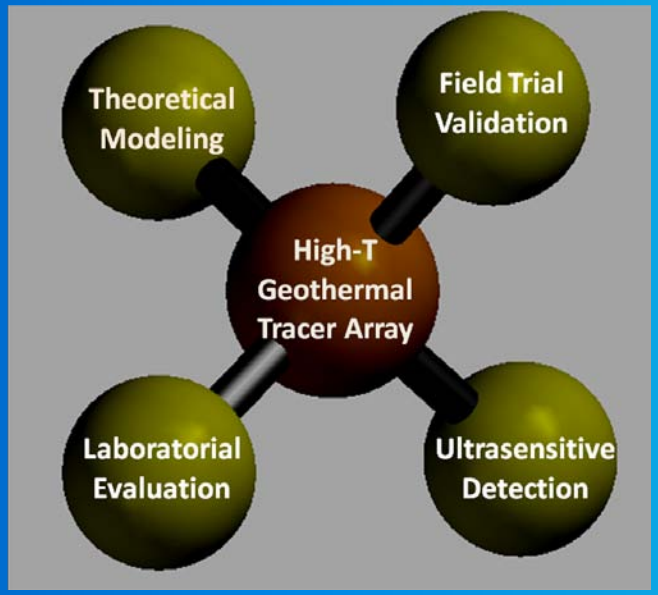
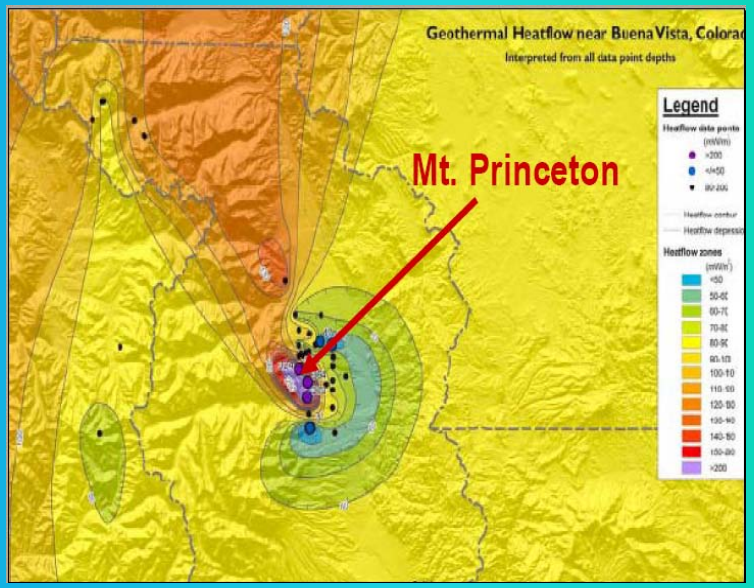



From Lab




To Field

# Novel Multidimensional Tracers for Geothermal Inter-Wall Diagnostics

May 19, 2010

Principal Investigator
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Power Environmental Energy Research Institute

DE-EE00003032

# Project Overview

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

**Project Title:** Novel Multidimensional Tracers for Geothermal Inter-Wall Diagnostics

**Project Period:** 01/29/2010 – 12/31/2012

**Percentage Completed:** Project Initialized

**Budget:**

| | DOE Share | Awardee Share | Total |
|---|---|---|---|
| TOTAL | $1,840,000 | $460,000 | $2,300,000 |
| FY09 | $0 | $0 | $0 |
| FY10 | $470,195 | $90,000 | $560,195 |

**Barrier:** Demonstrate ability to accurately detect reservoir characteristics including fluid pathways, dynamics, residence time, etc. (MYRDD)

**Partners:** California Institute of Technology (Theoretical Studies)
Mt. Princeton Geothermal LLC (on-site Field Test)
BJ Energy Service (Project Consultation and Commercialization)

# Project Objectives



The overall objective of this project is to develop a matrix of the smart geothermal tracer and its interpretation tools, including:

- Using advanced molecular simulation tools and identifying candidates of smart tracers in geothermal reservoir conditions
- Using novel experimental design and evaluation to screen and validate developed tracers from laboratory simulations
- Conducting field trials to validate selected tracer matrix which can lead to information beyond well-to-well connectivity. The information includes (1) porosities, (2) migration distance, and (3) fracture spacing.
- Developing user-friendly interpretation tools for developed tracer matrix application in the field.

