Enhanced Geothermal Systems & Frontier Observatory for Research in Geothermal Energy (FORGE) Overview

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





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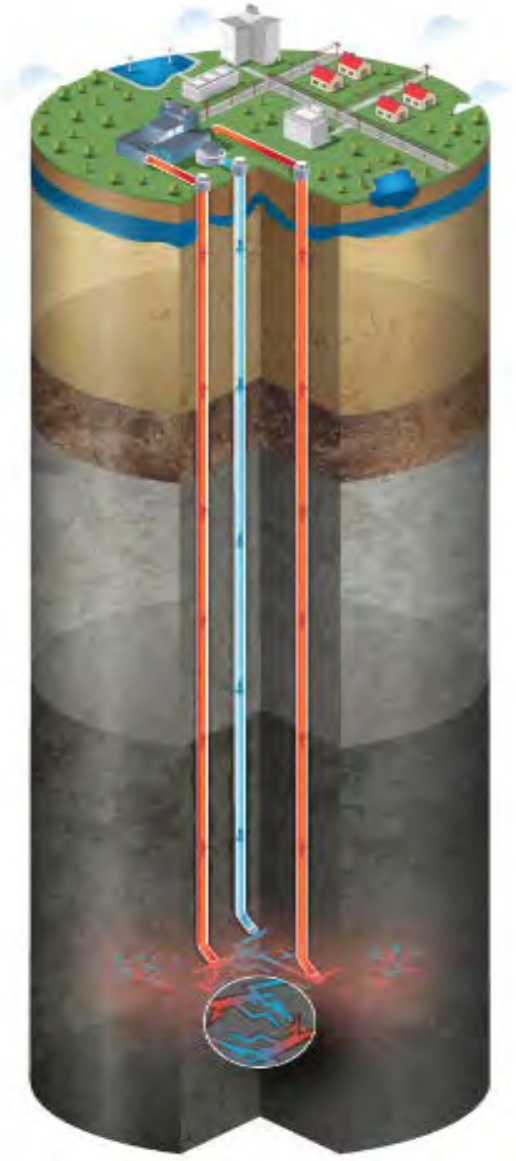
Why Does Geothermal Matter?

Geothermal…

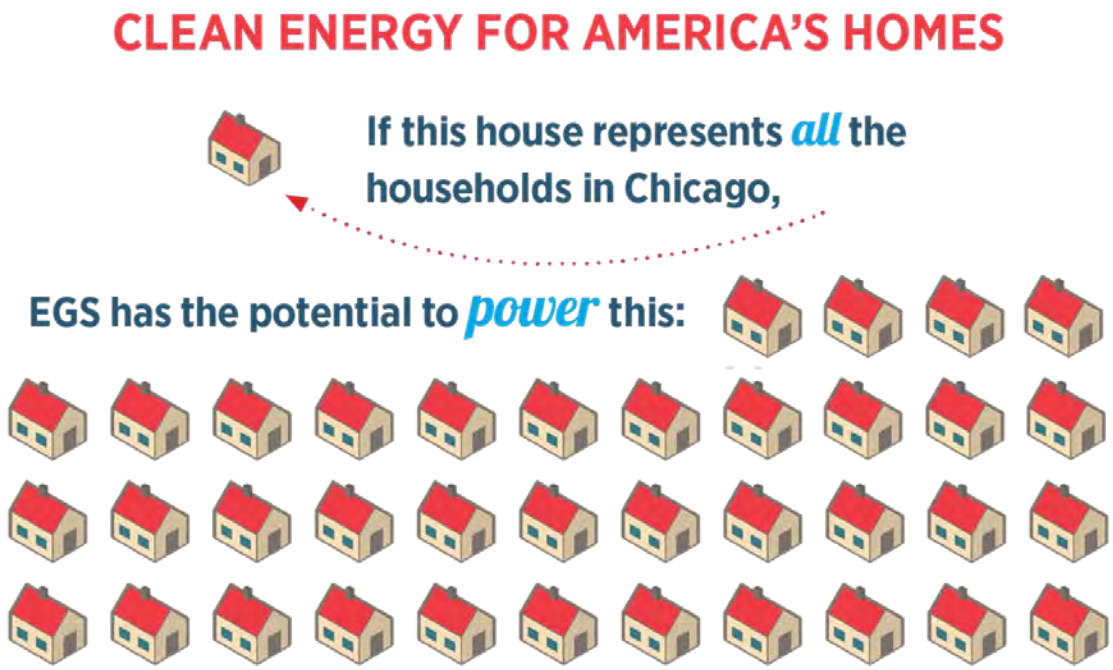
- An **always-on** energy source that harnesses the earth's natural heat
- Provides **flexible, baseload** (24-hr) power
- Creates thousands of valuable energy sector **jobs** and strengthens local economies
- Plants with 40-60 year lifespans
- Supports domestic technology innovation
- Improves domestic **energy security and** energy **independence**
- **No greenhouse gas** emissions
- EGS and deep direct use applications, combined with conventional geothermal systems, provides a widely available renewable energy source…**an "everywhere" solution**

Enhanced Geothermal Energy



EGS Technology would allow Americans to install a geothermal reservoir and produce baseload, flexible power anywhere.

