FY 2016 Industry Budget Briefing

February 24, 2015

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

Geothermal Technologies Office

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GTO Major Initiatives

Fiscal Year 2016

New Geothermal Opportunities

- "Play Fairway" FOA
- Pathway to next-step drilling validation

Accelerate EGS

- Build upon R&D and demonstration
- project successes
- EGS R&D FOA
- Frontier Observatory for Research in
- Geothermal Energy (FORGE) FOA kicked off

Tackle Deployment Barriers

- Regulatory Roadmap: Streamlining
- National Geothermal Data System: leveraging access to data

Additive Value

- Low Temp Mineral Recovery FOA
- Hybrid systems

NEW: Subsurface Engineering Crosscut

- Intra- and inter-agency efforts to address common subsurface challenges and better leverage DOE R&D

SOURCE: Novel energy storage device –FastCAP Systems; Raft River geothermal plant – GRC; First 300 C testing oven courtesy Baker Hughes.

Geothermal Program Balance

Transition from Near to Long Term

	Low Temp	Co-Production	Blind Hydrothermal	In- and Near-Field EGS	Greenfield EGS
Timeline	**Near Term**	**Near Term**	**Near to Intermediate**	**Near to Intermediate**	**Long Term**
Strategy	Utilize waste-heat / promote distributed energy	Leverage O&G infrastructure	Promote Sector Growth	Maintain / expand existing fields	Develop replicable model for commercial scale-up
Scale	**100's KW to several MW scale**	**10's-100's MW, aggregate to GWs potential**	**10's GW additional potential**	**5 - 10GWs potential- low risk**	**10's - 100's GW potential - higher risk**
Constituency	Local Direct Use	Growing Interest, New Potential Sector	Majority of the Private Sector	Private Sector, very few companies to date	High potential for growth and new entrants resulting from EGS Field Observatory

GTO Operational Space

Strategy and Approach

Program	Strategy	FY16 Approach
Enhanced Geothermal Systems	***Accelerate a Commercial Pathway to EGS***	• Implement Phase 3 of the Frontier Observatory for Research in Geothermal Energy (FORGE), dedicated to advancing EGS technologies • EGS R&D that targets key challenges/ complements work at the FORGE
Hydrothermal	***Explore for Blind Geothermal Opportunities***	• Conduct Play Fairway validation to confirm geothermal prospects • Leverage oil and gas technologies for use in geothermal
	Leverage and collaborate on crosscutting DOE RD&D	• Full implementation of RD&D collaboration across the Department that addresses common technical challenges found in the subsurface. • Target Induced Seismicity and Subsurface Stress, Permeability Manipulation, and new Subsurface Signals
Low Temperature and Coproduced Resources	***Identify Additional Value Streams***	• Conduct Phase 2 of Mineral Recovery program to advance projects to prototype development or field testing • Direct-use initiative to expand reach of geothermal to national scale
Systems Analysis	***Overcome Deployment Barriers***	• Geothermal vision study • Continued economic analysis and validation of funded R&D and sector progress • Data sharing and tool for public access to GTO-funded data

Innovative Geothermal R&D

With Translational Impacts

1. **Subsurface Characterization** – invented microseismic modeling for reservoir mapping, capitalized on by further investment through DOE's Unconventional Gas Research Programs. Now used by all subsurface communities.
2. **Drilling** –Developed polycrystalline diamond compact (PDC) drill bits, which are used in 60% of oil and gas well footage and are estimated to reduce oil and gas offshore costs by $56/foot drilled.
3. **Electric Submersible Pumps (ESP)** – Successful development of a high temperature/pressure ESP, through ARRA funding, led General Electric to create a new Artificial Lift business and acquire smaller lift companies to maintain market share .
4. **Power Plant** – Improved binary conversion cycles; for mid-level temperatures (150-190° C) resulting in a 15% increase in productivity over flash plants
5. **Reservoir Technology** – Developed geothermal reservoir models that are estimated to allow increased geothermal well productivity by 10% and oil and gas well productivity by up to 20% and (based on The Geysers)
6. **In-/Near-Field EGS** – Demonstrated and tested EGS technologies in a near and in-field environment that resulted in additional power of 2-5MW at $0.04/kWh.
7. **Data access** – the NGDS is reducing the upfront exploration and development risk by making geothermal data public and interoperable. Earth magazine has referred to this effort as "digitizing the earth" and will be able to leverage to other subsurface sectors.

