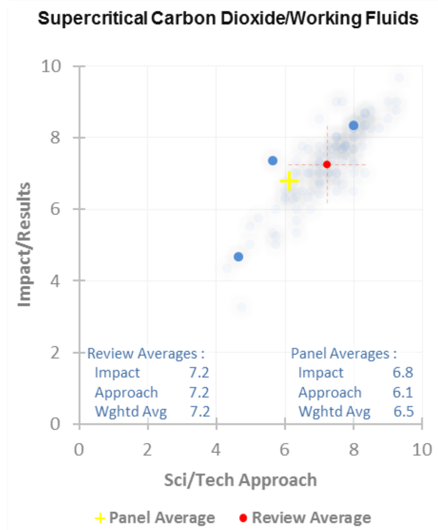

Figure 4.9.1

Table 4.9.1 Supercritical Carbon Dioxide/Working Fluids project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Push-pull well testing using CO2 with active source geophysical monitoring - Curt Oldenburg, Lawrence Berkley National Laboratory	8.3	8.0	**8.2**
Active Management of Integrated Geothermal CO2 Storage Reservoirs in Sedimentary Formations - Tom Buscheck, Lawrence Livermore National Laboratory	7.3	5.7	**6.7**
Geothermal Energy Production Coupled with CCS: Heat Recovery Using an Innovative High Efficiency Supercritical CO2 Turboexpansion Cycle - Barry Freifeld, Lawrence Berkley National Laboratory	4.7	4.7	**4.7**
Panel Average	**6.8**	**6.1**	**6.5**
Review Average	**7.2**	**7.2**	**7.2**

4.10 Exploration Validation/Play Fairway Analysis

Table 4.10.1 summarizes the projects and scores for the Exploration Validation/Play Fairway Analysis technology panel. This technology review area had 14 projects reviewed. The 14 projects were scored by an average of 3 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 6.1, 8.3 and 3.9 respectively.

Figure 4.10.1 shows scoring for individual project and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

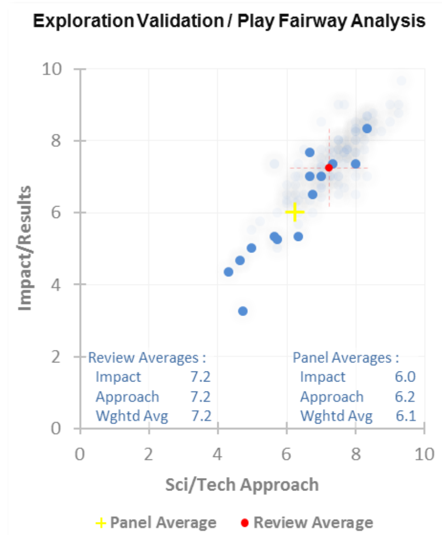

Figure 4.10.1

Table 4.10.1 Exploration Validation / Play Fairway Analysis projects scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Discovering Blind Geothermal Systems in the Great Basin Region: An Integrated Geologic and Geophysical Approach for Establishing Geothermal Play Fairways - James Faulds, Nevada Bureau of Mines and Geology, University of Nevada-Reno	8.3	8.3	**8.3**
Play Fairway Analysis of the Snake River Plain - John Shervais, Utah State University	7.3	8.0	**7.6**
Structurally Controlled Geothermal Systems in the Eastern Great Basin Extensional Regime, Utah - Phil Wannamaker, University of Utah/EGI	7.3	7.3	**7.3**
Comprehensive analysis of Hawaii's geothermal potential through Play Fairway integration of geophysical, geochemical, and geological data - Nicole Lautze, University of Hawaii	7.7	6.7	**7.3**
The Convergence of Heat, Groundwater, & Fracture Permeability: Innovative Play Fairway Modelling Applied to the Tularosa Basin - Dr. Greg Nash, Ruby Mountain Inc.	7.0	7.0	**7.0**
Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin - Teresa Jordan, Cornell University	7.0	6.7	**6.9**
Iceland Geophysics: Advanced 3D Geophysical Imaging Technologies for Geothermal Resource Characterization - Gregory Newman, Lawrence Berkley National Laboratory	6.5	6.8	**6.6**
Geothermal Potential of the Cascade and Aleutian Arcs, with Ranking of Individual Volcanic Centers for their Potential to Host Electricity-Grade Reservoirs - Lisa Shevenell, Atlas Geosciences Inc.	5.3	6.3	**5.7**
Structurally Controlled Geothermal Systems in the Central Cascadia Arc-BackArc Regime, Oregon - Phil Wannamaker, University of Utah/EGI	5.3	5.7	**5.5**
Recovery Act: Merging high resolution geophysical and geochemical surveys to reduce exploration risk at Glass Buttes, Oregon - Patrick Walsh, ORMAT Nevada, Inc.	5.3	5.8	**5.5**

Table 4.10.1 Exploration Validation / Play Fairway Analysis projects scores - continued

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Geothermal Play Fairway Analysis of Potential Geothermal Resources in NE California, NW Nevada, and Southern Oregon - James McClain, University of California - Davis	5.0	5.0	**5.0**
Hydrogeologic windows: Regional Signature Detection for Blind and Traditional Geothermal Play Fairways - Richard Stephen Middleton, Los Alamos National Laboratory	4.7	4.7	**4.7**
Geothermal Play-Fairway Analysis of Washington State Prospects - David Norman, Washington Division of Geology and Earth Resources	4.3	4.3	**4.3**
Recovery Act: Use Remote Sensing Data (selected visible and infrared spectrums) to locate high temp ground anomalies in Colorado. Confirm heat flow potential w/ on-site temp surveys to drill deep resource wells - Jerry Smith, Pagosa Verde LLC	3.3	4.8	**3.9**
Panel Average	**6.0**	**6.2**	**6.1**
Review Average	**7.2**	**7.2**	**7.2**

4.11 Tracers/Zonal Isolation/Geochemistry

Table 4.11.1 summarizes the projects and scores for the Tracers /Zonal Isolation/Geochemistry technology panel. This technology review area had 11 projects reviewed. The 11 projects were scored by an average of 4 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.4, 8.2 and 6.5 respectively.