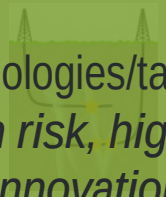
The resource potential of this is huge:



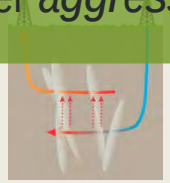
Challenges Remain

Targeted technology breakthroughs and field validation needed to demonstrate commercial replicability

Reservoir Access
New well geometries and concepts, optimized drilling



Reservoir Creation
Cost-effective, environmentally acceptable fracturing methods; increase fractured volume per well



Productivity
Increase flow rates without excessive pressure needs or flow localization

Sustainability
Maintain productivity with minimal thermal drawdown and water losses

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*

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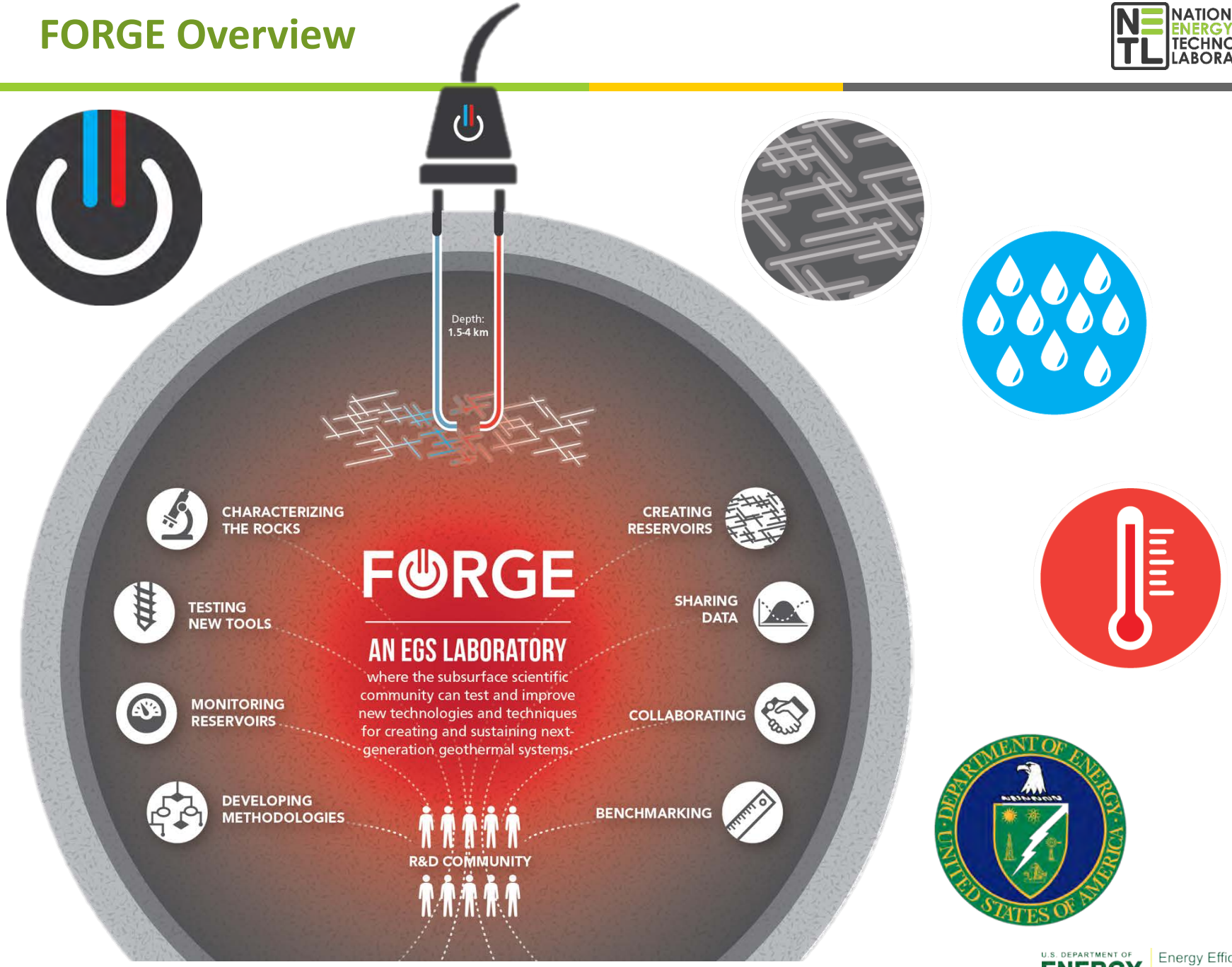
FORGE Overview



