FastCAP: GTO’s $2.2 million investment has yielded development and commercialization of a cutting-edge power system for geothermal exploration in high vibration, extreme drilling environments. courtesy FastCAP

Oregon Institute of Technology: Commissioned 1.5 MW of newly-installed geothermal power on campus, from a $1 million GTO award with $4 million match by Johnson Controls.

Pagosa Verde: GTO’s $3.9 million geothermal exploration project in Colorado was matched by a $1.98 million state bond, with a bill signed by Colorado Governor Hickenlooper in May 2014.

Stillwater Hybrid Geothermal-Solar: First-in-the-world hybrid geothermal-solar facility in Fallon, Nevada produces 33 MW geothermal and 26 MW photo voltaic. An additional 2 MW Concentrated Solar Power project is under construction. With Idaho National Lab and National Renewable Energy Lab, GTO entered into agreement with Enel Green Power to explore potential and quantify the benefits of integrating geo energy with solar. photo (left) courtesy of Enel Green Power North America

Surprise Valley Electrification Corp: a non-profit rural cooperative, plans to go online with a low-temperature, 3 MW geothermal power plant in the near future, funded with $2 million in GTO Recovery Act funds, matched by a $3M Oregon Department of Energy Business tax credit. Waste heat from the plant will be used for aquaculture, green house farming, and district heating.

* Expected
The Energy Department addresses geothermal challenges at every stage of development with a full complement of projects to accelerate the adoption of geothermal energy:

- Better targeted drilling
- Improved understanding of the subsurface
- Innovate new tools and techniques that improve the value equation
- Lower upfront costs
Mitigate the risks of geothermal exploration

- National Geothermal Data System
- Play Fairway Analysis
- New Subsurface Signals
- Geochemical/Geo-physical Tools
- Exploration Decision Tree
Deployed this best in class public tool for geothermal data collection and usability

- Addresses the lack of quantifiable data – a significant obstacle to geothermal development
- At deployment, nine million inter-operable GIS data points in 340 separate web feature and map services were available
- Supports the Energy Department’s efforts to reduce cost and risks associated with widespread adoption of geothermal energy
- All DOE-funded research and demonstration data is represented in the DOE Geothermal Data Repository, a node on the NGDS
- Award winning effort – 2014 Geothermal Energy Association Honors recognition
Play Fairway Analysis (PFA)

Before disturbing the ground, PFA reduces uncertainty and grades levels of prospectivity

- Identifies locations that have the highest probability of success
- Integrates known and conceptual data
- Determines potential plays
- Maps probabilities
- Focuses initially on unexplored and underexplored known geothermal regions
- Innovates analysis methods using public and private data
Projects can meet with success, or they can fail. Knowing how handle projects that remain at risk is vital to the economic production of geothermal energy.
The Exploration Funnel *(borrowed from Oil & Gas)*

- 100 Hot Spots
- 60 Plays
- 25 Prospects
- 11 Viable Projects
- One Economic Project
Stage Two: Resource Confirmation

Validate and confirm the resource with:

- Innovative exploration drilling
- Microdrilling
- Novel downhole tools
- Flowtesting
Validating prospective blind resources

- On-site active drilling projects
- Reduces risk through improvements in geothermal exploration
- USGS estimates 30 GW potential in blind hydrothermal systems in America
- Rigorous public-private collaboration
- Promotes economic viability of geothermal exploration technologies
- Identifies potential surface signals that can reveal deeper, hidden systems
- Play Fairway Validation Initiative
Reservoir engineering & optimization

- EGS R&D
- FORGE Laboratory
- EGS

Stage Three: Wellfield Development

Characterizing and Predicting
Resource Confirmation
Well-field Development
Power Plant Construction
Operation and Maintenance

BANKABILITY
Laboratory research will improve methods for sustaining engineered reservoirs over time. The EGS R&D funding opportunity:

- **Uses novel techniques** — isotope studies, innovative rock mechanics experiments, integrated with geophysical methods, for instance — to increase the precision and accuracy of measuring critical underground reservoir properties over time.

- Focuses on laboratory feasibility studies to characterize critical EGS reservoir parameters — such as fracture length and aperture and fluid flow pathways — to **precisely engineer reservoirs**.

- Ultimately yields integrated characterization methods and **prototypes ready to be validated in the field**.
FORGE Initiative

Undertaking transformative science to carve a commercial pathway for EGS

- Works collaboratively across national labs, academia, and industry

- To resolve some of the greatest hurdles to economic production of EGS geothermal energy
FORGE Initiative

Following a phased approach for fully implemented and characterized site selection

- $31 million solicitation in a phased approach
- Down-select to final site selection for the subsurface laboratory

Selections anticipated by March 2015
The Energy Department has valuable EGS demonstration projects in our portfolio.