INNOVATION ⇒ **FURTHER R&D** ⇒ **COMMERCIALIZATION**

e.g., microseismic modeling | ***DOE Fossil Energy refines seismic mapping techniques*** | ***Oil and gas community adopts technology as essential fracking tool***

"DOE's Geothermal Technologies Office is changing geothermal development in the U.S."

Lucien Bronicki, Founder
Chief Technology Officer, **Ormat,** May 2013

"DOE's long-term support was critical in the development of commercial tools for microseismic monitoring of fracturing procedures."

***NETL**, 2007, DOE's Unconventional Gas Research Programs , An Archive of Important Results*

Subsurface Crosscut (SubTER)

Funding Summary – FY16

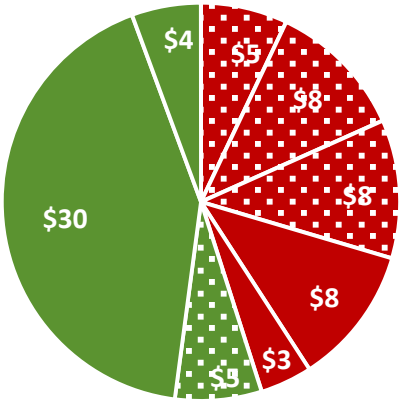
SOURCE: RAM Power; GRC.

FY 16 Request

$96M

FY 16 SubTER Request

$71M



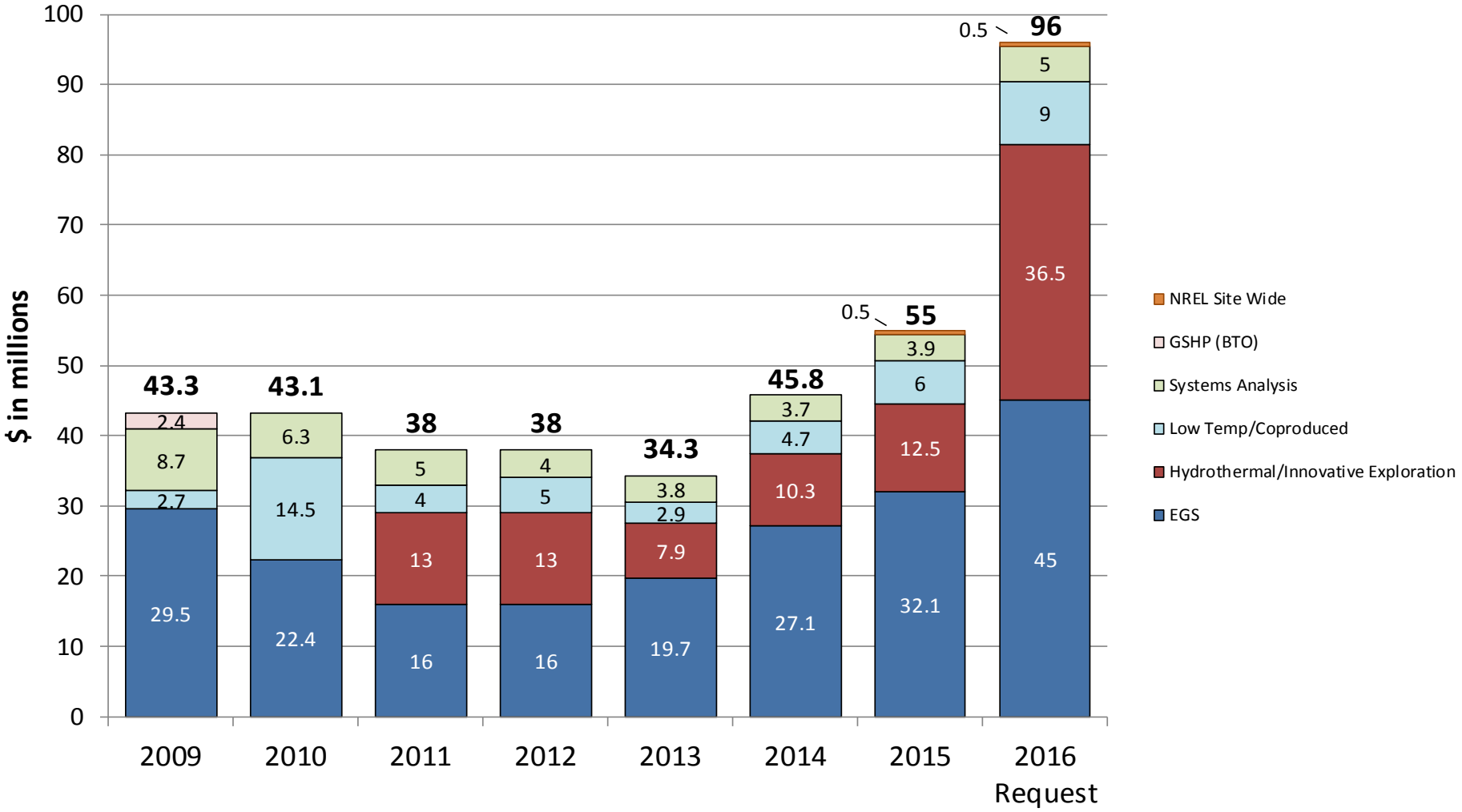
Enhanced Geothermal Systems:

- $4M - EGS R&D: Geothermal R&D with multi-sector benefits and alignment with SubTER priorities .
- $30M – FORGE: A geothermal energy field observatory that serves as a model for future dedicated SubTER sites.
- $5M – Subsurface Stress and **Induced Seismicity**

Hydrothermal:

- $3M – Funding for Hydrothermal R&D at Labs with cross-sector benefits.
- $8M – Slim-hole drilling for validation of play fairway analysis will yield subsurface data of interest to multiple offices.
- $8M - **New Subsurface Signals**
- $8M - **Permeability Manipulation**
- $5M – **Subsurface Stress** and Induced Seismicity

Geothermal Technologies Office Funding History



Enhanced Geothermal Systems (EGS)

FY16 Request:

Frontier Observatory for Research in Geothermal Energy (FORGE) ($35,000,000)

- Begin Phase 3 (Operations) of FORGE
- Initiate drilling of the first FORGE well and any auxiliary wells.
- Continue **microseismic and geophysical/geochemical signature monitoring** and input into dynamic reservoir modeling efforts.
- Issue first **R&D solicitation** on research and technology testing defined by the FORGE multi-year R&D strategy.
- Upload all characterization and monitoring data collected throughout the initial year of Phase 3 to the **FORGE Data System/Node** in real-time.

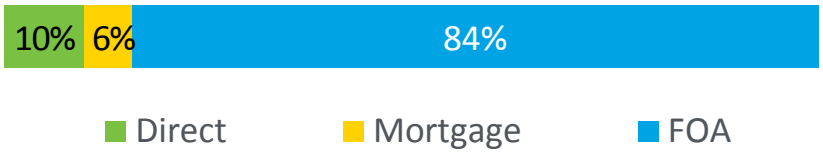
EGS National Lab R&D ($5,000,000)

- Competitively selected R&D targeting critical lab-scale work and first-of-their-kind feasibility studies on **fracture characterization**, **innovative tracer technology development**, and **joint geophysical methods** for reservoir imaging

Subsurface Crosscut ($5,000,000)

- Full launch of the Subsurface Technology and Engineering RD&D Crosscut, which will focus on targeted research, development, and field demonstrations that emphasize the following topic area: **induced seismicity** and subsurface stress.

Funding in millions	FY 2013 Current	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
EGS	$19.7	$26.5	$32.1	$45.0



FY 2016 Office Goals:

- To reduce the current LCOE of Greenfield EGS from 22.4 cents/kWh to **6 cents/kWh by 2030**.