FORGE Principles

- Gain fundamental understanding of the **key mechanisms controlling Enhanced Geothermal System (EGS) success**.
- Develop, test, and improve new **technologies 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

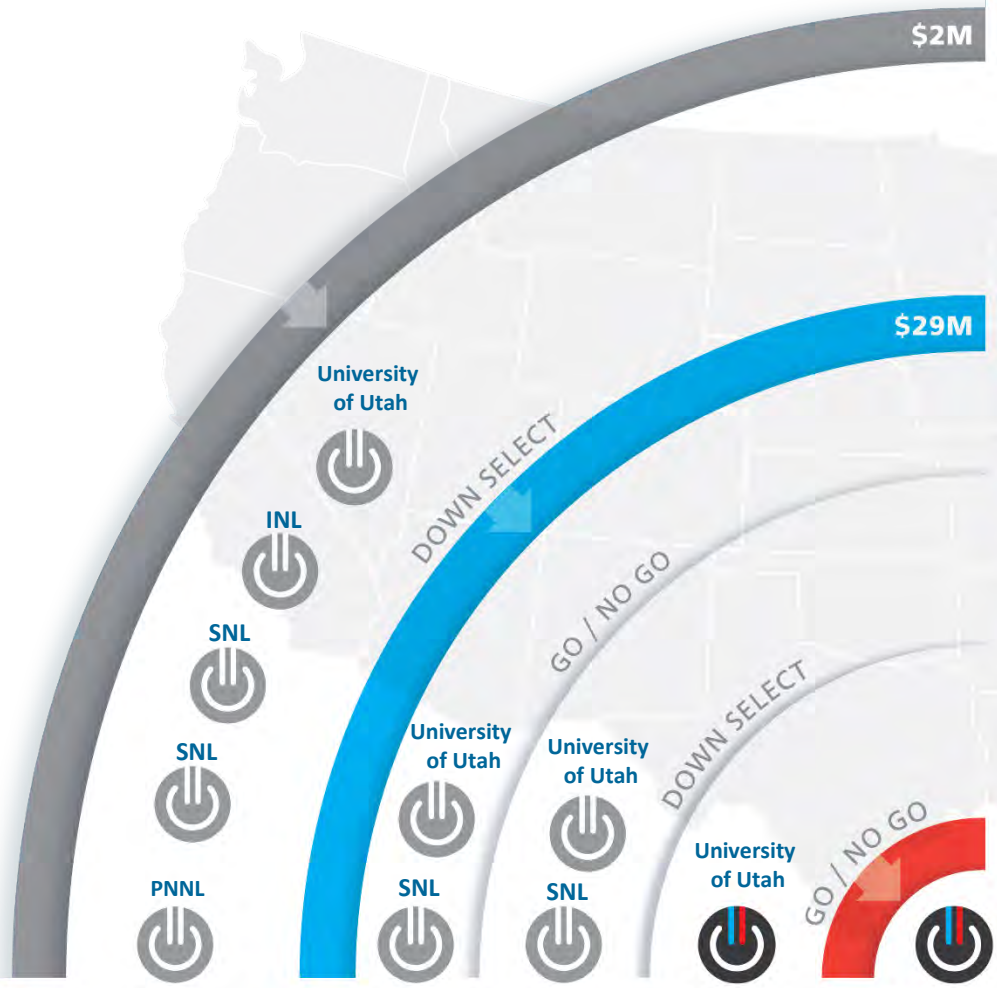
