FORGE & EGS Program Outlook

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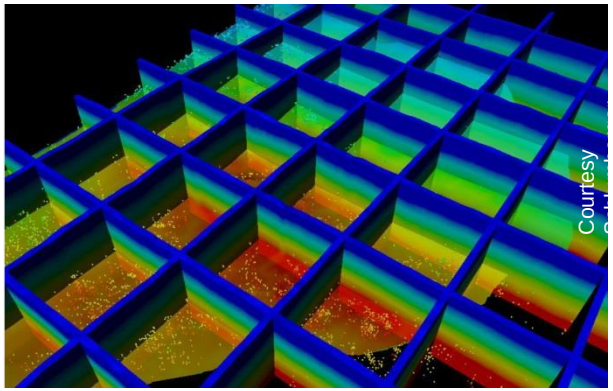

Lauren Boyd
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Geothermal Technologies Office

EGS Demonstration Portfolio

Core Area Results

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The Geysers, CA


Desert Peak, NV


Well head
Newberry, OR


Newberry, OR

Performer	Project Site	Site Information	Status	Funding
Ormat Technologies Inc.	Desert Peak, NV	Adjacent to existing hydrothermal development	***Successful stimulation completed - 1.7 MW additional capacity added***	**$ 4.3 M**
Geysers Power Company, LLC	The Geysers, CA	Reopen two existing wells to deepen for injection and stimulation in inactive part of field	***Successful stimulation completed – 5 MW equivalent created***	**$ 6.2 M**
University of Utah	Raft River, ID	Improve the performance of the existing Raft River geothermal field	***Successful Stimulation underway – injectivity increasing daily***	**$ 8.9 M**
AltaRock Energy Inc.	Newberry Volcano, OR	High potential in an area without existing geothermal development	***Successful stimulation completed – multiple zones stimulated***	**$ 21.4 M**
Ormat Technologies Inc.	Bradys Hot Springs, NV	Improve the performance of the existing Brady's geothermal field	***Initial stimulation complete & long term strategy under development***	**$ 3.4 M**

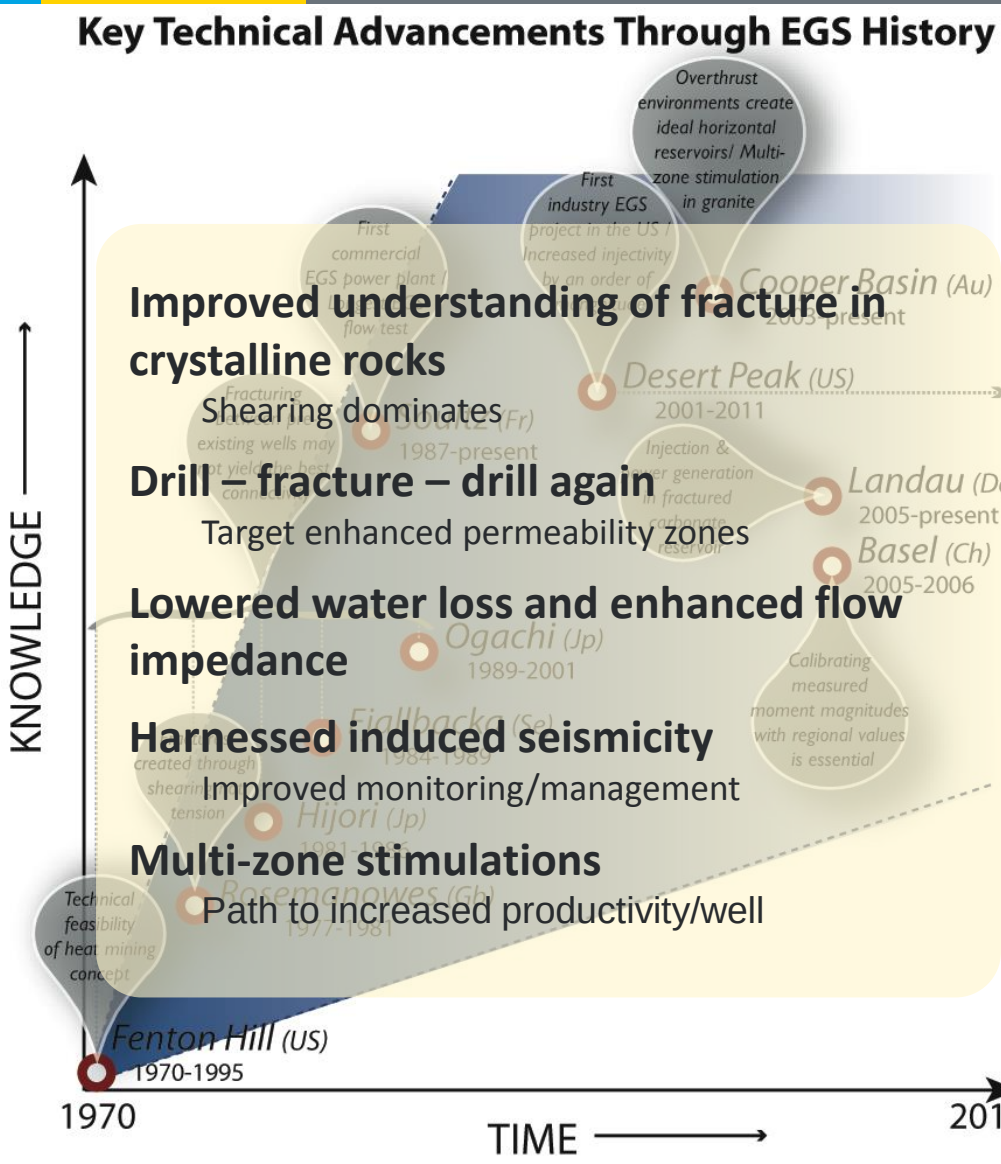
Foundational EGS Projects

Critical Needs:

- ***Characterization*** of ***local stress***, ***chemical potential***, and ***thermal pathways***
- Achieving ***sufficient productivity*** (and stimulated volume) for commercial EGS power generation

Path Forward:

- Remaining gaps are the foundation of the EGS portfolio
- Most ***technology needs*** are ***evolutionary- not revolutionary!***



Why FORGE?