# Relevance/Impact of Research



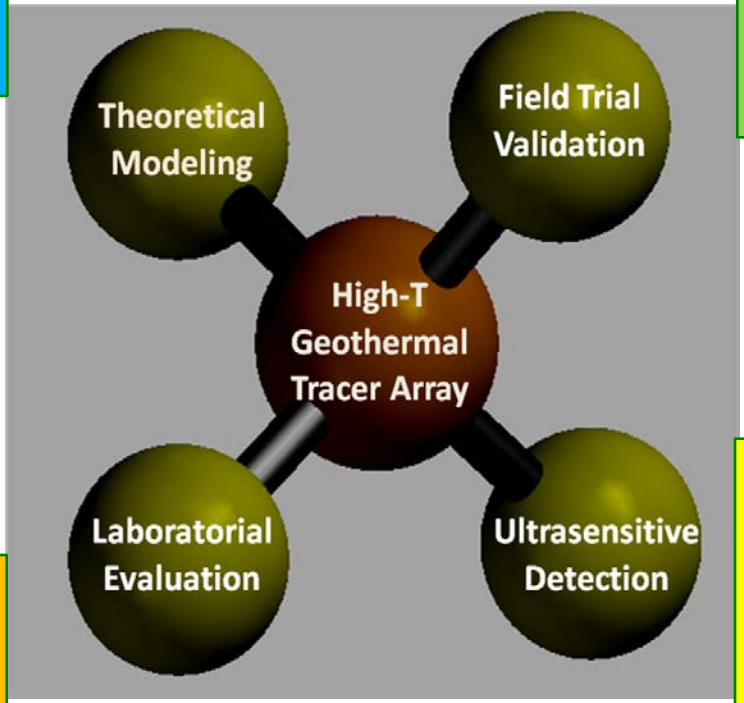
**The proposed project is applicable to the Geothermal Technologies Program (GTP) Multi-Year Research, Development, and Demonstration (MYRDD) plan in the following aspects:**

- Tracers and tracer interpretation are included in the continued RD&D in "*Current efforts on Enhanced Geothermal Systems (EGS)*".
- MYRDD technical plan "*4.1 Enhanced Geothermal Systems Research, Development, and Demonstration" include Inter-well Connectivity, "deals primarily with tools such as tracers that can be used to ensure that there is a suitable flow path that connects the various injection and production wells in an EGS field.*"
- "*Inadequate tracers and/or tracer methodology to accurately define the subsurface system of fractures and mapping of fluid flow*" is a barrier for inter-well connectivity, according to the MYRDD plan; "*Tracers do not exist that can reliably measure and/or monitor the surface area responsible for rock-fluid heat and mass exchange, thereby allowing for the quantification and prediction of EGS heat extraction efficiencies.*"
- In "*Inter-well Connectivity Objectives*" of MYRDD plan, it is proposed that demonstrate tracer technologies at operation temperatures of 250$^0$C, 275$^o$C, and 300$^o$C represent important benchmarks by 2012, 2015, and 2020.
- *For "Inter-well Connectivity Technical Approaches*" and "*Inter-well Connectivity Tasks"* of MYRDD plan, it is proposed that "*new and improved tracers will be developed to better determine the fluid flow pathways*", "*Develop improved tracers and tracer interpretation methods to define heat exchanger surface area (for thermal drawdown) and validate the reservoir model.*"

# Integrated Approaches



**Theoretical Model and Molecular Design Tool (Working with California Institute of Technology (Caltech)**




**Field Tests and Industrial Application Evaluation**
**(Mt. Princeton Geothermal LLC**
**BJ Energy Service)**

**Establish Laboratory Protocols**
(1) Thermal Stability
(2) Adsorption/Desorption
(3) Tracer Performance
(4) Tracer Evaluation

**Developing tracer detections:**
(1) sample pre-concentration
(2) GC/LC analyses
(3) Nitrogen Phosphorus Detector (NPD)
(4) Techniques to improve sensitivity and accuracy of tracer detection limitations

# Tasks to be Performed



**Task 1.0 Establish Laboratorial Evaluation Protocol to Screen Commercially Available Organic Tracers**

- Subtask 1.1 Developments of tracer detection and analysis tools
- Subtask 1.2 Establish laboratory protocol for tracer adsorption/desorption
- Subtask 1.3 Establish laboratory protocol for tracer thermal stability testing
- Subtask 1.4 Long slim tube (up to 600 FT) for evaluating tracer performance

**Task 2.0 Developments of Theoretical Model and Molecular Design Tool Based on Computational Simulation Techniques for Fast-Screening of Other Potential Tracer Components**