FORGE Site Criteria

- 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

FORGE Structure, Tasks, & Funding



PHASE 1
SITE SELECTION

- Planning and conceptual geologic model

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: Where We've Been

NATIONAL ENERGY TECHNOLOGY LABORATORY

Phase 2A & B

Phase 1

Phase 3

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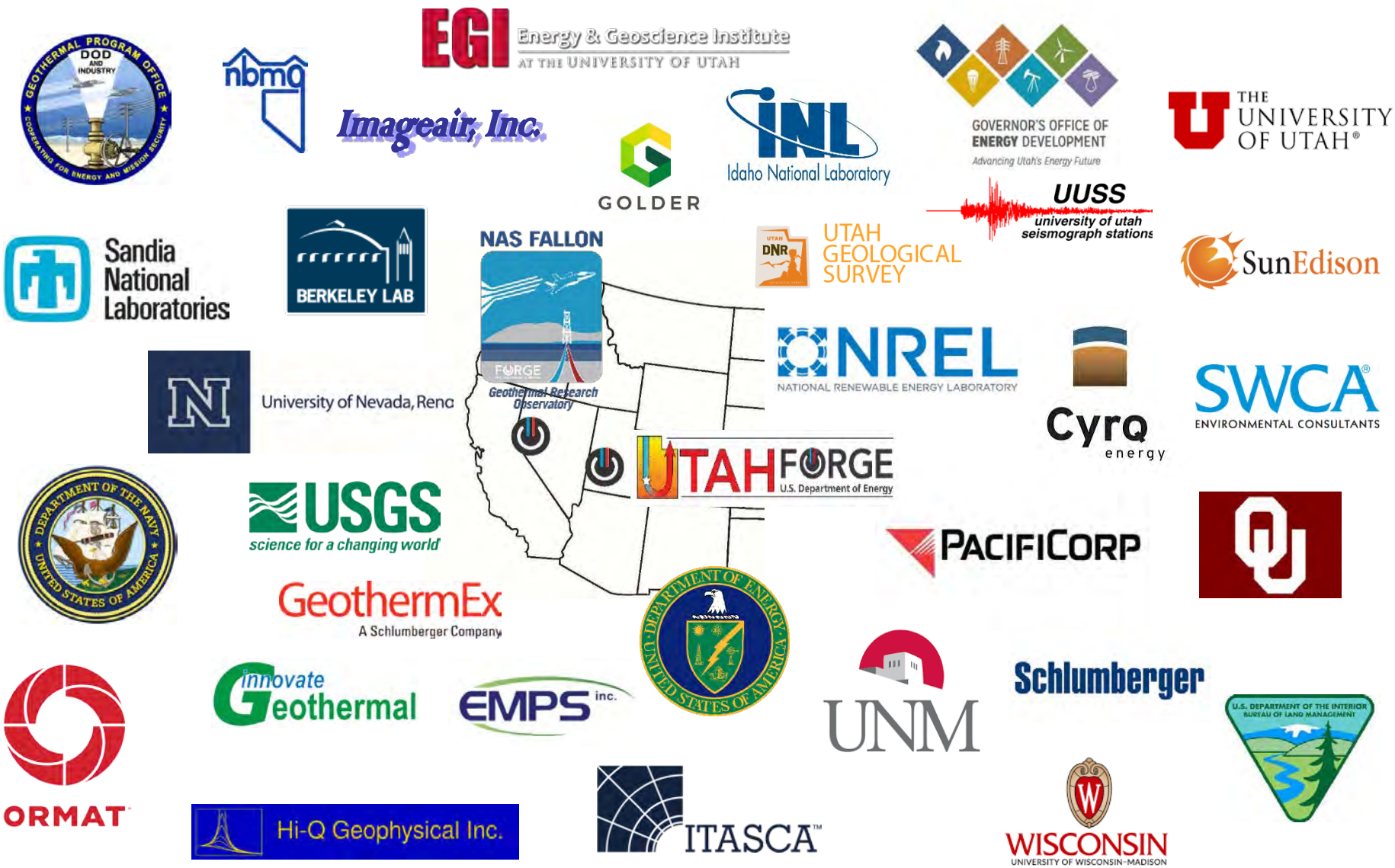
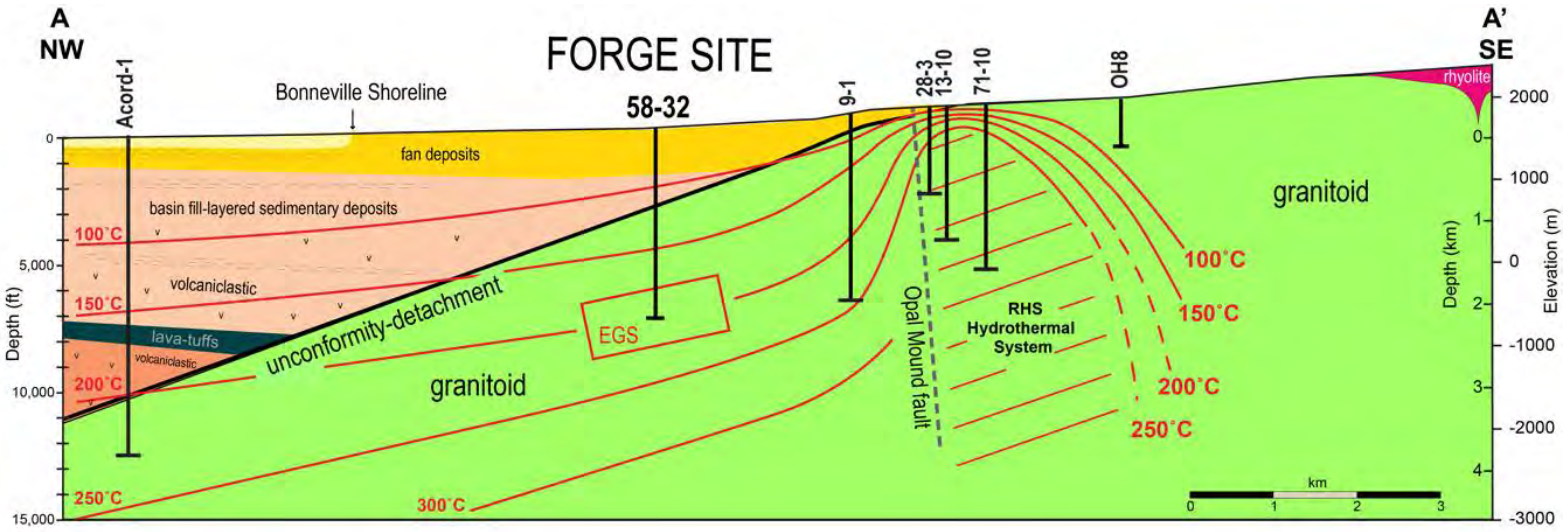
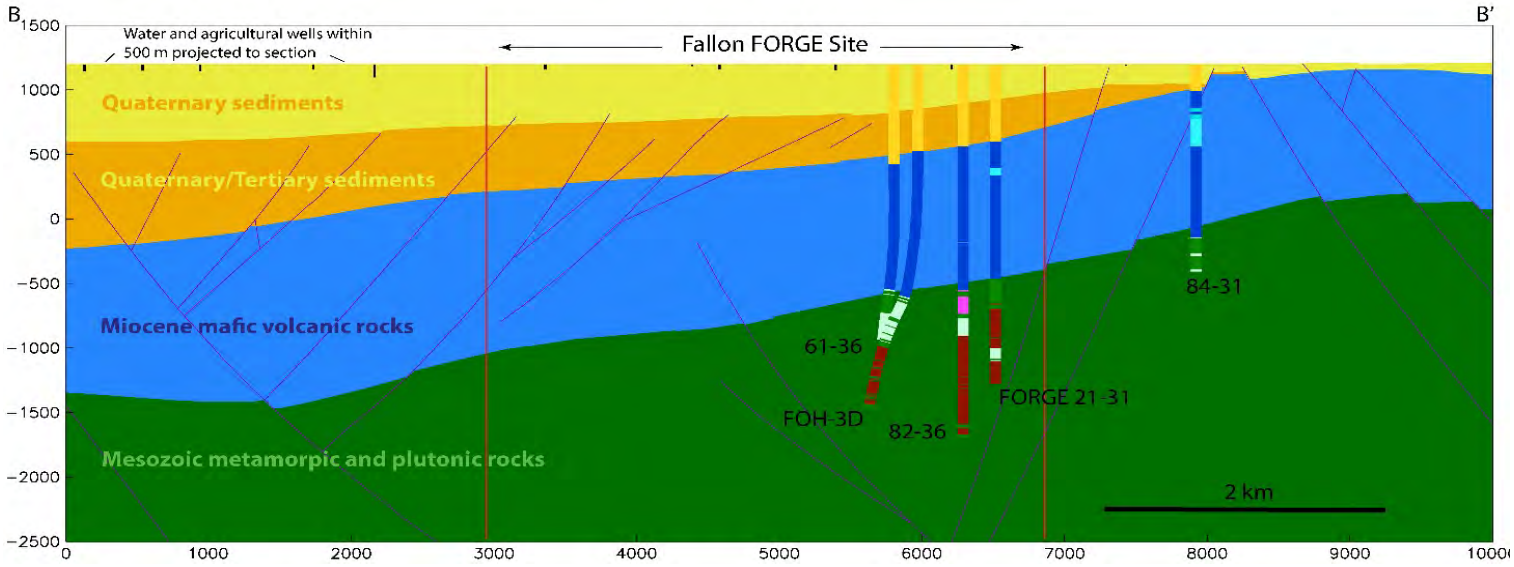
FORGE Phase 2A & B