Opportunity Space

- Heat is present almost ***everywhere at depth***
- Potential resource is estimated to be on the order of ***100+ GWe*** (USGS)

Federal Role:

- Test technologies/take ***technical risks*** not possible in private sector
  - ***High risk, high pay-off research and development***
- Advance ***innovation – domestic & international***
- Work under ***aggressive timeframe***

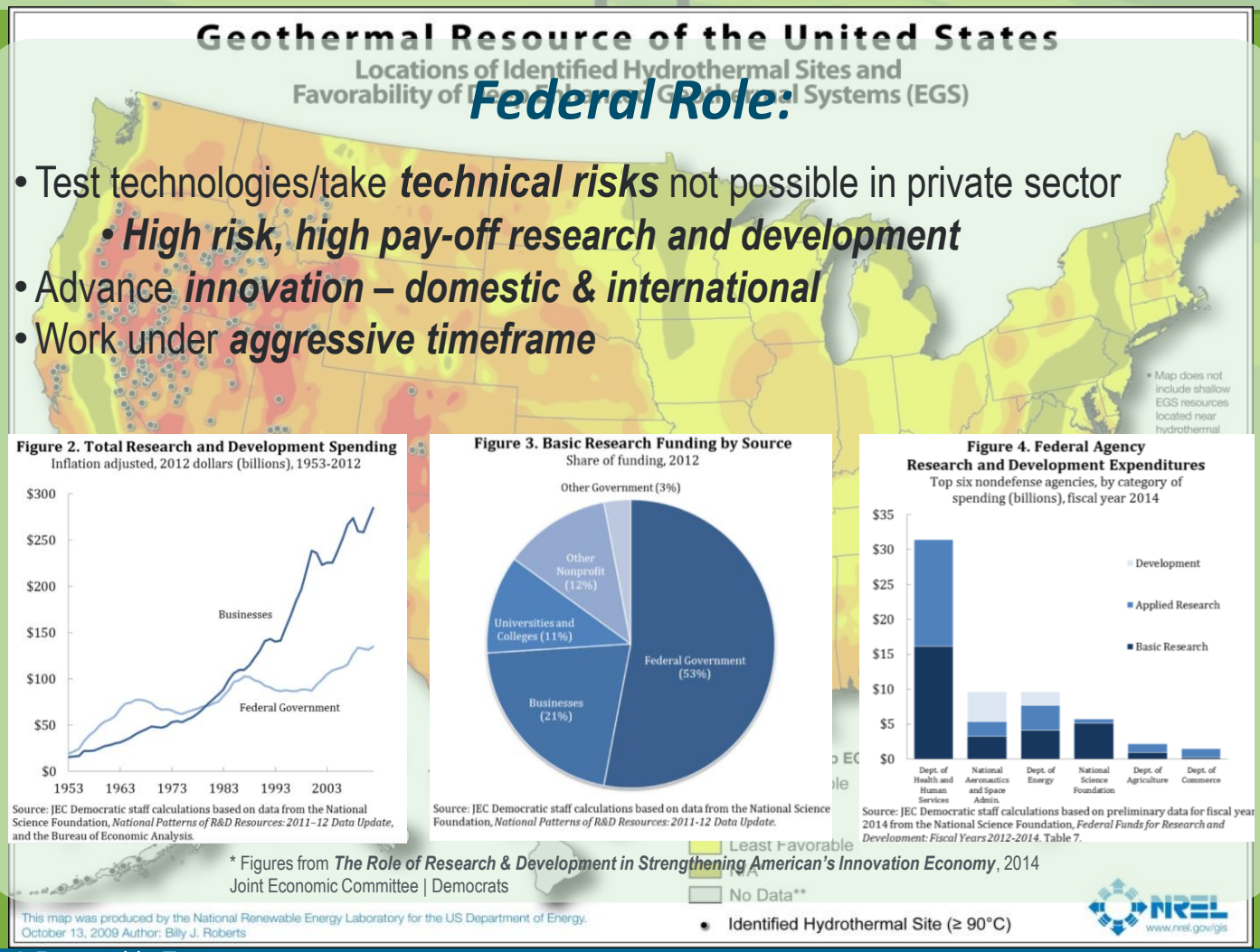


Figure 2. Total Research and Development Spending
Inflation adjusted, 2012 dollars (billions), 1953-2012

Source: JEC Democratic staff calculations based on data from the National Science Foundation, *National Patterns of R&D Resources: 2011–12 Data Update*, and the Bureau of Economic Analysis.

Figure 3. Basic Research Funding by Source
Share of funding, 2012

Source: JEC Democratic staff calculations based on data from the National Science Foundation, *National Patterns of R&D Resources: 2011-12 Data Update*.