**Task 3.0 Development of Smart Tracers to Provide Information about Subsurface Porosity, Fractural Spacing and Surface Area**

- Subtask 3.1: Evaluate thermal stabilities of proposed tracers
- Subtask 3.2: Determination of adsorption/desorption rates of selected tracer compounds

**Task 4.0 Work with Industrial Partner to Conduct Field Trial Testing of Selected Tracer Compounds**

**Task 5.0 Development of Multidimensional Tracer Interpretation System**

# Highlights of R&D Methods Applied



- Innovative and Effective Lab Evaluations
  - Ultra-sensitive tracer analysis and detection
    → $10^{-12}$ g/ml @ signal-to-noise ratio of 2
  - Unique testing approaches tracer property screening
    →Thermal stability testing with mini-gold-tube reactors under various geological conditions
    →Analysis of interactions of tracer with reservoir rocks (adsorption/desorption)
  - Tracer performance evaluation
    → Up to 600 FT long slim tube filled with different reservoir rocks
- Fast-Screening through Molecular Design and Computational Simulation
- Field Trial Testing & Evaluation and Tracer Interpretation System

# Schedule and Milestones



| Task | Description | Duration (Quarter) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **Task 1** | Lab Evaluation Protocol | ■ | ■ | ■ | | | | | | | | | |
| Subtask 1.1 | Analysis & Detector | ■ | ■ | | | | | | | | | | |
| Subtask 1.2 | Adsorption/Desorption | ■ | ■ | | | | | | | | | | |
| Subtask 1.3 | Thermal Stability | ■ | ■ | | | | | | | | | | |
| Subtask 1.4 | Tracer Performance Test | ■ | ■ | ■ | | | | | | | | | |
| **Task 2** | Theoretical Models | ■ | ■ | ■ | | | | | | | | | |
| **Task 3** | Smart Tracer Development | | | ■ | ■ | ■ | ■ | | | | | | |
| Subtask 3.1 | Thermal Stability Studies | | | ■ | ■ | | | | | | | | |
| Subtask 3.2 | Adsorption/Desorption Rate Determination | | | | ■ | ■ | ■ | | | | | | |
| **Task 4** | Field Trial Validation | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| **Task 5** | Tracer Interpretation System | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| **Task 6** | Report | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Milestone 1: Completion of methodology developments and data collections | | | | | | | | | | | | | |
| Milestone 2: Identification of several sets of tracer candidates and data collection from Long-slim tube experiments | | | | | | | | | | | | | |
| Milestone 3: Completion of field test and development of multidimensional tracer interpretation system | | | | | | | | | | | | | |

# FY10 Planned Milestones and Go/No-Go



- FY10: 1st to 3rd Quarters of the project; currently, 1st quarter completed
- Milestone 1: Completion of methodology developments and data collections (Tasks 1 and 2)
- Go/No-Go Decisions:
  - to achieve all required tracer detection sensitivities → GO
  - to establish protocol for adsorption/desorption measurement with at least semi-qualitative comparability to flow conditions →GO
  - to demonstrate the feasibility of identifying tracer candidates meeting the thermal stability requirement →GO
  - to demonstrate the laboratory evaluation approach of tracer performance as a gate for field trial → GO
  - to establish theoretical models which are calibrated by experiments and provide fast-screen guidance and criterions for new tracer designs → GO