FORGE: Groundbreaking Work

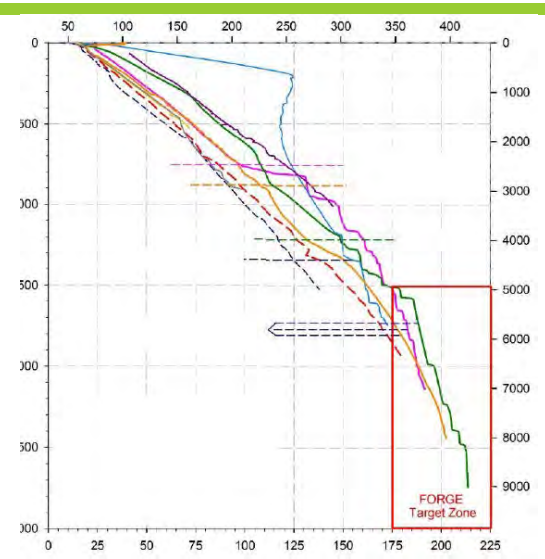


FORGE Cross Sectional Views

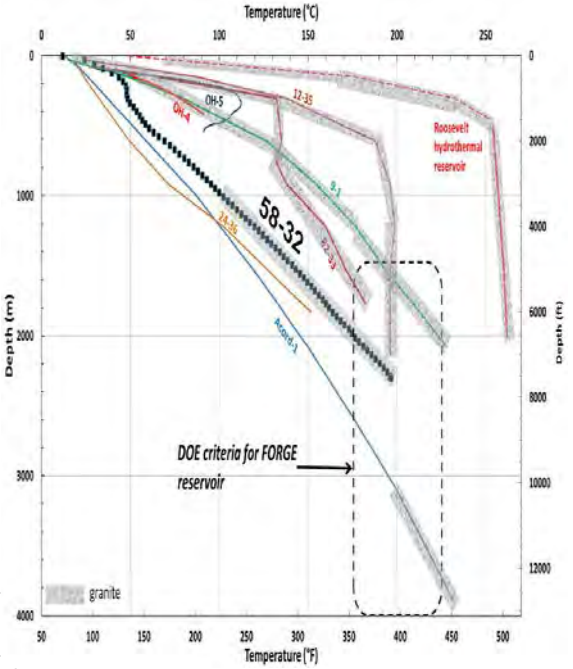


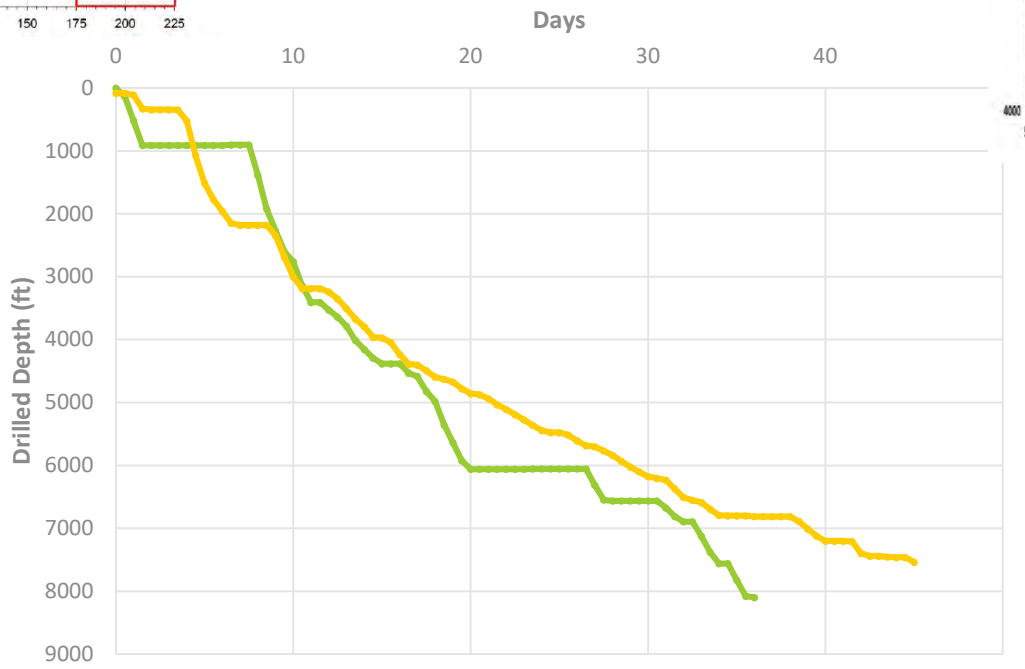


FORGE: Phase 2B Drilling Results

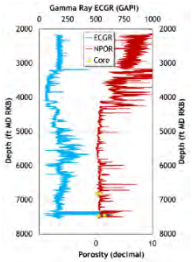


FORGE Phase 2B wells

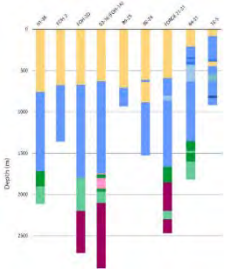


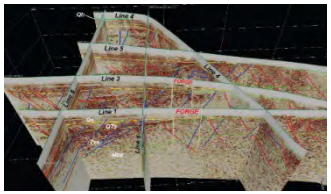


FORGE: Phase 2 Data Results

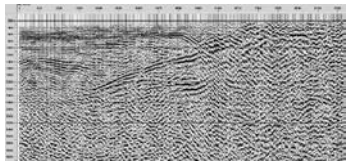


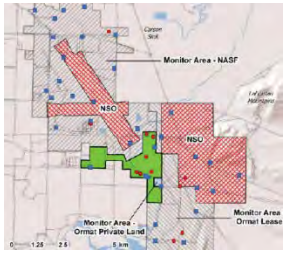
Well Data