Figure 4. Federal Agency Research and Development Expenditures
Top six nondefense agencies, by category of spending (billions), fiscal year 2014

Source: JEC Democratic staff calculations based on preliminary data for fiscal year 2014 from the National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2012-2014*. Table 7.

* Figures from ***The Role of Research & Development in Strengthening American's Innovation Economy***, 2014
Joint Economic Committee | Democrats

Critical FORGE Objectives

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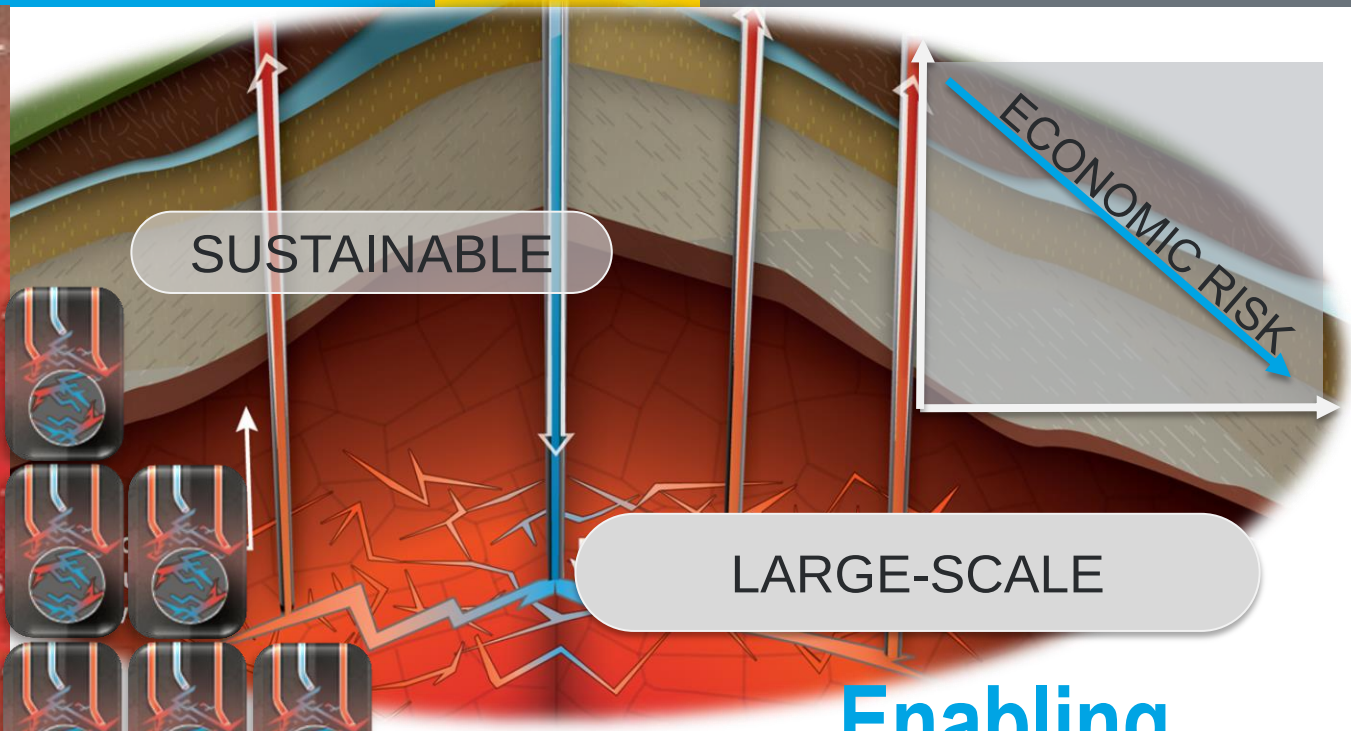
FORGE is an EGS laboratory where the subsurface scientific community can test and improve new technologies and techniques for creating and sustaining next-generation geothermal systems.

R&D COMMUNITY



Enabling
100-500
GWe

FORGE Research tenets

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Systematic – Innovative – Community-Driven

SHARE, COMMUNICATE, and EDUCATE the broader technical and non-technical community

- ❑ Gain a **fundamental understanding** of the **key mechanisms controlling EGS** success
- ❑ **Develop**, **test** and **improve** new **fundamental** and **techniques** in an ideal EGS environment.
- ❑ Make **Integrated comparison** of **technologies** and **tools** in a controlled environment
- ❑ Rapidly **disseminate technical data** and **communicate** to the research community, developers, and other interested parties.

FORGE Site Criteria

- Well characterized, with high temperatures in the target formation in the range of **175-225 ° C**
- Moderate permeability of order **10^{-16} m^2**, below the limit that typically supports natural hydrothermal systems
- Target formation between **1.5-4 km depth**, to avoid excessive costs associated with the drilling of new wells while attaining stress and temperature characteristics that are suitable to EGS and advancement of new technologies
- Must **not be within an operational hydrothermal field**
- Does **not stimulate** or **circulate fluids through overlying sedimentary units**, if applicable

Other site selection considerations included:

- **Owner/lease holder commitment** to the project
- **Environmental review** and **regulatory permitting**
- Available **infrastructure** necessary for carrying out the operation of FORGE

