Geothermal Technologies Program

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

Glass Buttes, OR (DOE)

Stanford Geothermal Workshop

2012 Annual Meeting Jan 30-Feb 1, 2012

Doug Hollett, Program Manager

Geothermal Technology Program Mission

A major contributor to the nation's baseload energy supply

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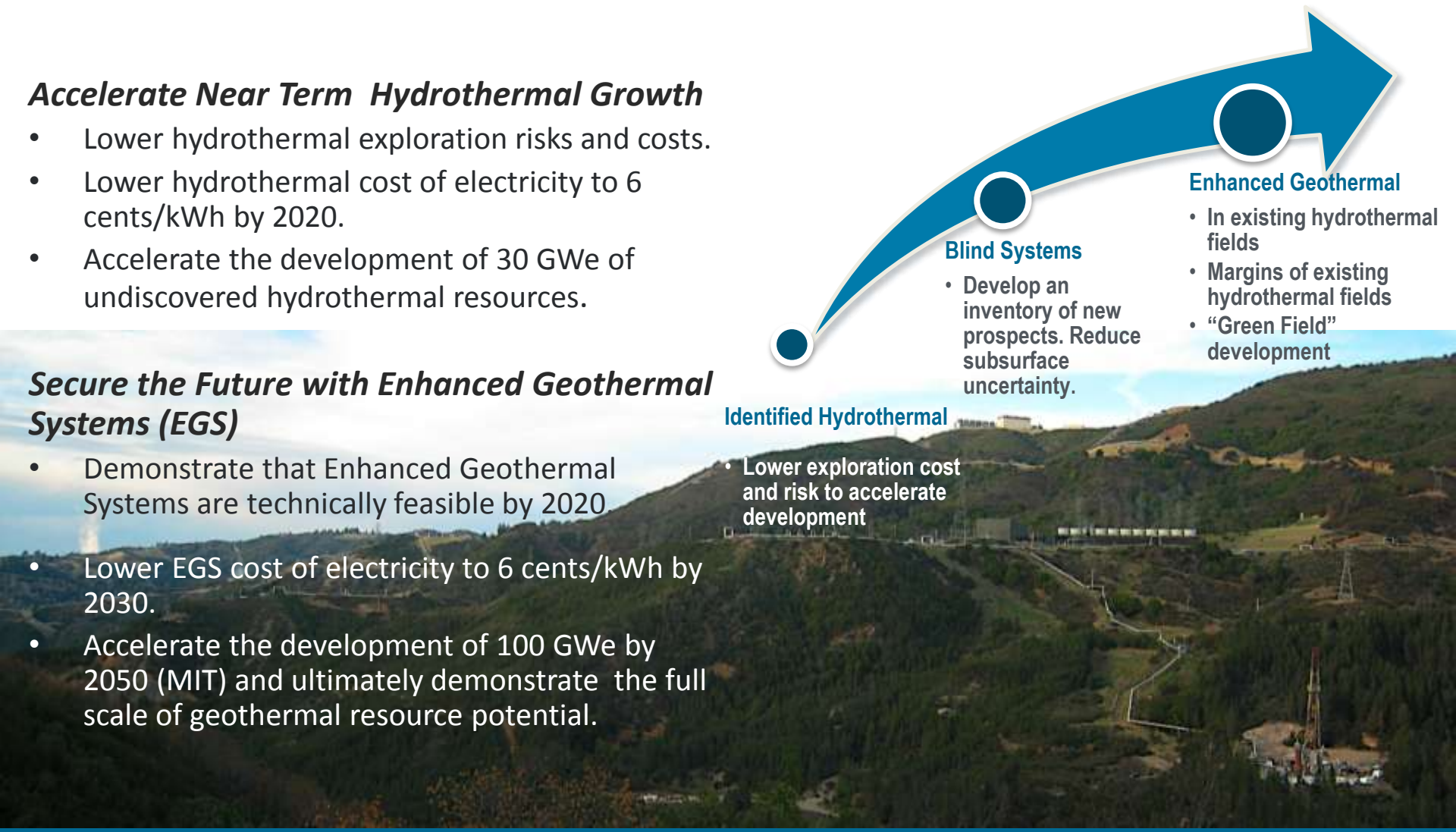
Accelerate Near Term Hydrothermal Growth

- Lower hydrothermal exploration risks and costs.
- Lower hydrothermal cost of electricity to 6 cents/kWh by 2020.
- Accelerate the development of 30 GWe of undiscovered hydrothermal resources.

Secure the Future with Enhanced Geothermal Systems (EGS)

- Demonstrate that Enhanced Geothermal Systems are technically feasible by 2020.
- Lower EGS cost of electricity to 6 cents/kWh by 2030.
- Accelerate the development of 100 GWe by 2050 (MIT) and ultimately demonstrate the full scale of geothermal resource potential.