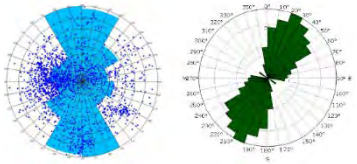
Seismic Data



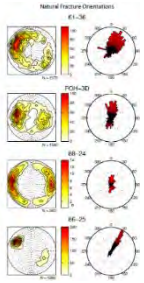


GIS Data

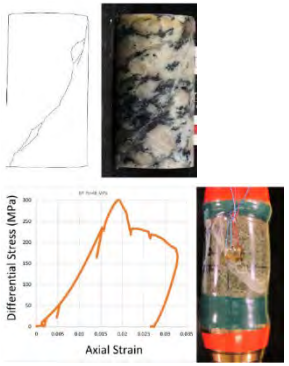
GDR



Fracture Mapping



Rock Properties

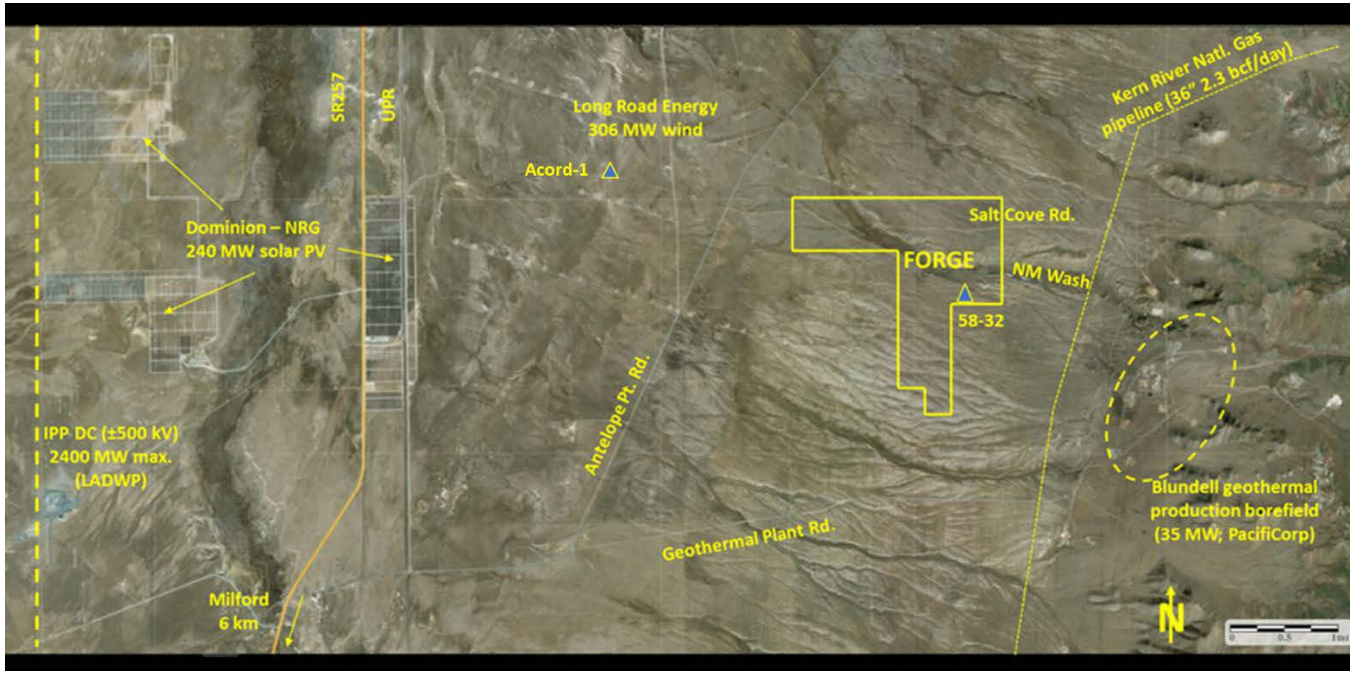


FORGE: Where We Are

Utah FORGE is a flagship 7-year initiative to design and test a breakthrough approach to developing large-scale, economically sustainable EGS reservoirs.

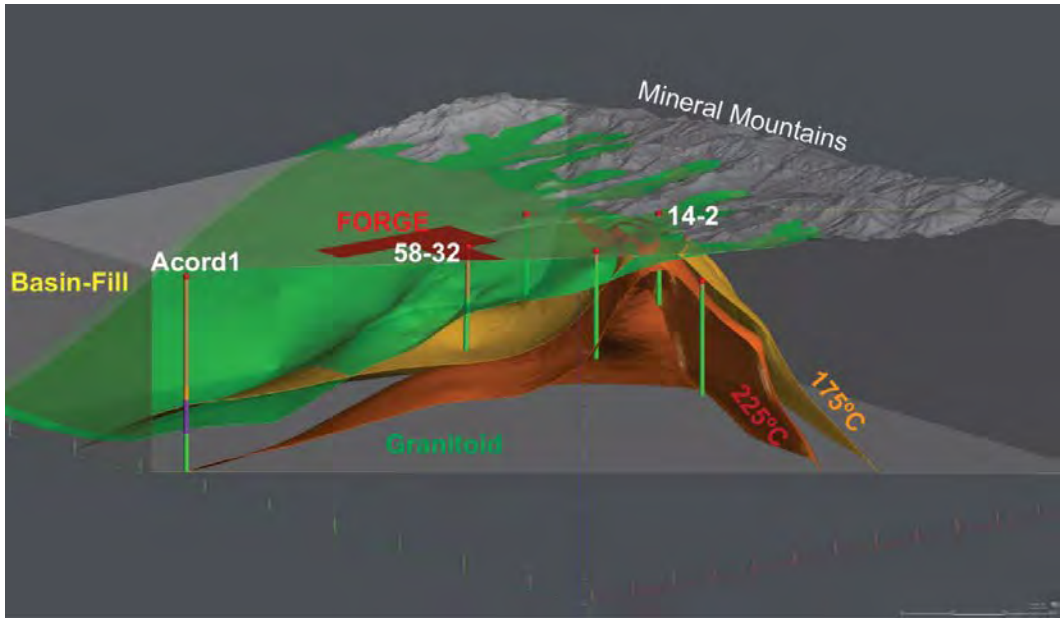
Key Attribute of the Milford, Utah FORGE