FOA Structure

Multi-phased Approach

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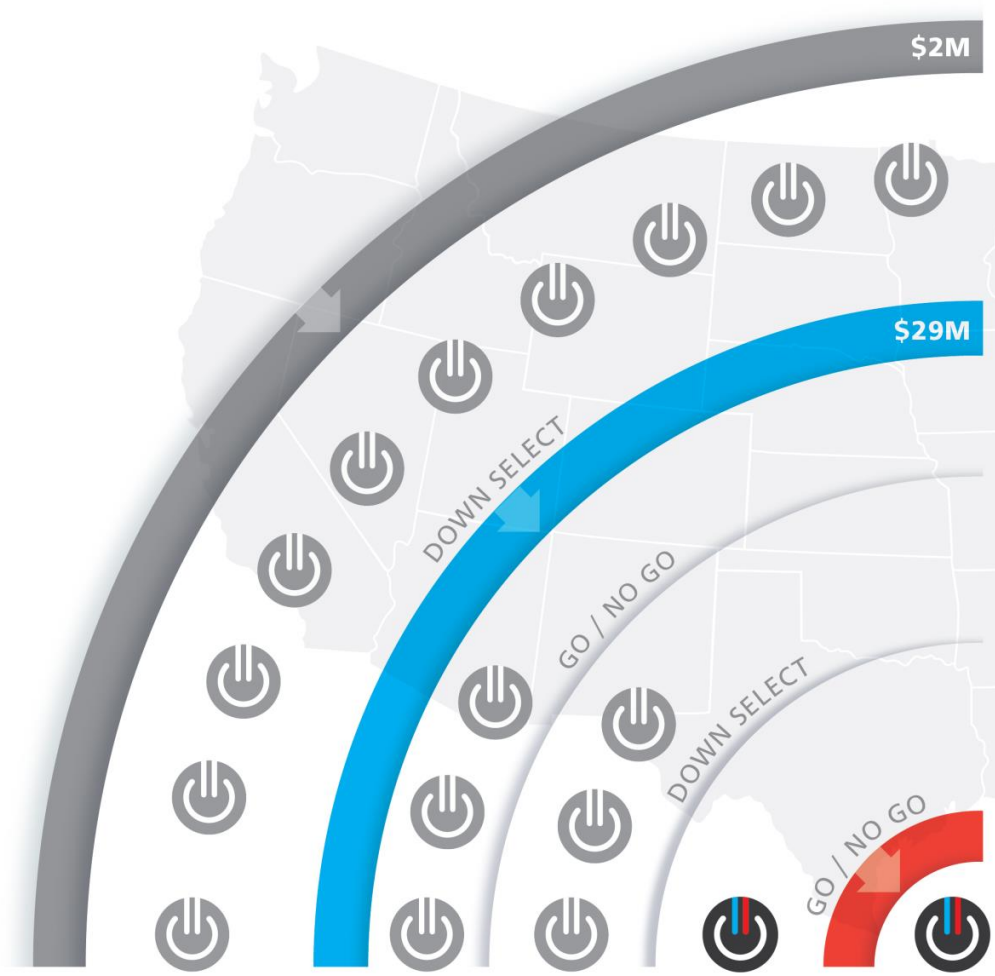

PHASE 1

SITE SELECTION

- Planning and conceptual geologic model

Negotiations with FIVE Phase 1 teams underway

PHASE 2

SET-UP & CHARACTERIZATION

2A
- Environmental Information Volume
- Preliminary seismic monitoring

2B
- NEPA
- Induced Seismicity Mitigation Plan
- Initial site characterization

2C
- Full site characterization
- Data system development
- Leadership team assemblage
- Baseline metrics
- R&D plan

PHASE 3

IMPLEMENTATION

- Drilling
- Reservoir stimulation and testing
- Site monitoring
- Competitive R&D

FORGE

Full implementation of FORGE and tasks specific to the identification, testing and evaluation of new and innovative EGS techniques and technologies

= Team = Final Site & Team

Based on annual appropriations, DOE reserves the right to fund, in whole or in part, any, all, or none of the Phase 1 applications or subsequent phases. ***The maximum number of teams are represented.***

FORGE Phase 1: Planning

Duration: 1 year
Up to 10 projects
Total Federal Funds available $2M

The Phase 1 objective is to complete mission-critical technical and logistical tasks that demonstrate site viability and the Applicant's full commitment and capability to meet envisioned FORGE objectives through Phases 2 and 3. Minimum requirements for Phase 1 include:

- Assess all available site characterization data;
- Compile site data into a conceptual geologic model of the proposed site;
- Archive site data used to support the conceptual geologic model to GTO's Existing NGDS Node, the Geothermal Data Repository (GDR)
- Finalize all teaming and cost-sharing arrangements; and
- Develop the key operational plans
- Develop Environmental Information Synopsis

End Phase 1: down select to **1-3** sites via Renewal Application

FOA Structure – Phase 2: Site Prep & Characterization

Duration: 1-2 years
1- 3 projects
Total Federal Funds available $29M

- *The objective of Phase 2 is to fully instrument the site and bring FORGE to full readiness for the testing of new technologies and techniques in Phase 3.*

- Phase 2 is split into the following three sub phases:
  - Phase 2A – Environmental Information Volume (EIV) and Preliminary Seismic Monitoring
  - Phase 2B – NEPA Compliance, Final Induced Seismicity Mitigation Plan, and Initial Site Characterization
  - Phase 2C – Subsurface Characterization and Site Readiness

FORGE Structure: Phase 2 Breakdown

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Phase 2A — 4 months – 1-3 Teams – *$2M*

