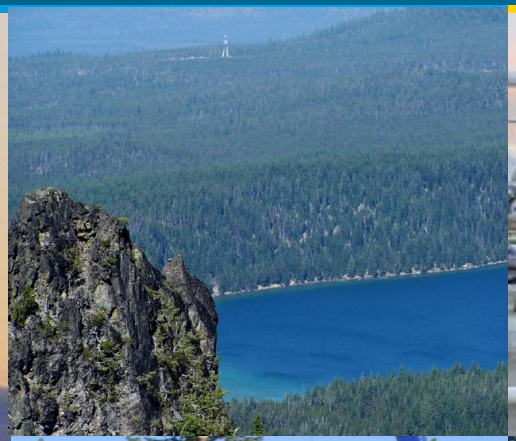
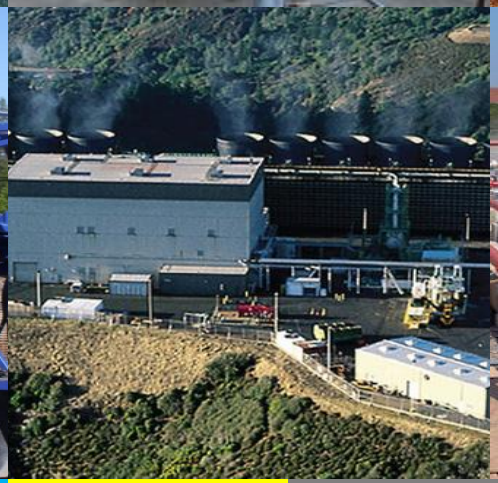
GTO 2013 Peer Review

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






Geothermal Technologies Office

Overview

- Geothermal Technologies Office:
  - Where are we now, and where are we going?
- Exploration Roadmap
- EGS Roadmap

Geothermal Program Balance

Transition from Near to Long Term

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	Low Temp	Co-Production	Blind Hydrothermal	In-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 GW potential**	**10's GW additional potential**	**Many MWs-GW potential- low risk**	**10's - 100's GW potential -high risk**
Constituency	Local or Rural, Direct Use	Growing Interest, New Potential Sector	Majority of the Private Sector	Private Sector	Fewer Players

- **Rollout of FY 2014 Budget**
- **Personnel**
  - New Staff: Josh Mengers (PMF); Dan King (AAAS); Chris Richards; Jodi Deprizio; Steve Hanson; Sharon Cosgrove; Erik Swanton (GFO); Caroline Mann
  - Leadership: Eric Hass (Hydrothermal); Lauren Boyd (EGS); Margaret Schaus (Operations and Systems Analysis); Jay Nathwani (Chief Engineer)
- **Upcoming**
  - Workshop planned to better inform the Program – June 2013
    - Location TBD
  - GTO FY 2014 AOP Planning – Begin May 2014, reach out to Labs in late May
  - GTO FY 2014 FOAs – Scheduled for release October 1, 2013
    - Topics being identified
  - ****Tomorrow**** Tuesday evening "Knowledge Exchange"
    - 4:45PM, Big Thompson