- Located on primarily on private and SITLA land close to major paved roads, graded dirt roads, an airport, and rail line with year-round accessibility
- Located 10 miles (16 km) northeast of Milford City, Utah and 217 m (350 km) south of Salt Lake City
- Area contains no state or federally protected flora, fauna, or historical sites
- Sufficient amounts of non- potable water available for all testing needs
- Long history of geothermal development beginning in the 1970's when fifteen deep exploration and development wells and over 80 gradient wells were drilled, extensively logged and sampled.



Key Attribute of the Milford, Utah FORGE

- Sufficient amounts of non- potable water available for all testing needs
- Low risk of local and regional seismicity - University of Utah seismic monitoring in place since 1981
- Granitic basement rocks are characteristic of basement rocks across much of the USA.
  - Learnings from this project have broad and relevant application to potential EGS sites across the country.
- Well 58-32 drilled to 7536 ft. (2073 m) and a maximum temperature of 386ºF (197ºC) after penetrating more than 4500 ft. of granite
  - Core was collected at 6800-6810 ft. and 7440-7452 ft. for geomechanical and permeability testing
  - A full suite of geophysical logs was run in the open hole section of the well (2172 ft. to 7375 ft.)
- The volume of the reservoir (crystalline rock between 175 – 225°C) beneath the FORGE footprint, close to 4.6 km
  - The volume of hot crystalline rock suitable for EGS development expands to nearly 100 km



FORGE Phase 2C: Site Readiness

- Complete high-resolution geophysical, geochemical, and geological data acquisition and analysis to meet critical project goals necessary for implementation of Phase 3.
- Design and deploy a permanent, high-resolution, surface and subsurface seismic monitoring system (via dedicated monitoring boreholes) to supplement initial surface array
- Refine the Phase 2B conceptual geologic site model to incorporate new characterization and monitoring data.
- Conduct dynamic reservoir modeling based on the refined geologic site model to inform drilling and stimulation design for Phase 3.
- Implement an NGDS-compatible, data-sharing mechanism (FORGE Data System/Node) for real-time sharing of all baseline site characterization and monitoring data.
- Establish a Science and Technology Analysis Team (STAT)
  - STAT will provide overall technical guidance throughout Phases 2C and 3 and ensure that DOE objectives are fully considered and incorporated into the execution of FORGE and associated R&D projects.
  - Convene initial meeting(s) of the STAT to assess the current state of technology, establish technical baseline information and performance metrics for FORGE activities and develop a Baseline Metric Report
  - Determine topics for 1st round of R&D solicitation(s) during Phase 3 and produce a draft of said solicitation ready for issuance at start of Phase 3.
- Prepare annual update to the R&D Vision and Implementation Plan to include Year 1 technology testing and evaluation and draft Year 1 R&D solicitations.

FORGE Phase 3: Technology Testing & Evaluation

- Full implementation of FORGE.
- Drilling of two or more full-sized wells, reservoir stimulation, connectivity and flow testing, dynamic reservoir modeling, and continuous monitoring.
- Annual R&D solicitations 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 may participate in R&D FOAs**.
- **At least 50% of annual Phase 3 FORGE funding** will be directed towards competitive R&D solicitations, exclusive of funds dedicated to innovative drilling and flow testing.

FORGE Roadmap Development Workshop

- Held last week, August 9 & 10, to investigate R&D actions that are important to meet the goals and mission of FORGE and that are feasible to accomplish at the FORGE site.

- The workshop was designed to provide technical input on the following:
  - R&D actions that address EGS technical challenges that are well-suited to the FORGE timeline, scope, and site geology
  - A timeline and technical milestones for FORGE's five years of operation
  - Criteria to measure technical progress

- Breakout session focused on the following FORGE roadmap topic areas:
  - Site Planning
  - Well Development
  - Reservoir Stimulation
  - Fracture Management

Questions?

https://www.egi.utah.edu/research/forge

https://energy.gov/eere/forge/forge-home

https://energy.gov/eere/geothermal/enhanced-geothermal-systems-0

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