- **Environmental Information Volume :** skeleton of NEPA document
- **Surface MEQ monitoring array:** At least 5 surface stations operational, with telemetry and collecting data

GO/NO-GO at conclusion of PHASE 2A

Phase 2B — 4-12 months – 1-3 Teams – *$17M*

- Implementation & completion of **National Environmental Policy Act**
- Comprehensive **site characterization & monitoring**:
  - Seismic, Geological analysis, Conceptual Modeling
  - Development of **Induced Seismicity Mitigation Plan**

DOWNSELECT at the end of Phase 2B

Phase 2C — 4-8 months – 1 Team – *$10M*

- **Full site characterization** (subsurface and invasive characterization)
- Develop and **deploy data-system** to serve live site data for project life
  - Real-time data sharing via data system
- **STAT Charter** and governance document
- First round of **R&D solicitation**
- **Baseline metrics**
- Updated **geologic model**

FORGE Structure – Phase 3: Technology Testing & Evaluation

Duration: 5 years
1 project
Total Federal Funds available subject to appropriations

- *Phase 3 involves full implementation of FORGE and tasks specific to the solicitation, selection, testing and evaluation of new and innovative EGS tools, techniques, and supporting science.*
- Requires drilling of two or more full-sized wells, reservoir stimulation, connectivity and flow testing, dynamic reservoir modeling, and continuous monitoring
- Annual R&D solicitations will be issued with 10-20 subcontracts awarded for research and technology testing per competition (subject to annual appropriations) in the following categories:
    - Reservoir characterization (coupled imaging, drilling for interrogation and monitoring, high-temperature tools and sensors)
    - Reservoir creation (formation access, fracture characterization, zonal isolation, stimulation technologies)
    - Reservoir sustainability (long-term testing, monitoring, and operational feedback)
  - All entities (including industry, universities, Federally Funded Research and Development Centers, non-profit organizations, government agencies, etc.) will be eligible to submit proposals for testing and evaluating innovative tools and techniques at FORGE.
- **At least 50% of annual Phase 3 FORGE funding** must be directed towards competitive R&D solicitations, exclusive of funds dedicated to innovative drilling and flow testing.

Selected Teams

Broad Collaboration & Data Rich Sites

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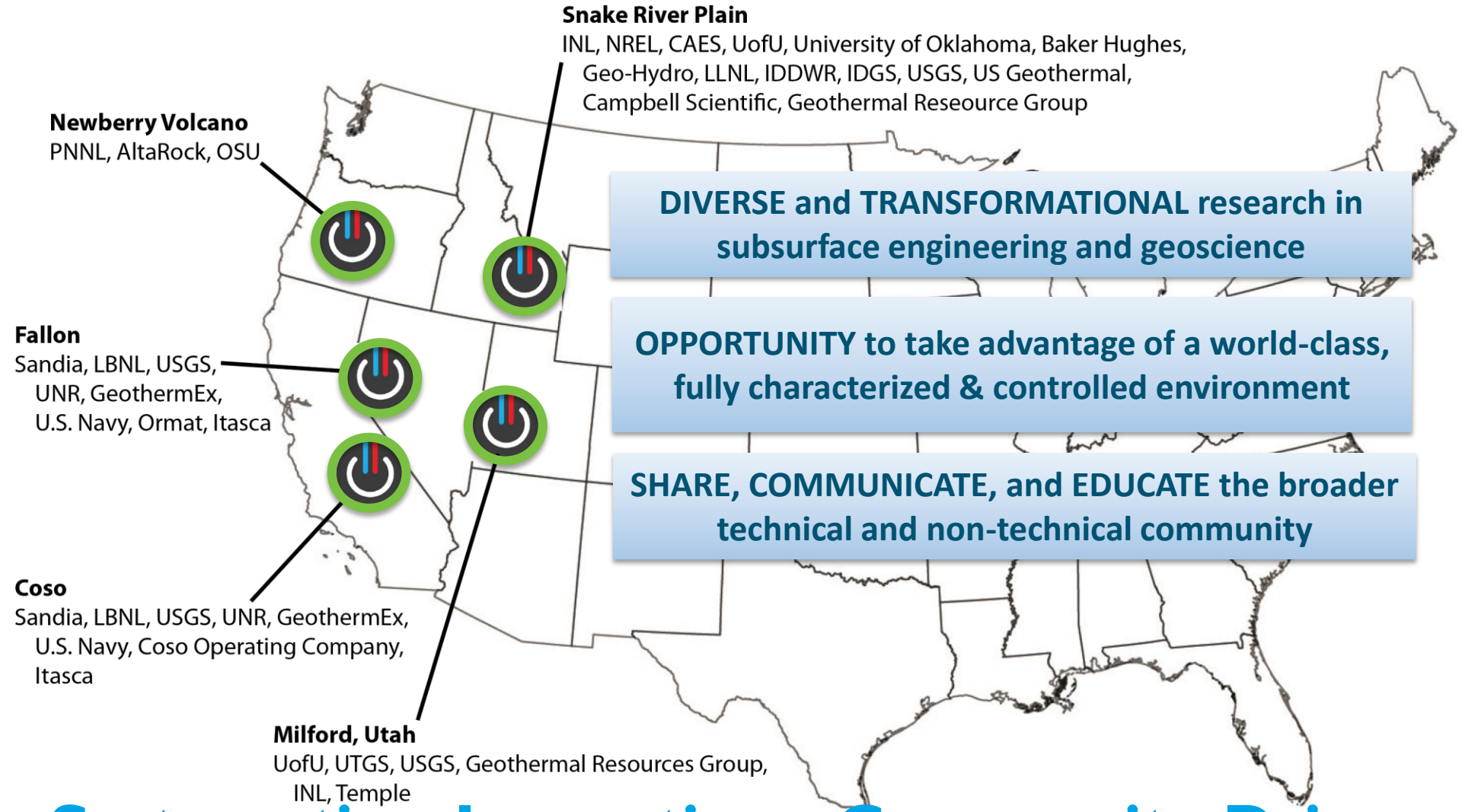