Benefits of the Program

Value Added Through Federal Role

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- ***Increased Speed of Innovation***
  - Advance innovation at a high rate, to achieve development and power generation targets
- ***Reduced Exploration & Development Risk and Cost***
  - Tools and technologies which can both lower costs, and identify new resources
- ***Information:* National Geothermal Data System and Geothermal Data Repository benefit entire US Geothermal Industry**
  - One-stop source for all existing public data
  - Rapid evolution from concept, to exploration and development
- ***Technology and System Validation to Increase Investor Confidence***
  - Increased and more favorable funding to private sector
- ***Is it enough?***
  - *Not yet: Getting to <u>targeted scale</u>, will still require dramatic change*

The Geysers Prati 5 St-1 (Calpine)

Impact of R&D and Policy
Shale Gas – Geothermal Comparison

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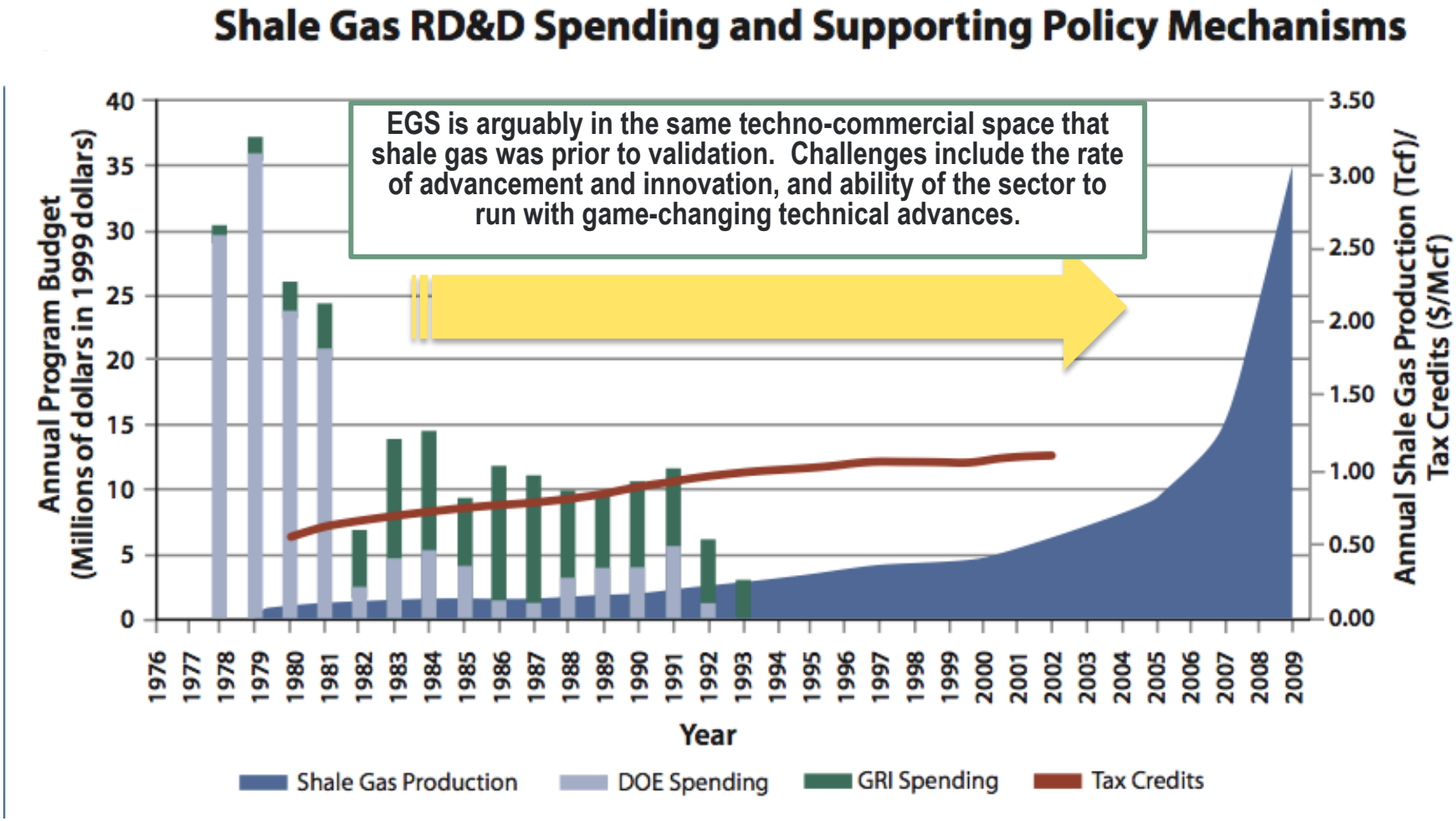
*Over 25 years of government and private investment in shale gas RD&D and supporting policy mechanisms were necessary to have a "material impact"**



* from the MIT report titled, *The Future of Natural Gas,* available at http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml *c*

