Enhanced Geothermal Systems

The U.S. Department of Energy's (DOE) Geothermal Technologies Program (GTP) research, development, and demonstration (RD&D) activities are carried out in partnership with industry, academia, and national laboratories to improve technologies for finding, characterizing, accessing, and producing geothermal resources. The Enhanced Geothermal Systems (EGS) subprogram pursues RD&D projects to improve performance, reduce cost, and facilitate technology validation and deployment. EGS RD&D projects will move industry along the learning curve toward technological readiness.

EGS Technologies Metrics and Milestones Roadmapping Information Exchange

In an effort to facilitate development of and overcome the challenges associated with EGS, GTP invited subject matter experts to take part in *EGS Technology Roadmapping Information Exchange* held in San Francisco, CA, August 3-4, 2011.

The meeting focused on translating high-priority technology needs into targeted technology improvements. The meeting broke into three subgroups to discuss technology needs specific to:

- Reservoir characterization,
- Reservoir creation, and
- Reservoir sustainability/operation.

Action

At this time GTP would like your input on the technology improvement areas identified at the meeting. Input from a diverse group of experts is paramount in developing a robust technology roadmap. Some questions to consider:

- Do you think there are other new or innovative technologies that were missed as part of this evaluation?
- Are there additional technology improvement areas that should be included?
- Do you have any comments on the timelines or metrics used to evaluate these technologies?

We would greatly appreciate your insight in order to further refine the final roadmap.

Comments

Please feel free to attach your comments to this document or email them to the address below for consideration before February 29, 2012.

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EGS Reservoir Sustainability/Operations

Photo: Jennifer Boyer.

Reservoir Sustainability/Operations Technology Improvement Areas Identified at the August 2011 Meeting

1) **Develop techniques to maintain acceptable flow rates**
   a) Improve Zonal Isolation Tools
   b) Improve Pumping Technology
   c) Control Scaling
2) **Develop new monitoring tools and sensors**
   a) Nano-Sensors and/or Smart Tracers
   b) Develop Fiber Optic Sensors
   c) Continue to Develop Conventional Wireline Tools
3) **Develop techniques to maintain geothermal reservoir**
   a) Fracture Permeability Evolution
   b) Chemical Injection
   c) Improve Fracture Fluid Flow Imaging
   d) Permanent Instrumentation Monitoring Production and Injection Wells
   e) Permanent Zonal Isolation Technologies
   f) Improve Ultra-Slimhole Costs
   g) Improve Broadband Seismic Sensors
   h) Improve MEQ Analysis
4) **Develop new reservoir modeling capabilities**
   a) Induced Seismicity Models
   b) Geomechanical/Fracture Models
   c) Geochemical Models (Equations of State)
   d) Geomechanical/MEQ (T-H-M)
   e) Integration of Models into T-H-M-Q-C Model
   f) Model Comparison and Validation
   g) Field Expansion/Wellbore Modification
   h) Models to Maintain Enthalpy and/or Forecast Reservoir Expansion
   i) Stimulation to Increase/Maintain Economic Flow Rates

Maintian Geothermal Reservoir

Maintain Geothermal Reservoir, Mitigate Fluid Loss, Track Reservoir Evolution – Track Fracture Growth and Evolution

Technology Advancement	Technology Metrics			
	Metric Unit for Advancement	2011 Status	Target	When
Fracture Permeability Evolution	Continuous data to illustrate shifts in cement agents (calcium, silica) and isotopes	Data has not been continuously collected from any field yet. Unconstrained reactive transport models	Identify geochemistry and geochemical interactions along flow paths. Constrained models	>2017
Chemical Injection	Permeability maintenance or enhancement. Delivery – radial meters from wellbore	Fluids can be injected, delivery to near-wellbore; delivery into reservoir unknown	Inject and deliver fluids with precision	2017
Improve Fracture Fluid Flow Imaging	Improve data resolution and interpretation techniques	Technology exists, but need to apply in with improved interpretation techniques	Improved coupling and correlation with other data sets	?
Permanent Instrumentation and Monitoring of Production and Injection Wells	Increase continuous operating temperatures, decrease diameter of tools	Tools exist for deployment at 80 °C, but are not small enough	Tools of 1-1.5" diameter that can operate continuously at high temperatures (above 250 °C)	2015
Permanent Zonal Isolation Techniques	Stop a short circuit pathway or reduce permeability to restore enthalpy, or permeability reduction to reservoir average = permeability K of material. Multi-year survivability at operation pressures	Proprietary info on field tests, public info on laboratory results only, and permeability of high K zones	Reduce short circuit zones to formation average K	Long-term (2020)
Improve Ultra-slimhole Costs	Cost per well ($)	100K for a 1" diameter, 2,000' depth slimhole with casing in crystalline rock	$100K for a 1"-1.25" diameter, 5,000' (75% of reservoir depth) depth slimhole with casing in crystalline rock	2015
Improve Broadband Seismic Sensors	Sensitivity, Maximum Temperature, Signal-to-Noise Ratio, Dynamic Range, Size, and Spatial Resolution (accuracy)	1 Hz – 100s of Hz @ 200 °C	0.1 Hz to kHz @ 250 °C, 20 Nano-G's per square root of Hz, -1 magnitude sensing, 1 m fracture actuation @ 1 bar stress drop, signal to noise ratio of 60 dB, 24 bit dynamic range, 1" OD size, +/- 10 meter accuracy	2017
Improve MEQ Analysis	?	?	The link between seismic events and stress, fracture, flow and failure mechanism needs study	2015

Reservoir Modeling

T=Thermo, H=Hydrological, M=Mechanical, Q=MEQ, C=Chemical/Models (not meant to provide analysis in real-time)

Technology Advancement	Technology Metrics			
	Metric Unit for Advancement	2011 Status	Target	When
Induced Seismicity Models	Conversion of seismicity cloud to hydraulic structure, accurately predict MEQs prior to stimulation (hazard analysis).	Lack of understanding of relative importance of effects (MEQ only)	MEQ models that are coupled with T-H-M models.	?
Geomechanical/fracture Models	Conversion of model results to hydraulic structure	Reactive modeling	Predictive modeling	?
Geochemical Models (equations of state)	Having binary (H_20+NaCl/CO_2)/tertiary (H_20+NaCl+$C0_2$) equations of state over various pressure and temperature ranges	H_20-NaCl equations over limited pressures and temperatures, uniqueness issues	H_20-NaCl-CO_2 equations over continuous temperatures and pressures, especially through critical points (500 °C and 5,000 MPa)	2015+
Geomechanical/MEQ (T-H-M)	Predict ground shaking for permitting (probable seismic hazard model), Design and control and verify stimulation for K enhancement, and Monitor MEQs to find what is happening during operations	Insufficiently accurate models for permitting EA and C only, T-H-M only, Q only	Issue EA, permits based on high-fidelity models, and T-H-M-Q-C Models	2015
Integration of Models into (T-H-M-Q-C) Model	Model integration capabilities	C only, T-H-M only, Q only	T-H-M-Q-C Model	Long-term
Model Comparison and Validation	?	?	?	?
Field Expansion/Wellbore Modification	Maintenance or improvement of existing reservoir enthalpy	?	?	?
Models to maintain Enthalpy and/or forecast reservoir expansion	$$	?	?	2015
Stimulation to Increase/ Maintain Economic Flow Rate	$$ Cost to stimulate a well	?	?	?