DIVERSE and TRANSFORMATIONAL research in subsurface engineering and geoscience

OPPORTUNITY to take advantage of a world-class, fully characterized & controlled environment

SHARE, COMMUNICATE, and EDUCATE the broader technical and non-technical community

Systematic – Innovative – Community-Driven

FORGE Communications - DOE

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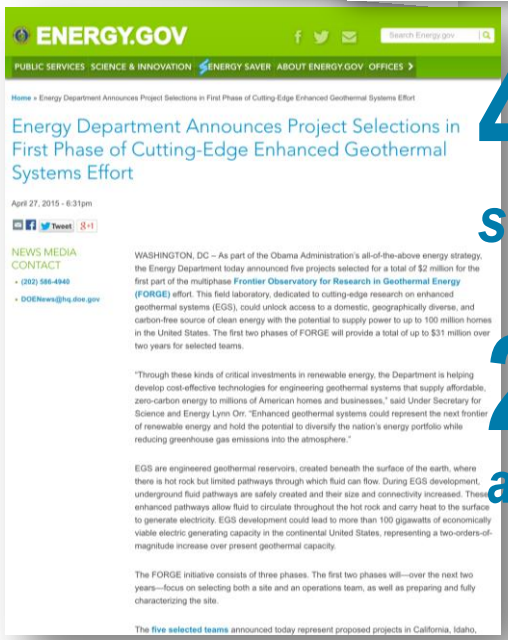
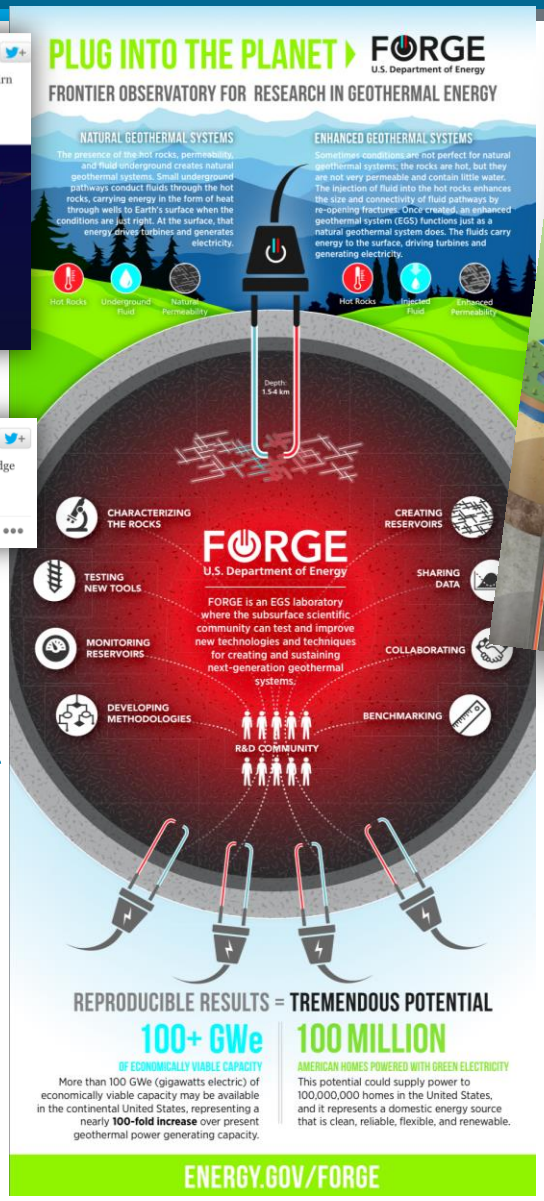
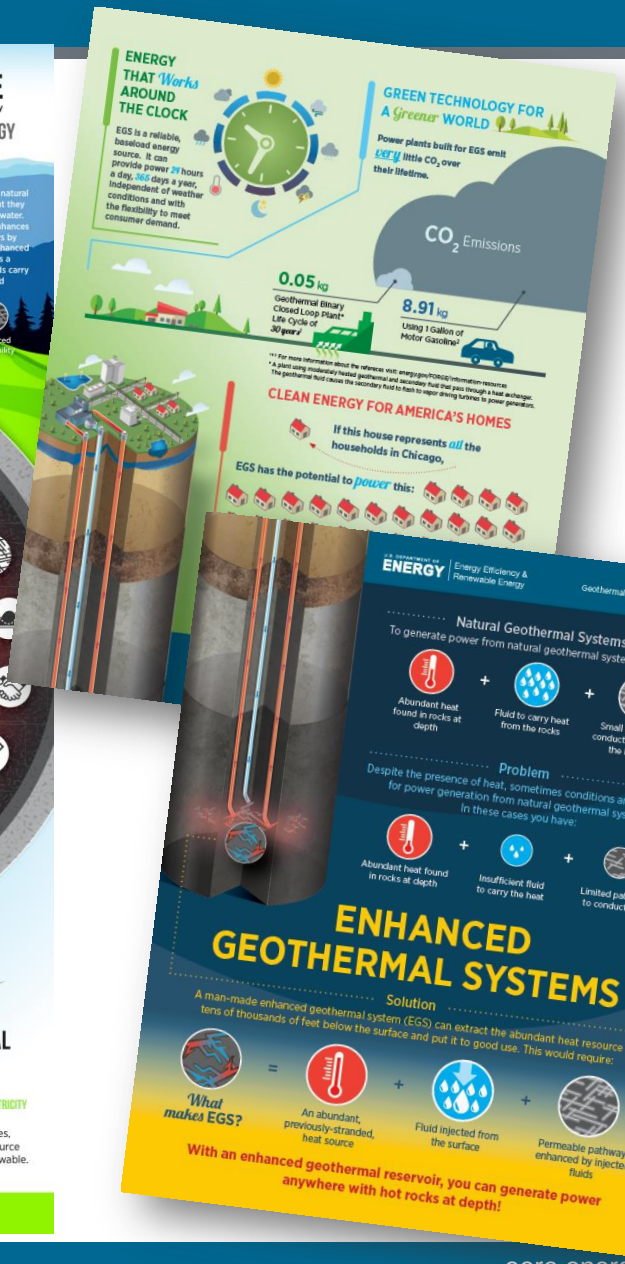