GTP Budget

FY12 Update

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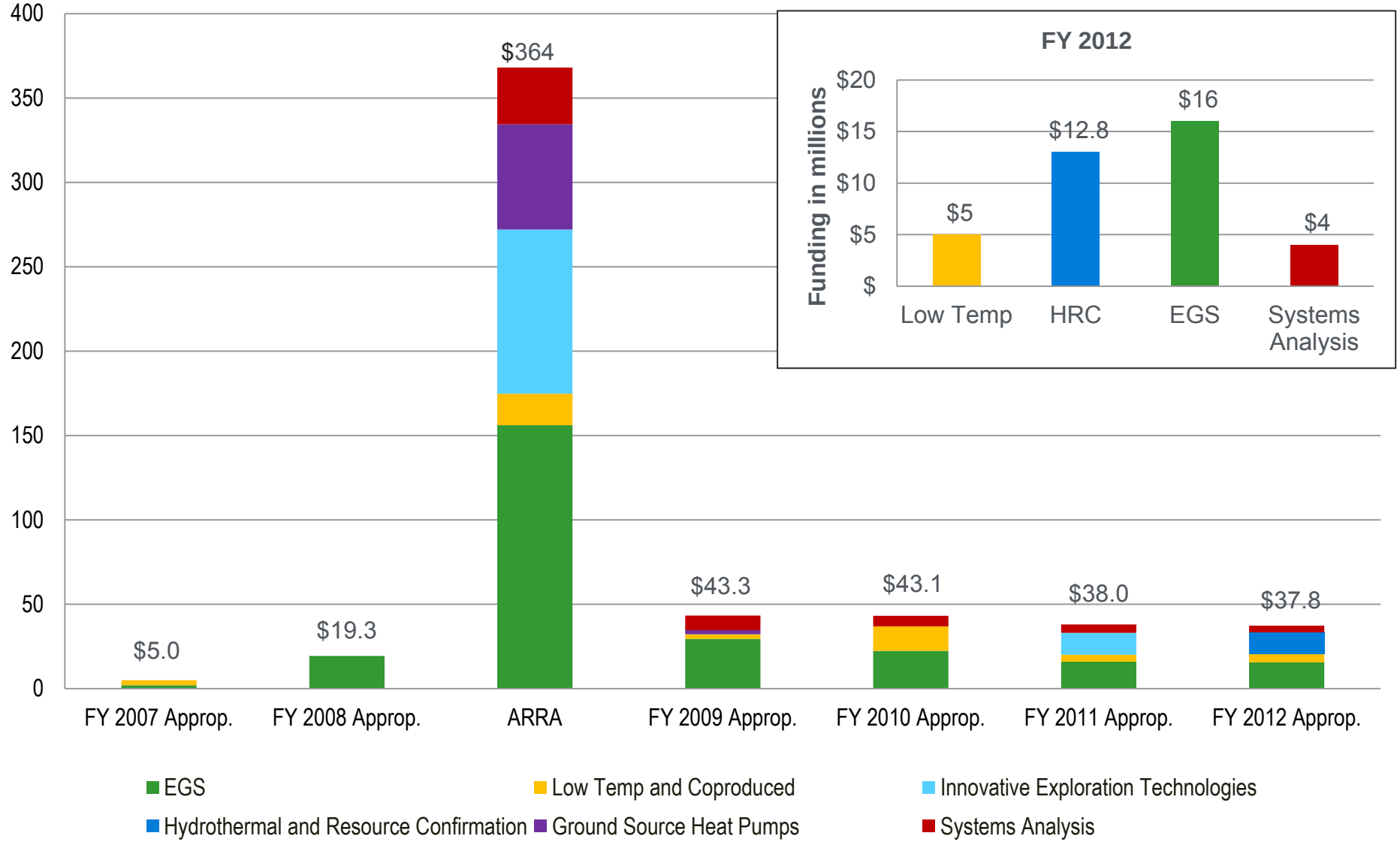

Hydrothermal and Resource Characterization

TRL Context

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	TRL 2-3	TRL 4-6	TRL 7-9
Reservoir Characterization	•Resource Assessment •Geophysical techniques •Geochemical methods •Remote sensing		
Access Reservoir	•Drilling systems •Advanced drilling tools		
Energy Conversion	•Coproduction demonstrations •Thermodynamic cycles •Operation and maintenances •Low temperature demonstrations		