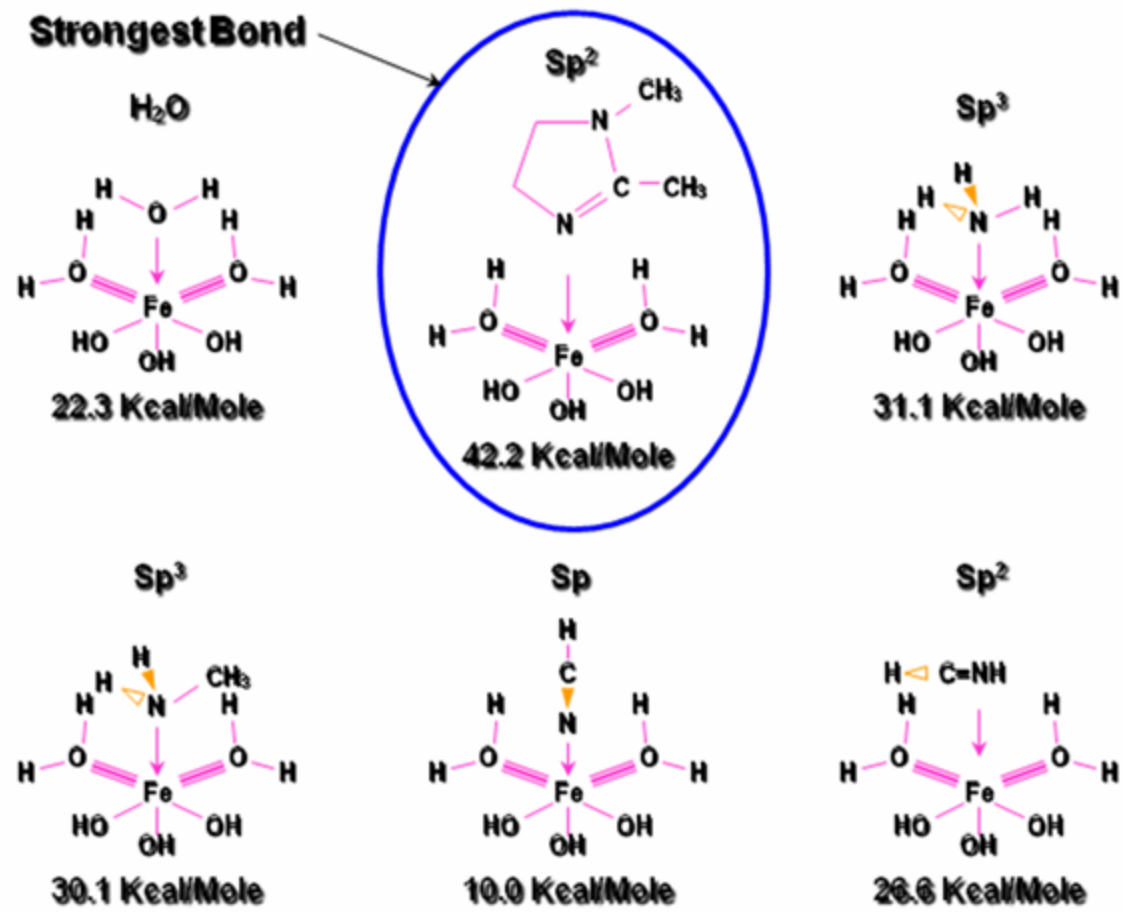
# Accomplishments, Expected Outcomes and Progress



- Literature survey and data collection to confine candidate tracer components within the category of No or Less significant impacts to environment
- Ultrasensitive tracer detection and analysis instruments set-up: GC with FID, TCD NPD and MECD detectors and pre-concentration accessories.
- Preliminary theoretical modeling on some N-heterocyclic derivatives: tunnable adsorption/desorption characteristics

# Accomplishments, Expected Outcomes and Progress






**Preliminary calculations of binding energies of different N-heterocycles on solid surfaces**

# Project Management/Coordination



- For overview projects:
  - Summarize project management plans
  - Schedule
  - Application of resources and leveraged funds/budget/spend plan

| Period | DOE | | | COST SHARE | | TOTAL | |
|---|---|---|---|---|---|---|---|
| | Phase | Plan | Actual | Plan | Actual | Plan | Actual |
| 10-Jan | 1 | $35,183 | $29,844 | $7,500 | $7,461 | $42,683 | $37,305 |
| 10-Feb | 1 | $35,183 | $29,844 | $7,500 | $7,461 | $42,683 | $37,305 |
| 10-Mar | 1 | $35,183 | $29,844 | $7,500 | $7,461 | $42,683 | $37,305 |

**Currently working on Phase I, tasks 1 and 2 to preliminary screen from data collection, analysis, modeling and report writing.**

# Future Directions



- Focuses for the next step
  - Tracer candidate category identification based on potential environmental impacts → No or less significant impacts to environment for NEPA evaluation
  - Tracer detection and analysis tool and protocol establishment → Required sensitivities
  - Preliminary molecular modeling to establish fundamental views of interactions of tracer and selective rock surface, tracer transport mechanism and kinetics.

# Summary



- Ultimate Project Goal: develop a matrix of the smart tracer and its interpretation tools for geothermal inter-well diagnostics
- Innovated and efficient scientific and technical approach with well-planned task schedule
- Well assembled and coordinated team with needed relevant expertise/experiences
- Currently at the initial stage of the project with expected progresses following the project schedule.
- Future directions of project appropriately and clearly identified