48 *AP story hits*

23 *articles*





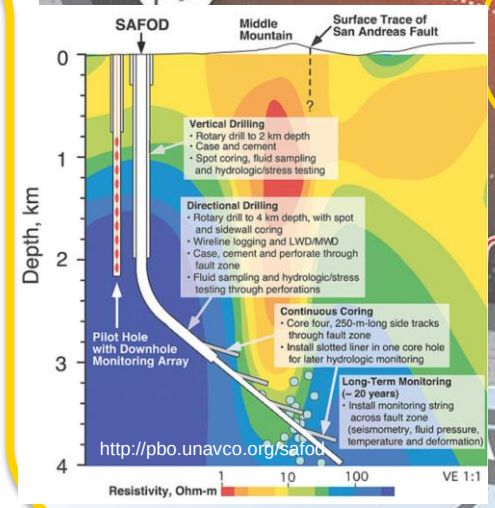
FORGE Communications - Selectees

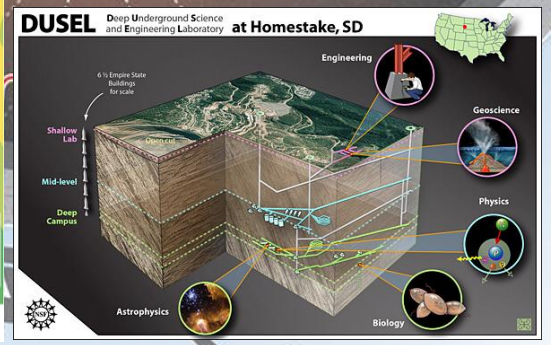
Develop a comprehensive and innovative plan for communications, education, and outreach in collaboration with DOE and stakeholders to increase geothermal science technology literacy

- Variety of communications, education, and outreach methods will be utilized
- Education and workforce development to occur through engagement of students and educators (K-12 and higher education) onsite and in the classroom regarding EGS science and technology
- Frequent public meetings to report on FORGE status to take place with local stakeholders and the broader technical community