Budget Overview

Challenging but a good path forward

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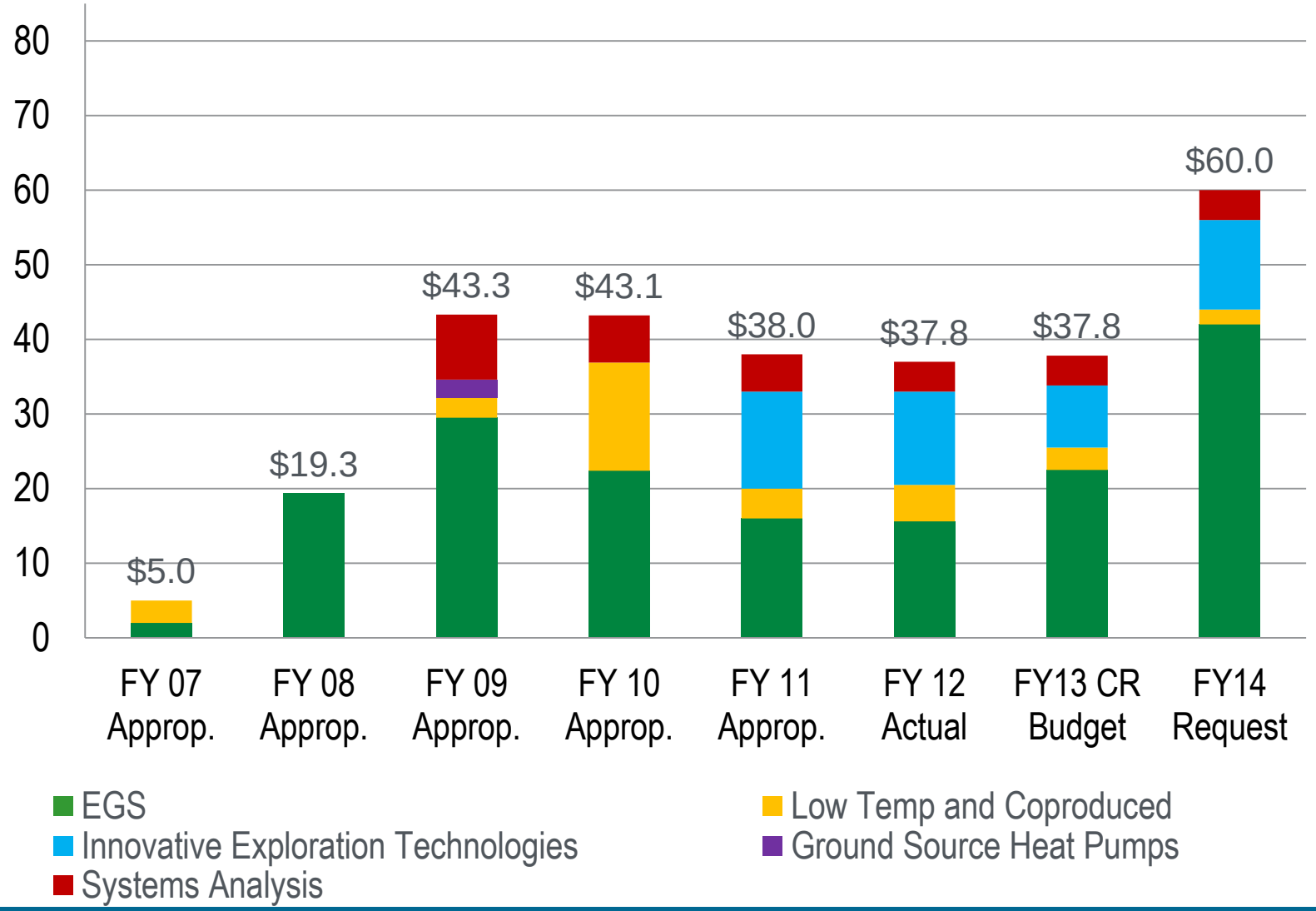

FY14 Budget Request Breakdown of Funding

High-Level Outline

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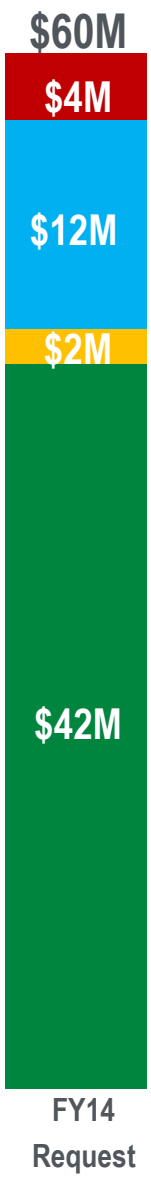


Systems Analysis ($4M)

- Deploy the National Geothermal Data System
- Detailed analysis of LCOE breakdown by drilling, exploration, and reservoir creation using GETEM
- Continue developing a life-cycle emissions inventory of geothermal technologies

Enhanced Geothermal Systems ($42M)

- EGS Field Lab Activities
- R&D focused on zonal isolation, novel stimulation methodologies, joint geophysical techniques, and advanced tracer technologies
- Initiate R&D on unique well designs and configurations, including first-of its-kind horizontal wells in geothermal settings

