### Types of Geothermal

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Characteristics</th>
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</table>
| **Geothermal Heat Pumps/ Ground Source Heat Pumps** | Use relatively constant temperature of the earth as heat source for commercial and residential heating and cooling | • Near ambient temperatures (40-80°F)  
• Shallow depths - trenches to wells hundreds of feet deep |
| **Direct Use Geothermal**                | Use thermal energy (heat) from the earth directly for heating/cooling buildings, greenhouses, aquaculture, pools, spas, etc. | • Moderate temperatures (100-300°F)  
• Wells hundreds to thousands of feet deep |
| **Geothermal Power (Electricity Generation)** | Use thermal energy (heat) from the earth to generate electricity | • High temperatures (>300°F) as well as low temperatures (<300°F)  
• Wells up to many thousands of feet deep  
• Baseload generation value proposition |
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
• With enhanced geothermal systems and deep direct use, becomes a widely available renewable energy source...an “everywhere” solution
EGS Technology would allow Americans to install a geothermal reservoir and produce baseload, flexible power anywhere.

The resource potential of this is huge:

**CLEAN ENERGY FOR AMERICA’S HOMES**

If this house represents *all* the households in Chicago,

EGS has the potential to *power* this:
But Technology Challenges Remain

Targeted technology breakthroughs and field validation needed to demonstrate commercial replicability

Reservoir Access
New well geometries and concepts, optimized drilling

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

Productivity
Increase flow rates without excessive pressure needs or flow localization

Sustainability
Maintain productivity with minimal thermal drawdown and water losses
FORGE Overview

AN EGS LABORATORY
where the subsurface scientific community can test and improve new technologies and techniques for creating and sustaining next-generation geothermal systems.

- CHARACTERIZING THE ROCKS
- TESTING NEW TOOLS
- MONITORING RESERVOIRS
- DEVELOPING METHODOLOGIES
- CREATING RESERVOIRS
- SHARING DATA
- COLLABORATING
- BENCHMARKING
- R&D COMMUNITY
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 **$10^{-16}$ m²**, 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

$2M$ $29M$ $~12$ months $~4$ mo. $~4-12$ mo. $~4-8$ mo. $~60$ months

University of Utah
INL
SNL
PNNL

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

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

Phase 1

Phase 2

Phase 3

AWARDED TO

AWARDED TO

Newberry GEOTHERMAL ENERGY
SRG
China Lake WEST FLANK
NAWSI
Utah FORGE
NAS FALLON

Geothermal Research Observatory
Geothermal Research Observatory
Geothermal Research Observatory
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:
  o Reservoir characterization (coupled imaging, drilling for interrogation and monitoring, high-temperature tools and sensors)
  o Reservoir creation (formation access, fracture characterization, zonal isolation, stimulation technologies)
  o Reservoir sustainability (long-term testing, monitoring, and operational feedback)

• **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.
The EGS Collab will aid in the acceleration of near-term FORGE R&D activities and testing via research conducted at readily accessible underground facilities at intermediate (on the order of 10 m) scales.

This National Lab collaboration will refine our understanding of rock mass response to stimulation and provide a test bed for the validation of thermal-hydrological-mechanical-chemical (THMC) modeling approaches as well as novel monitoring tools.
Geothermal Resource of the United States
Locations of Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems (EGS)

The map above illustrates the geothermal resource potential across the United States. It identifies areas with identified hydrothermal sites and categorizes the favorability of deep enhanced geothermal systems (EGS) based on temperature and resource availability. The color coding ranges from 'Most Favorable' (red) to 'Least Favorable' (blue), with 'N/A' and 'No Data' indicating areas without sufficient data.

Key points:
- Map does not include shallow EGS resources located near hydrothermal sites or USGS assessment of undiscovered hydrothermal resources.
- Source data for deep EGS includes temperature at depth from 3 to 10 km provided by Southern Methodist University Geothermal Laboratory (Blackwell & Richards, 2009) and analyses for regions with temperatures ≥150°C performed by NREL (2009).
- Source data for identified hydrothermal sites from USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (2009).
- "N/A" regions have temperatures less than 150°C at 10 km depth and were not assessed for deep EGS potential.
- Temperature at depth data for deep EGS in Alaska and Hawaii not available.
EGS Information

https://energy.gov/eere/geothermal/geothermal-energy-us-department-energy

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

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

https://energy.gov/eere/forge/sandia-national-laboratories-fallon

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

https://energy.gov/eere/geothermal/egs-collab

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