Stanford University

University of Nevada, Reno

Berkeley Lab

The University of Texas at Austin

The University of Utah

Mines

ORMAT

NGP

PRESCO, INC

Oak Ridge National Laboratory

IMPACT

Los Alamos National Laboratory

FastCAP Systems

Atlas Copco

Sandia National Laboratories

OASYS Water

GE

Johnson Controls

UND

energent

Pacific Northwest National Laboratory

ElectraTherm

OSKI Energy

Note: not all entities listed

Enhanced Geothermal Systems

TRL Context

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

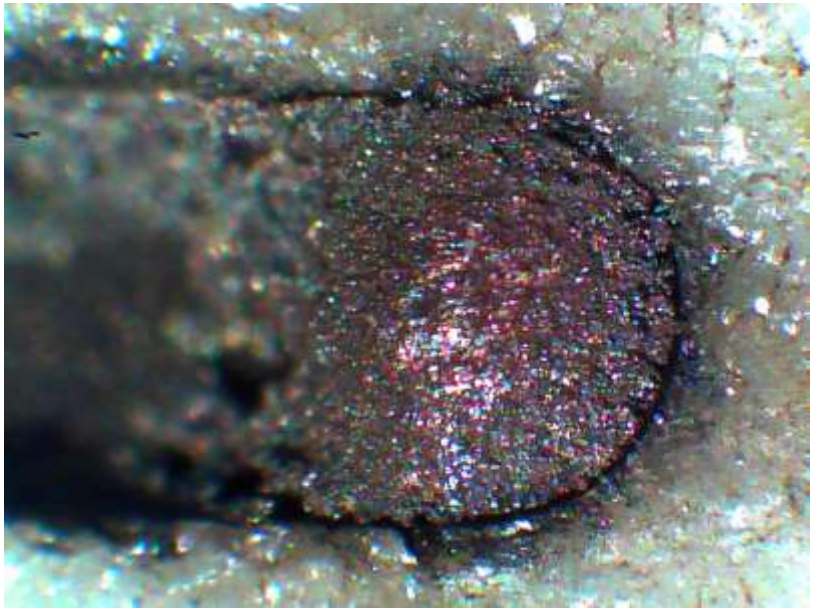
	TRL 2-3	TRL 4-6	TRL 7-8
Reservoir Characterization •Fracture characterization-Seismic •Drilling •Stress orientation and magnitude (minifrac)	Oak Ridge National Laboratory University of Nevada, Reno	Potter Drilling Atlas Copco	Berkeley Lab The University of Texas at Austin AltaRock
Reservoir Creation •Stimulation technologies •Zonal isolation •MEQ Imaging	Massachusetts Institute of Technology Sandia National Laboratories	Baker Hughes CSI Technologies A Superior Energy Services Company	ORMAT AltaRock The University of Utah Berkeley Lab Calpine
Reservoir Sustainability •Reservoir monitoring •Coupled reservoir modeling •Fluid imaging (neutron and joint inversion)	Baker Hughes Temple University Oak Ridge National Laboratory Los Alamos National Laboratory	GE Global Research Sandia National Laboratories Mines	Berkeley Lab π

Note: not all entities listed

Perma Works LLC

Well Monitoring Systems for EGS

Principal Investigator: Randy Normann



Solder Prototype 300°C-500°C
(Photo provided by Perma Works LLC)

- Partnered with Sandia National Laboratories
- Developing new digital pressure/temp/flow (PT-Flow) tool capable of operation at 40k psi and 300° C
- Potentially capable of permanent installation in the wellbore for long-term reservoir monitoring
- Currently, conducting long-term lab tests of individual components

DOE Cost Share	Awardee Cost Share	Total Cost
$2,200,000	$769,978	$2,969,978

Sandia National Laboratories

Technology Development and Field Trials of EGS Drilling Systems

Principal Investigator: David Raymond

Bit 1A: Pre-Drill Sharp Condition

Bit 1A: With 725 ft footage

(Photos provided by SNL)

- Partnership between SNL, Navy Geothermal Program, Barber Drilling, and NOV Reed Hycalog. Drilling in granite in the Chocolate Mountains (NE of Salton Sea)
- Successful deployment of high performance synthetic diamond drill bits in hard-rock geothermal wells
- Project targeting longer bit life and increased penetration rates – significant impact on drilling cost reduction
- Initial data indicates good performance (~30 ft/hr vs. ~10 ft/hr with roller bits), additional analysis and R&D to follow

DOE Cost Share	Awardee Cost Share	Total Cost
$981,000	-	$981,000

Simbol Materials

Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids

Principal Investigator: Stephen Harrison

Lithium Extraction Demonstration Plant
(Photo provided by Simbol Materials)

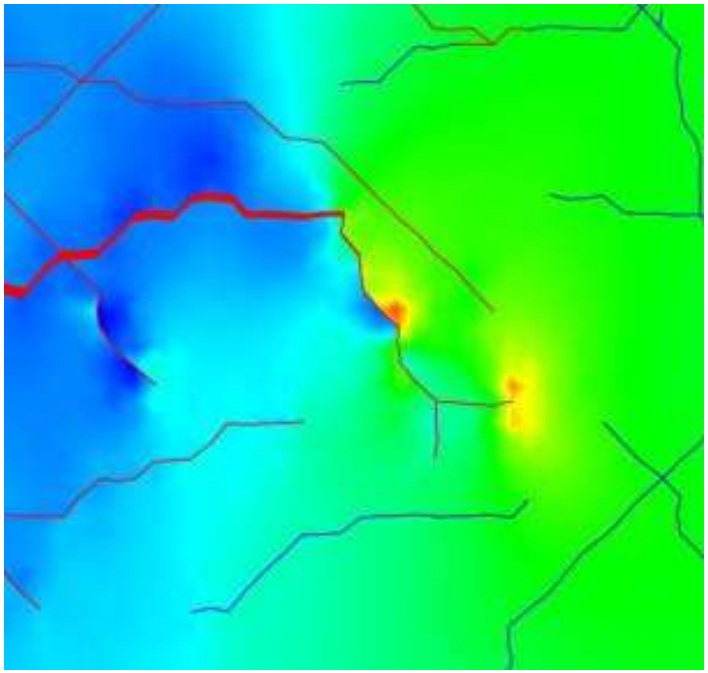
- Successfully scaled up laboratory process for making a lithium extraction material
- Currently running a pilot plant that filters 20 gallons/minute
- Plan to develop processes to cost-effectively extract additional materials (manganese, zinc, potassium, cesium, and rubidium) from geothermal brines
- A commercial plant, near Salton Sea, will begin construction in late 2012