Enhanced Geothermal Systems (EGS)

FY15/16 Funding Distribution

FY 2015 Enacted	FY 2016 Request
$32,100,000	$45,000,000

- Down-select to **up to three potential FORGE sites.**
- **Initiate the NEPA process** for FORGE activities at each site.
- Initiate permitted **site characterization and monitoring activities** at each site including high-resolution surface and subsurface seismic monitoring systems.
- Release the first **R&D Request for Proposal (RFP) for projects at Final FORGE site.**
- **Mission-critical R&D** focused on addressing EGS barriers. Topics will focus on **zonal isolation**, **novel stimulation methodologies**, and **unique well designs and configurations.**
- First-of-its-kind **super-critical phase CO_2 EGS field pilot test.**

- **Collaboratively developed FORGE multi-year R&D strategy.**
- Continue any further characterization of the in-situ stress field needed, utilizing various techniques and further characterization of fluid content and composition at depth.
- Incorporate **field testing** of methodologies/tools/procedures developed through the EGS subprogram's FY 2014 Integrated EGS R&D solicitation (12 awards), depending on the sequencing of the FORGE multi-year R&D strategy.
- Continue **micro-seismic** and other **geophysical and geochemical signature monitoring** initiated in Phase 2.
- **Finalize design and initiate drilling** of the first FORGE well and any auxiliary wells
- Upload all **characterization and monitoring data** collected throughout the initial year of Phase 3 to the FORGE Data System/Node in real-time.
- Select and make awards on 1st **FORGE R&D solicitation**,
- **Develop and implement seismic response simulations and risk models**, as part of the subsurface stress state/induced seismicity topical pillar within the SubTER.

Hydrothermal

FY16 Request:

Play Fairway Validation ($9,500,000)

- The subprogram will launch an industry Play Fairway FOA and conduct the down-select for the Phase I Play Fairway Analysis.
- Efforts will target exploration slim hole and/or temperature gradient well drilling to characterize the prospective geothermal areas derived from the Phase I Play Fairway Analysis maps.

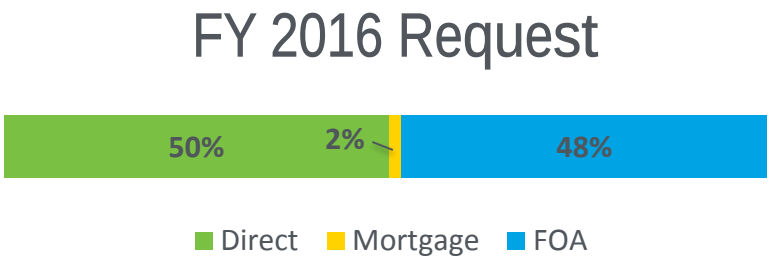
Hydrothermal National Lab R&D ($6,000,000)

- This R&D will focus on blind geothermal resources and leveraging O&G/mining technologies that will work to more aggressively transfer select oil and gas exploration, drilling, and completion technologies as well as incorporating mining technology transfer to the geothermal industry.

Subsurface Crosscut ($21,000,000)

- Full launch of the Subsurface Technology and Engineering RD&D Crosscut, which will focus on targeted research, development, and field demonstrations that emphasize the following three complementary topic areas: induced seismicity and subsurface stress, permeability manipulation, and new subsurface signals.

Funding in millions	FY 2013 Current	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
Hydro-thermal	$7.9	$10.0	$12.5	$36.5



FY 2016 Office Goals:

- To reduce the current LCOE of undiscovered hydrothermal from 14 cents/kWh to **10 cents/ kWh by 2020**.

Hydrothermal

FY15/16 Funding Distribution

FY 2015 Enacted	FY 2016 Request
$12,500,000	$36,500,000

- The program will focus on **Play Fairway Analysis** through the completion of **Phase 1** of eleven previously funded competitive awards.
- **Targeted R&D** for Blind Geothermal Resources and Leveraging Oil and Gas (O&G)/Mining Technologies focused on **blind resource characterization and exploration, downhole completion tool development, and oil and gas drilling/completion transfer.**
- Manage SubTER activities associated with projects funded in FY 14 with seedling funding and expanded funding in FY 15.