Community

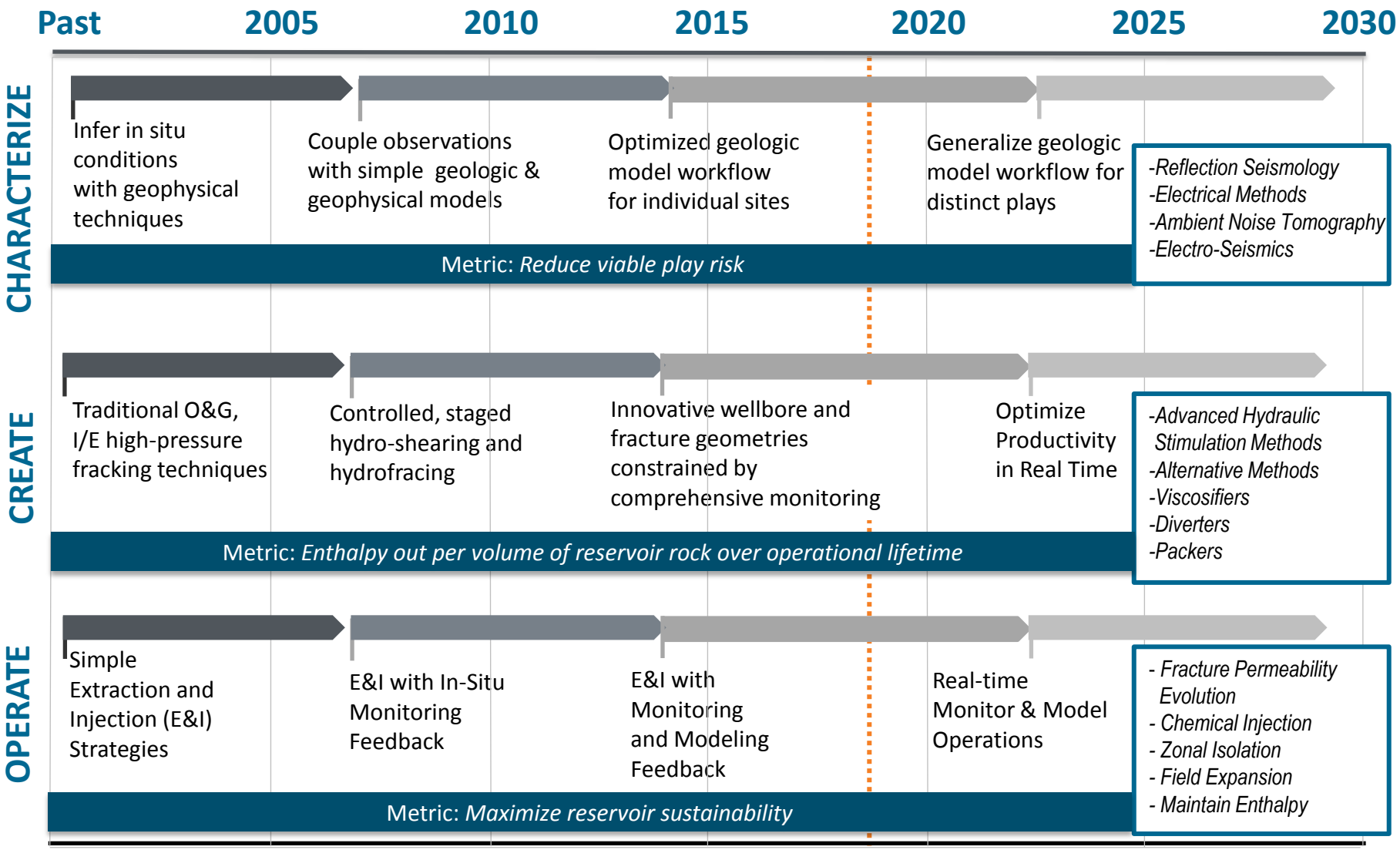
- Community engagement
  - Communications
  - Science Technology Analysis Team
  - EGS Roadmap 2.0
- Community driven transformational research
  - Deep Underground Science and Engineering Lab (DUSEL)/ Sanford Underground Research Facility (SURF)
  - NSF Plate Boundary Observatory (PBO)
  - The San Andreas Fault Observatory at Depth (SAFOD)





http://www2.lbl.gov/nsd/homestake/images/dusel_h.jpg

EGS Technology Evolution
Characterize, Create and Operate



EGS Technology Pathway Metrics

Measuring R&D Progress

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Topic	Metric	Technology Pathway	Metric	Description
Characterize	Risk Reduction	Identify Natural Fractures and Flow Paths	Spatial resolution and ability to predict a priori reservoir performance	Develop precision geophysical methods, validated play books, and improved tools for subsurface.
Create	Reservoir Performance	Create New Fractures and Flow Paths	Fractured rock volume ability to predict a priori reservoir performance	Develop techniques to maximize heat extraction from a given volume of reservoir rock with a minimum of boreholes.
Create/Operate	Reservoir Performance	Monitor Flow Paths	Enthalpy and/or fractured rock volume	Develop ability to more accurately monitor and control flow paths in the reservoir.
Create/Operate	Reservoir Performance	Zonal Isolation	Enthalpy and/or fractured rock volume	Demonstrate the ability to isolate sections of the wellbore and reservoir.
Operate	Reservoir Performance	Manage Fractures and Flow Paths	Thermal drawdown and reservoir sustainability	Develop the ability to manage EGS reservoirs improving reservoir lifetime and productivity.
All	RR and RP	Drilling	ROP/Costs	Develop next generation rock reduction, drilling and well completion technologies.
All	RR and RP	Modeling	Ability to predict a priori and manage in real time reservoir performance	Develop robust, capable, and validated models of the subsurface.
All	RR and RP	Tools	T/P limits, sensitivity and durability	Develop tools that can withstand hostile EGS environments.

FORGE Milestones (potential)

- At the start of Phase 3 demonstrate full functionality of an NGDS-compatible, data-sharing mechanism (FORGE Data System/Node) for real-time sharing of all site characterization and monitoring data.
- At the conclusion of year 1, design of first FORGE well based on in-situ stresses and informed by continuously updated reservoir models. Initiate drilling of first well in year 2.
- Issue R&D solicitations annually and ensure all awards are made and work initiated within the fiscal year of solicitation release.
- Demonstrate sustained functionality of transient reservoir interrogation tools at 200 ° C for at least 6 months or in-situ monitoring tools for at least one year.
- Demonstrate at least three innovative stimulation techniques for initiating or re-opening fractures.
- **Demonstrate the ability to enhance multiple reservoir volumes from a single wellbore and correlate to progressively-increased well performance as a function of number of stimulated zones.**
- **Demonstrate innovative precision geophysical methods that increase spatial resolution of subsurface features over state-of-the-art and validate methods with actual subsurface data or mine back.**
- Demonstrate the functionality of innovative drilling tools and components capable of operating at 200+ °C in crystalline rock, uninterrupted for 30 hours.
- Demonstrate validation of reservoir and site models based on ability to predict post-stimulation fracture initiation directions, total reservoir volume, and connectivity.
- Validate the capability of new tracers to improve flow path, volume, and fracture surface area estimates.
- **Develop sufficient flow paths between wellbores over a reservoir volume greater than 1 km3 and quantitatively constrain their capacity to sustain production with less than 2°C temperature decline over one year.**
- Demonstrate a methodology for reproducible EGS reservoir creation and sustainability.

PLUG INTO THE PLANET

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