Figure 4.11.1 shows scoring for individual project and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

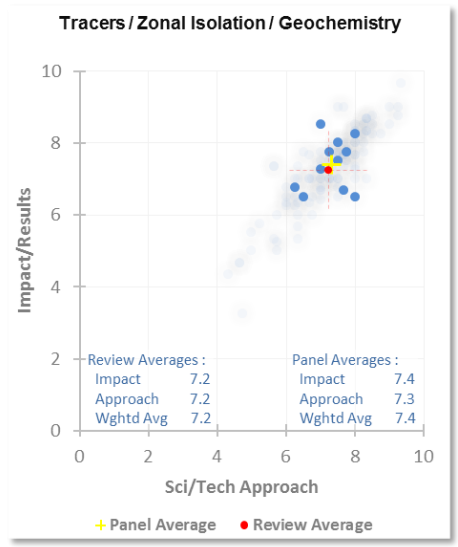

Figure 4.11.1

Table 4.11.1 Tracers / Zonal Isolation / Geochemistry project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Weighted Average
Integration of Nontraditional Isotopic Systems Into Reaction-Transport Models of EGS For Exploration, Evaluation of Water-Rock Interaction, and Impacts of Water Chemistry on Reservoir Sustainability - Eric Sonnenthal, Lawrence Berkley National Laboratory	8.3	8.0	**8.2**
Geothermometry Mapping of Deep Hydrothermal Reservoirs in Southeastern Idaho - Mark Conrad & Earl Mattson, Lawrence Berkley National Laboratory /Idaho National Laboratory	8.5	7.0	**7.9**
Surprise Valley Geochemistry - Nicholas Spycher, Lawrence Berkley National Laboratory	8.0	7.5	**7.8**
Temporary Sealer Materials - Toshi Sugama, Brookhaven National Laboratory	7.8	7.8	**7.8**
Tagged Nanoparticles for Fluid Flow Monitoring - Richard Kemp, Sandia National Laboratories	7.8	7.3	**7.6**
Use of He isotopes for geothermal resource identification in the Cascades and Snake River Plain - Patrick Dobson, Lawrence Berkley National Laboratory	7.5	7.5	**7.5**
Surface estimates of deep permeability - Mack Kennedy, Lawrence Berkley National Laboratory	7.3	7.0	**7.2**
Radioisotope Tracers and Fracture Attributes for Enhanced Geothermal Systems - John Christensen, Lawrence Berkley National Laboratory	6.5	8.0	**7.1**
Fluid Chemistry and Fracture Growth: What's the Connection? - Kevin Knauss, Lawrence Berkley National Laboratory	6.7	7.7	**7.1**
SPI Conformance Gel Applications in Geothermal Zonal Isolation - Lyle Burns, Clean Tech Innovations, LLC	6.8	6.3	**6.6**
A Reactive Tracer Method for Predicting EGS Reservoir Geometry and Thermal Lifetime: Development and Field Validation - Jefferson Tester, Cornell University	6.5	6.5	**6.5**
Panel Average	**7.4**	**7.3**	**7.4**
Review Average	**7.2**	**7.2**	**7.2**

4.12 Innovative Stimulation Techniques

Table 4.12.1 summarizes the projects and scores for Innovative Stimulation technology panel. This technology review area had 3 projects reviewed. The 3 projects were scored by an average of 3 reviewers. The weighted average scores for this group of projects had an average, maximum, and minimum value of 7.6, 7.4 and 7.5 respectively.

Figure 4.12.1 shows scoring for individual project and the group as a whole in relation to the review.

See Appendix I for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

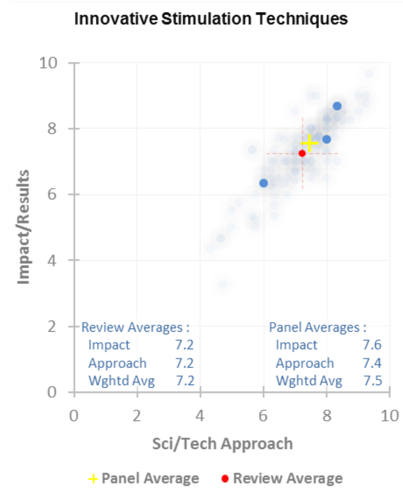

Figure 4.12.1

Table 4.12.1 Innovative Stimulation Techniques project scores

Project - Principal investigator, Organization	Impact / Results (60% weight)	Sci / Tech Approach (40% weight)	Overall Rating
Gas Generator Development and Testing for Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation - Mark Grubelich, Sandia National Laboratories	8.7	8.3	**8.5**
Validation of EGS Feasibility and Explosive Fracturing Techniques - Charles Carrigan, Lawrence Livermore National Laboratories	7.7	8.0	**7.8**
Reservoir Stimulation Optimization with Operational Monitoring for Creation of EGS - Carlos Fernandez, Pacific Northwest National Laboratory	6.3	6.0	**6.2**
Panel Average	**7.6**	**7.4**	**7.5**
Program Average	**7.2**	**7.2**	**7.2**

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DOE/EE-1305 • December 2015