DOE Cost Share	Awardee Cost Share	Total Cost
$3,000,000	$6,633,543	$9,633,543

Lawrence Livermore National Lab

Predicting Stimulation Response Relationships for Engineered Geothermal Reservoirs

Principal Investigator: Charles Carrigan



Hydrofracture allowing interaction with pre-existing fracture network (Photo provided by LLNL)

- Developing a computational test bed to produce realistic models of engineered geothermal system (EGS) stimulation-response scenarios
- Successfully modeled a 10% enhancement in a stimulated fracture network
- Model and simulations demonstrate how a propagating hydrofracture is affected by a pre-existing fracture network

DOE Cost Share	Awardee Cost Share	Total Cost
$925,000	-	$925,000

U.S. Geothermal

Finding Large Aperture Fractures in Geothermal Resource Areas Using a Three-Component Long-Offset Surface Seismic Survey

Principal Investigator: William Teplow

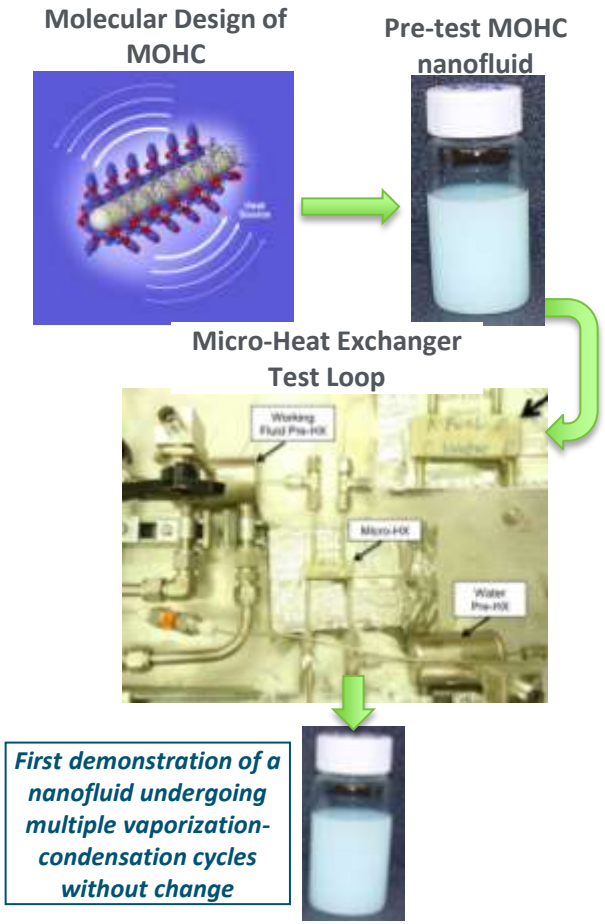
Large Aperture Fracture (LAF) in Range Front Fault
San Emidio North, Wind Mountain Mine Pit
(Photo provided by U.S. Geothermal)

- Completed Geophysical Exploration (Dilatational fault mapping, Seismic reflection, Gravity, PSInSAR, 3D seismic refraction, Shallow temperature survey)
- The combination of techniques developed in Phase 1 appears to be an effective methodology for identifying drilling target wells.
- Commencing Phase II based on promising results: Temperature Gradient Wells are currently being drilled in the southern resources area

DOE Cost Share	Awardee Cost Share	Total Cost
$3,772,560	$3,451,878	$7,224,438

Pacific Northwest National Lab

Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems



(Photo provided by PNNL)

Principal Investigator: Pete McGrail

- Nanofluids offer improved efficiency of ORC systems without major modifications to equipment or operating conditions
  - Better thermal conductivity
  - Improved heat transfer coefficient
- Metal Organic Heat Carrier (MOHC) nanomaterials augment nanofluid performance
  - Boost heat carrying capacity per kg
  - Increase effective latent heat of vaporization
  - Can be designed for complex interactions
- Techno-economic analysis underway