**AltaRock EGS demonstration project**
- $21.4 million DOE Recovery Act investment
- Currently only project in our EGS portfolio located in a greenfield setting
- September 2014 – Stimulation was repeated after installing new casing
- EGS-6, 1st, 10:45am

**Raft River EGS demonstration project in Idaho**
- April 2014 – 10°C water at 3000-4000 lpm was injected – for hydraulic stimulation
- As of Jan 2015 over 666 million liters (176 million gallons)

SOURCE: C. Pike, Alaska Center for Energy and Power
Stage Four: Power Plant Construction

Enhancing efficiencies

- Hybrid Power Systems
- Advanced heat transfer cycles
- Low-temperature applications
- Direct use & cascaded use

PROJECT RISK

BANKABILITY
Direct Use and Hybrid Systems

Thermal energy applied directly for heating/cooling, buildings, greenhouses, aquaculture, pools and spas

- Moderate temperatures between 100 – 300°F
- Wells hundreds to thousands of feet deep

GTO is investing in innovative technologies to secure balanced renewable energy through hybrid systems

Stillwater geothermal plant, with a total net installed capacity of 33 MWe, will be integrated with a 17 MW solar thermal facility. This is the first hybrid plant in the world able to combine the continuous generating capacity of binary-cycle, medium-enthalpy geothermal power with solar thermal technology.
Increasing value propositions to make geothermal more economical

- Mineral recovery
- Innovative O&M Tools, Sensors, Methodology

Stage Five: Operation & Maintenance and Additive Value
Mineral Recovery

Economically extracting rare earths and other strategic materials from geothermal brines increases the value proposition of geothermal energy production.

- Feasibility studies that include fully developed business plans laying out the technical feasibility and economic viability of mineral extraction technology(s) combined with geothermal power production at a new or existing geothermal resource.

- Assessments of the current rare earth and near-critical metal resource base, with potential extraction volumes/rates including coupled techno-economic analysis.

- Geochemical modeling and leaching experiments to optimize the composition of down-hole fluids and identify additives that selectively leach high value strategic elements.
GTO Major Initiatives

New Prospecting Opportunities
Play Fairway Analysis GO/NO GO decision
Announcing play fairway drilling validation opportunity

Advancing Innovative Geothermal Tools & Techniques
Build upon R&D and demonstration project successes
Initiate Phase I, Frontier Observatory for Research in Geothermal Energy (FORGE)

Geothermal Vision Study
Geothermal continuum
Value proposition and its Impact on the President’s Climate Action Plan

Additive Value
Low-Temperature Mineral Recovery
Hybrid systems

Subsurface Engineering Crosscut (SubTER)
Intra- and inter-agency effort to address common subsurface challenges and better leverage DOE R&D
By 2016, DOE seeks to develop credible analysis jointly with the GEA/GRC community that:

I. Articulates clear *GTO investment strategies* across different sectors and has a cohesive plan to attain the goals;

II. Discusses *geothermal growth scenarios* for 2020, 2030 and 2050 backed by robust data, modeling and analysis;

III. *Addresses all market segments*: existing and potential hydrothermal, electrical and non-electrical usages, new EGS sector, and other value streams; and is

IV. Supported by *objective and peer-reviewed industry data* and *available to decision-makers*

V. Is *aspirational* and *inspirational*
GTO Vision Study

DOE Geothermal Technologies Office

Federal Project Management and Leadership
Jay Nathwani

Vision

- Aspirational and inspirational
- Growth scenarios (near, mid, long)
- Clear GTO investment strategies
- Objective and peer-reviewed data
- All market segments

IQA compliance
Federal compliance

Task Forces
- Resource Potential
- Sub-surface Technologies
- Surface Technologies
- Sector Capabilities (market, data analysis)
- Scenario Modeling
- Project Financing, Siting & Permitting
- Transmission, Distribution & Integration

External Peer Review
- Completely independent, reviewers not involved in study
- Report will be reviewed by domestic and international subject matter experts

Senior Peer Review Team
- Meet regularly throughout project
- Industry leaders
- Government agencies leaders
- Academia gurus
- NGO leaders

EERE Coordination/Consultation
- GTO team leads
- Wind, Solar, and Hydro
- Deputy Assistant Secretary
- Assistant Secretary

DOE Review
- General Counsel
- OE, EIA, and EPSA
- Under Secretary for Science & Energy
- Secretary of Energy

Other Federal Agencies
- DOI - BLM and USGS
- DOA - USFS and USFWL
- DOD - GPO

Contributors, no consensus required
Reviewers, no consensus required
Federal stakeholders, consensus required

National Laboratories
- NREL
- Lead task forces
- Modeling and analysis

U.S. Department of Energy
Energy Efficiency & Renewable Energy
The Geothermal Technologies Program annual budget peaked in the late 1970s, helping to drive an increase in installed capacity that lasted about ten years.

**Annual Budget for the Geothermal Technologies Office and Installed Capacity 1976 - 2014**

- 1978: The Public Utility Regulatory Policies Act forces utilities to buy renewable sources at a higher price and drives geothermal development until 1990.
- 1990: After a spike in the mid-1980s, natural gas prices are low.
- 1997: With the help of the DOE, a wastewater injection program begins at the Geysers, restoring production and prolonging the life of the field.
- 2000: Growth attributed to GRED program.
- 2008: Economic crisis slows development across all sectors and is addressed with the Recovery Act.

**Key Events**

- 1978: The Public Utility Regulatory Policies Act forces utilities to buy renewable sources at a higher price and drives geothermal development until 1990.
- 1990: After a spike in the mid-1980s, natural gas prices are low.
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**Legend**

- **Red**: Annual Budget (Nominal $)
- **Blue**: Annual Budget (Real $)
- **Blue**: Geothermal Installed Capacity (MW)