- The Hydrothermal program will launch the **Phase 2 validation effort for Play Fairway Analysis** in FY 2016, rather than in FY 2015, to allow for well-structured timing between Phase 1 project completion and Phase 2 validation. In addition to the Phase 2 validation effort, an industry-focused play fairway FOA will be posted to target exploration slim hole and/or temperature gradient well drilling similar to those conducted in the, non-industry focused, Play Fairway Analysis Phase II validation effort.
- **Targeted R&D** for Blind Geothermal Resources and Leveraging Oil and Gas (O&G)/Mining Technologies that will work to more aggressively transfer select **oil and gas exploration, drilling, and completion technologies** as well as incorporating **mining** technology transfer to the geothermal industry.
- **Full implementation of the Subsurface Engineering crosscut,** a critical effort for advancing innovative RD&D under the Hydrothermal program to reduce the cost and risk of geothermal development by targeting opportunities to leverage advances in other subsurface sectors. The geothermal proposal focuses on geothermal-specific R&D in **Subsurface Stress and Induced Seismicity, Permeability Manipulation**, and **New Subsurface Signals**, and the cross-cutting nature of these topics aims to result in outcomes that are accretive across multiple DOE Offices.

Low Temperature and Coproduced

FY16 Request:

Low Temp Mineral Recovery Phase 2 ($5,000,000)

- To allow for well-structured timing between Phase 1 and Phase 2, the subprogram will instead launch Phase 2 of the **Low Temperature Mineral Recovery initiative** in FY 2016, rather than in FY 2015.

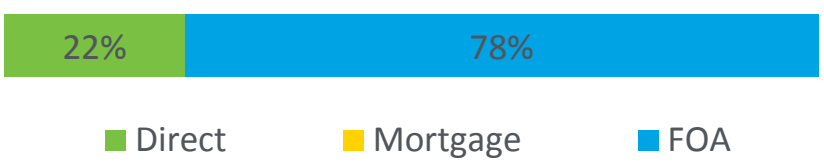
Deep Direct Use FOA ($2,000,000)

- Due to funding and schedule considerations, the subprogram will instead launch the **Direct Use FOA** to identify and assess new geothermal resource opportunities in FY 2016.

Low Temp National Lab R&D ($2,000,000)

- The program will continue funding targeted R&D of **value-added technologies**, to include pilot-scale demonstration(s) of geothermal **water purification** processes.

Funding in millions	FY 2013 Current	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
Low Temp/ Coproduced	$2.9	$4.6	$6	$9



FY 2016 Office Goals:

- To reduce the current LCOE of undiscovered hydrothermal from 14 cents/kWh to **10 cents/ kWh by 2020**.

Low Temperature and Coproduced

FY15/16 Funding Distribution

FY 2015 Enacted	FY 2016 Request
$6,000,000	$9,000,000

- Initiation of **Phase II of the Low Temperature Mineral Recovery FOA** will occur via planning activities to include – stakeholder workshop and request for information release.
- Continuing from FY 2014 funded efforts, transition the most successful feasibility studies **to technology prototype development** or **field demonstration project(s).**
- Fund **cost-shared demonstrations** of extraction technologies at geothermal mining and power production sites.
- Demonstrate a **commercial-ready hybrid cycle binary power plant** in cooperation with National lab and industry partners.
- Through the use of **Metal Organic Heat Carriers (MOHCs)** in a commercial binary plant, improve the heat transfer coefficients in the plant's heat exchanger by at least 5 percent.
- Successfully demonstrate that the thermal energy in low-temperature geothermal fluid is sufficient to drive a **Forward Osmosis** water purification process.
- Initiation of **Direct Use FOA** to identify and assess new geothermal resource opportunities via planning activities to include two shareholder workshops and a request for information release.
- To allow for well-structured timing between the completion of the **nine Phase I** projects and an open call for Phase 2projects, the Low Temperature and Coproduced Resources subprogram will release the **Phase 2 FOA** and award projects for the **Low Temperature Mineral Recovery initiative** in FY 2016.
- The Low Temperature and Coproduced Resources subprogram will **launch the Direct Use FOA** to identify and assess new geothermal resource opportunities in FY 2016. It is anticipated that **six to ten feasibility and assessment projects** will be awarded.
- The program will continue funding targeted R&D of **value-added technologies**, to include at least one pilot-scale demonstration(s) of geothermal water purification processes.