DOE Cost Share	Awardee Cost Share	Total Cost
$760,000	-	$760,000

AltaRock

EGS Demonstration at Newberry Volcano

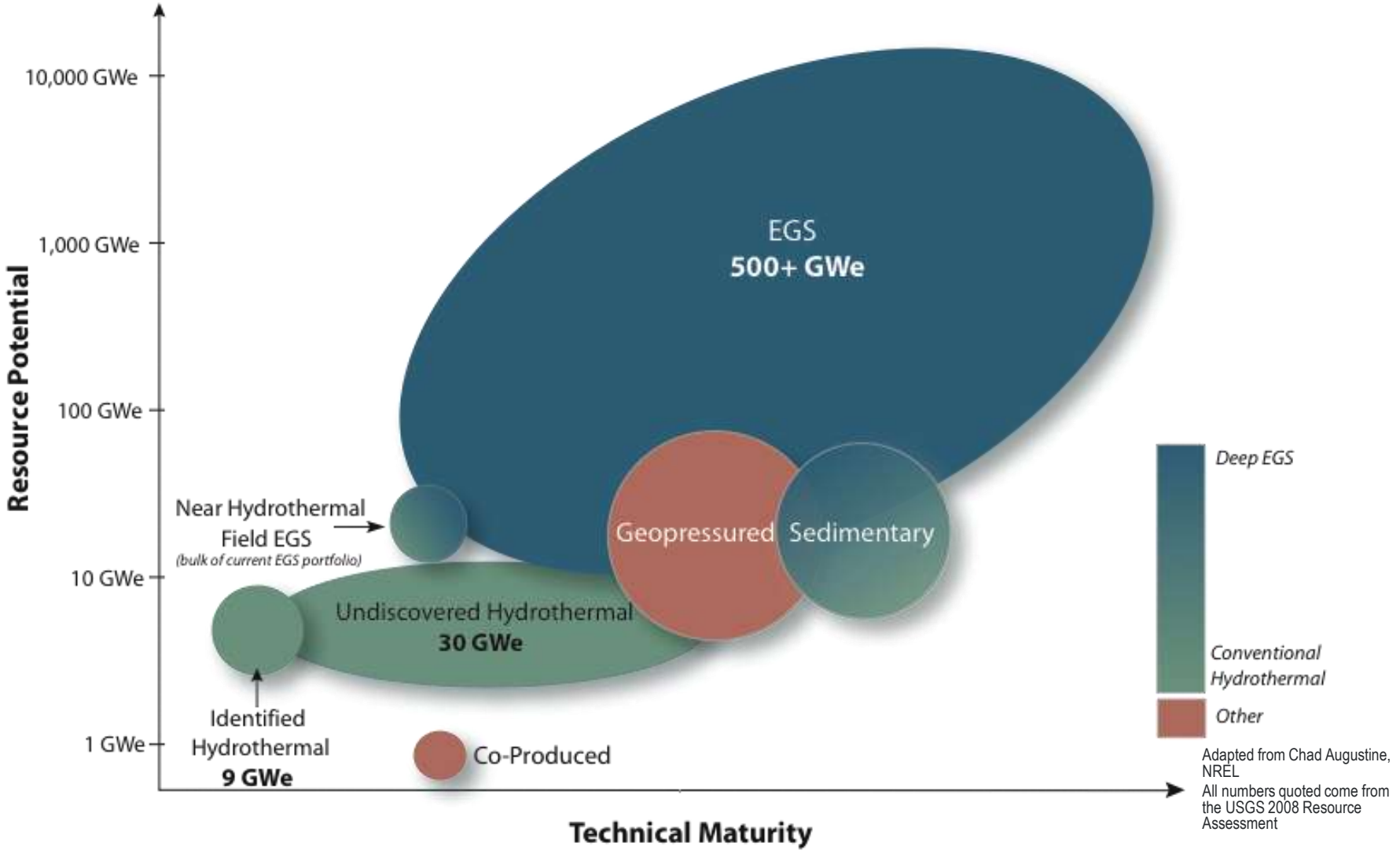
Principal Investigator: Susan Petty

Well 55-29, Newberry, OR
(Photo provided by AltaRock)

- BLM Environmental Assessment (EA) process underway: public comment period closed January 25
- AltaRock and partners have worked to characterize the EGS resource at Newberry through development of a comprehensive geologic model, characterization of in situ stresses, induced seismicity and geomechanical analysis

DOE Cost Share	Awardee Cost Share	Total Cost
$21,448,389	$22,355,008	$43,803,397

Realizing the Full Potential of Geothermal



Adapted from Chad Augustine, NREL

All numbers quoted come from the USGS 2008 Resource Assessment

EGS Resource and Reserve Space

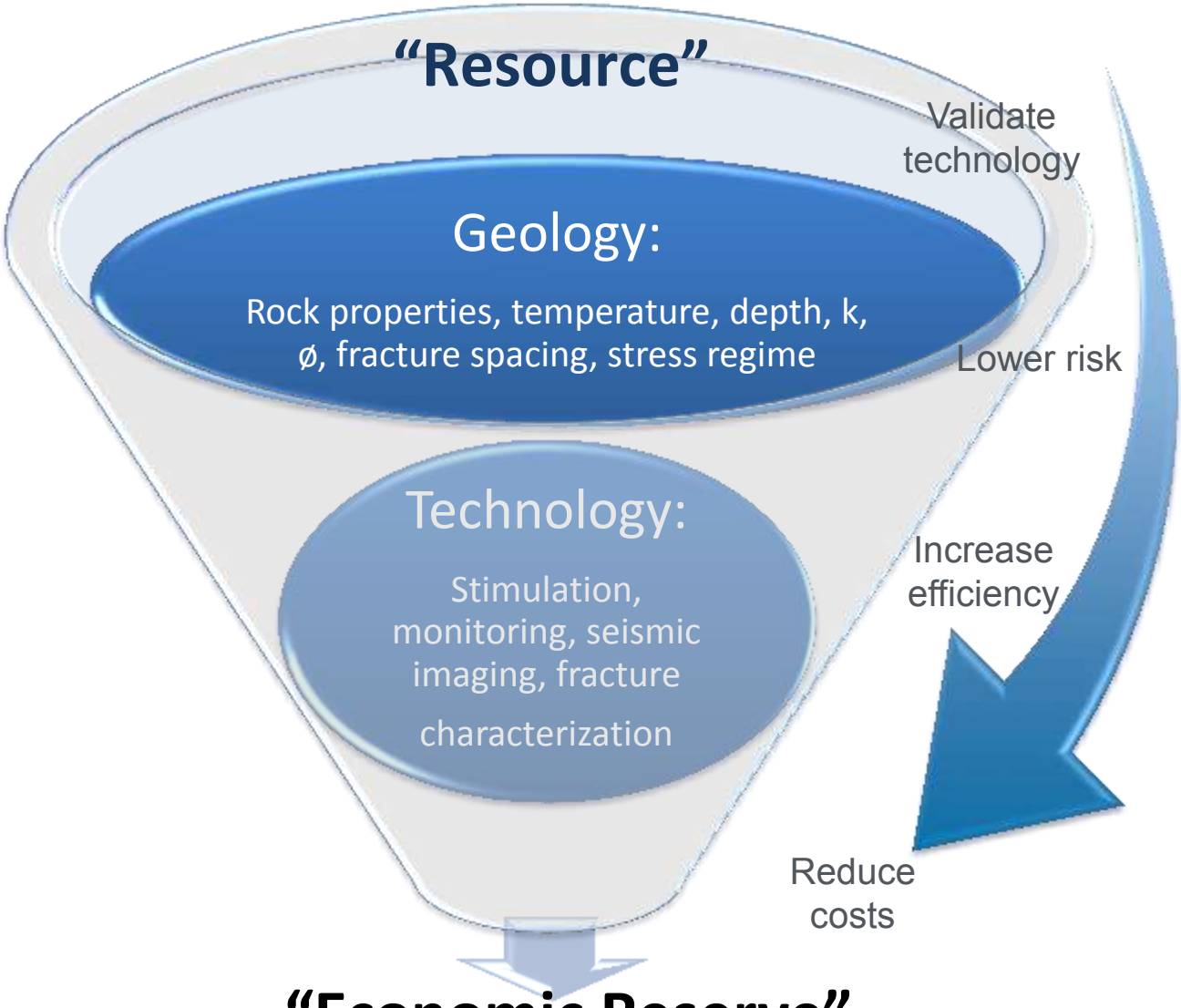
Moving from Potential to Confirmation

Resource:
Thermal energy in rock 3-10 km & ≥150 C

Accessible resource:
< 7 km depth

Useful Resource:
< 5 km

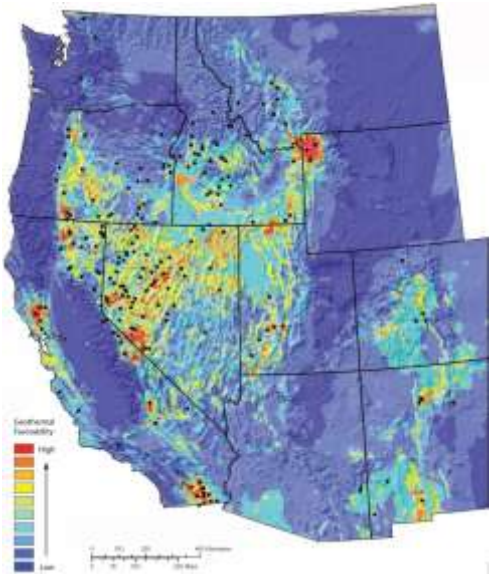
What is the realistic geothermal resource and reserve range?