Systems Analysis

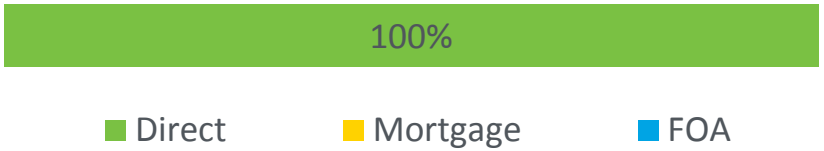
FY16 Request:

Systems Analysis National Lab R&D ($5,000,000)

In FY 2016, the subprogram will fund activities to support specific EGS, Hydrothermal, and Low Temp strategic, market and techno-economic analysis projects, as well as projects that remove deployment barriers including:

- **Strategic analysis** targeting a robust, forward-looking analysis of the future state of geothermal deployment and related economic, policy and environmental considerations.
- **Techno-economic analysis and validation** of the impact of GTO investments on the geothermal sector.
- **Data collection and dissemination** for GTO subprograms, such as assisting FORGE Teams in deploying a node on the NGDS tailored to researcher data requirements, for immediate and easy public access.
- **Regional modeling and analysis of commercial geothermal resources** that will allow us to develop updated assessment of resource targets in the U.S., **which complements the program's vision study and Play Fairway initiative.**

Funding in millions	FY 2013 Current	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
Systems Analysis	$3.8	$3.7	$3.9	$5.0



FY 2016 Office Goals:

- To reduce the current LCOE of undiscovered hydrothermal from 14 cents/kWh to **10 cents/ kWh by 2020**.
- To reduce the current LCOE of Greenfield EGS from 22.4 cents/kWh to **6 cents/kWh by 2030**.

Systems Analysis

FY15/16 Funding Distribution

FY 2015 Enacted	FY 2016 Request
$3,900,000	$5,000,000

- Two environmental analyses that continue to assess the **lifecycle greenhouse gas and water use impacts** of geothermal systems, incorporating the latest data on EGS;
- **Policy and regulatory analysis**, in the form of the Regulatory Roadmap and five inter-agency technical working papers on environmental issues relevant to geothermal technologies.
- Updated assessment of **financial policies and market drivers** affecting the geothermal sector, as part of NREL's Strategic Analysis.
- **Techno-economic analysis** including an impact assessment study of the emerging and commercialized technologies initially funded by the R&D portfolio (GT-Mod and GETEM); and
- Data collection and tools development including development of a **node-in-a-box repository** for public sharing of data resulting from the FORGE initiative.
- A robust, forward-looking **Vision Study** to illustrate the geothermal potential and impacts in 2020, 2030 and 2050, based on scenarios within a geothermal continuum addressing the valuation of a full spectrum of geothermal technologies.
- **Techno-economic analysis and validation** of the impact of investments on the geothermal sector, including tracking the commercialization of funded R&D investments.
- A continued **regional water resources assessment**, integrating data from program-funded projects, in support of the **Energy-Water Nexus crosscut**.
- Evaluation of the **potential for direct use** applications to utilize the full range of geothermal resources, including EGS technologies.
- **Regional modeling and analysis** of power generation, as well as commercial geothermal resources ("geothermal reserves") that will allow us to develop updated assessment of resource targets in the U.S., to complement the Geothermal Technology Program's Play Fairway Analysis initiative.

Geothermal Technologies Office

Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**Reduce the LCOE from newly developed geothermal systems (cents/kWh)**		
Target	22.4	22.3	22.2
Result	Met - 22.4	N/A	N/A
Endpoint Target	**6 cents/kWh by 2030**		