Geothermal Technologies

Program Direction

- ***Potential is huge and remains highly attractive***
- ***Technical headroom exists***
- ***Non-Technical risks are definable and manageable***
- ***Success is:***
  - Decreased and predictable risk profile
  - Commercial and sustainable scale
  - Business case which industry can use for funding
- ***Increased Focus FY12 thru FY14***
  - EGS test sites concept
  - Identification of new geothermal prospects
  - Programmatic EA
  - Funding leverage and interagency co-operation
  - O&G strategic engagement



Geothermal Technologies Program 2012 Peer Review

The Westin Westminster Hotel

Westminster, Colorado

- Principal investigators will present the results of their projects for peer review
- Approximately 169 projects will be presented, representing a total DOE investment over $340 million
- Learn and network with other stakeholders and program staff

For more information and to register, visit:
geothermal.energy.gov/peerreview

Growing Technical and Staff Capabilities of the Program

- Postings coming soon for Physical Scientist and Subsurface Engineer
  - www.usajobs.gov
- Post Doc Research opportunities to work on collaborative applied research with the host facility, and the EERE Program sponsoring the award. Awards administered by Oak Ridge Institute for Science and Education (ORISE) in collaboration with EERE - **Deadline May 1, 2012.**
  - www.eere.energy.gov/education/postdoctoral
- Summer internship open - **Closing date Feb 21, 2012.**
  - For Physical Science and Engineering Positions, apply here:
    - http://usajobs.gov/GetJob/ViewDetails/307544100
- Volunteer internship open; contact the program office or:
  - http://www1.eere.energy.gov/office_eere/careers/internships_fellowships.html#volunteer

Program Updates

- Roadmaps (9) – comments - **needed by March 1, 2012**
- IS Protocol

State of the Union 2012

Commitment to Renewable Energy

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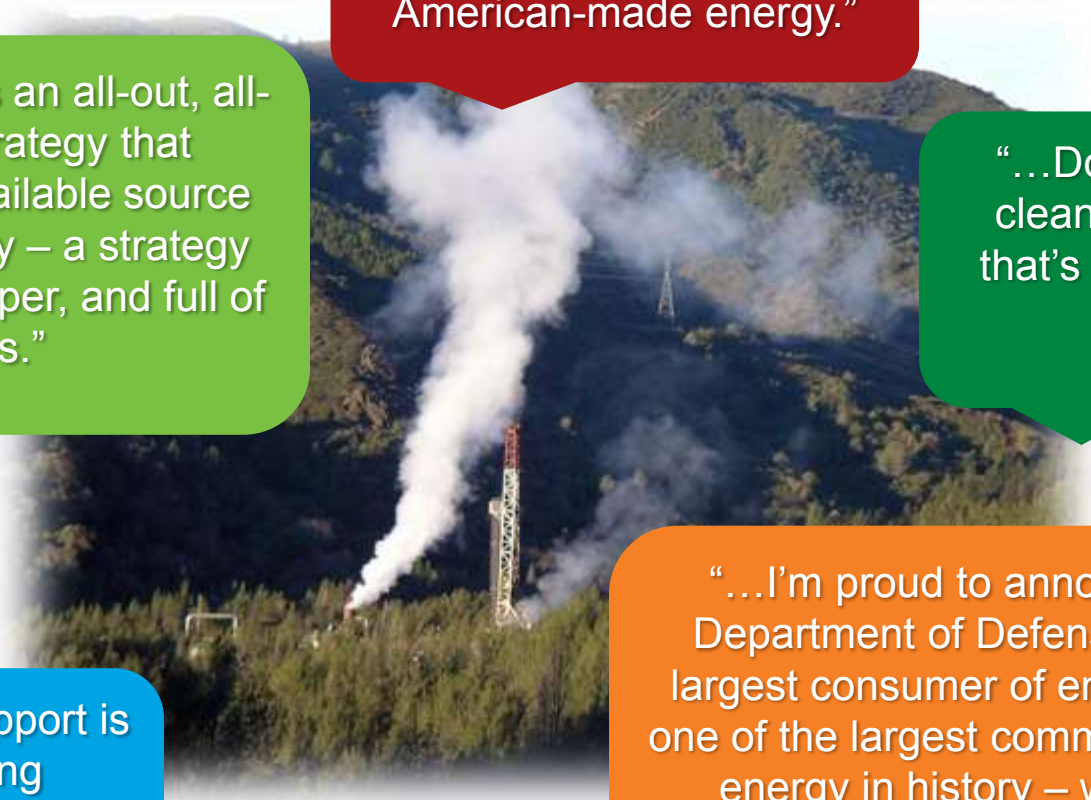
"Nowhere is the promise of innovation greater than in American-made energy."

"This country needs an all-out, all-of-the-above strategy that develops every available source of American energy – a strategy that's cleaner, cheaper, and full of new jobs."



"…Double-down on a clean energy industry that's never been more promising."

"…Government support is critical in helping businesses get new energy ideas off the ground."

"…I'm proud to announce that the Department of Defense, the world's largest consumer of energy, will make one of the largest commitments to clean energy in history – with the Navy purchasing enough capacity to power a quarter of a million homes a year."