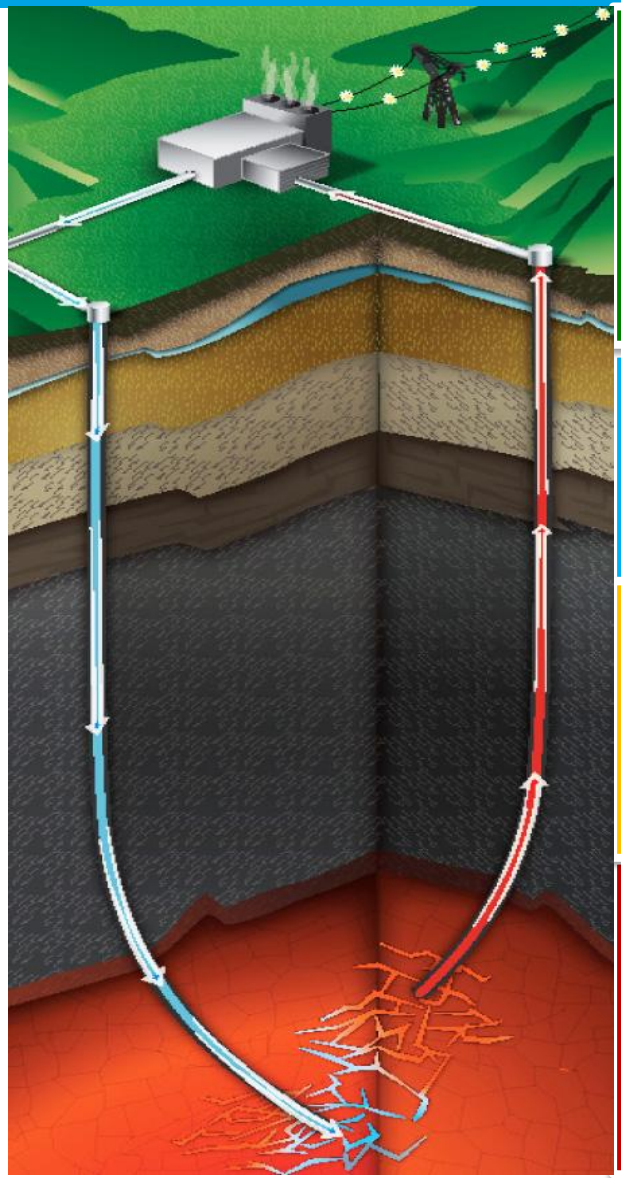
Low Temperature/Coproduced ($2M)

- R&D on hybrid cycles for binary power plants
- Begin strategic material initiative
- Collect and analyze data on demonstration projects: validate economics of binary units in commercial O&G applications.

Hydrothermal ($12M)

- R&D on advanced geophysical methods and geochem. techniques and tools
- Advance drilling technologies for harsh geothermal environments
- Analyze key resource information on undeveloped regions to build a robust set of prospect areas and promote industry dev't

Future GTO Initiatives/Focus Areas



Enhanced Geothermal Systems

- Commence EGS Field Observatory
- Improve drilling technologies
- Advance down hole R&D
- Characterization/Assessment tools

Hydrothermal

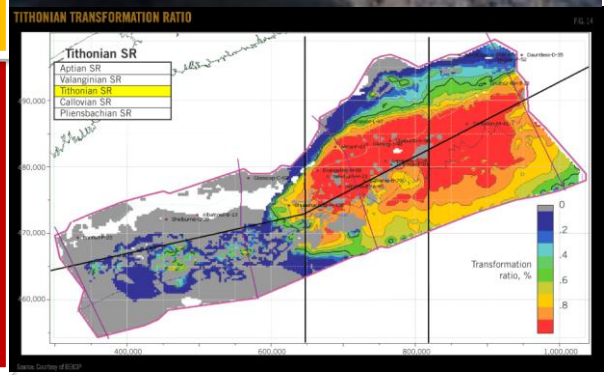
- Play Fairway Analysis/Mapping
- Advancing horizontal drilling technologies and capabilities

Low Temp/Coproduced

- Binary units installed and collecting data
- Increase LT deployment
- Increase O&G collaboration
- Direct Use Growth

Systems Analysis

- Completion of Regulatory Roadmap
- National Geothermal Data System (NGDS) deployment
- Complete 5/10 technical working papers



EERE's 5 Core Questions

Where Does your Research Fit?

1. **High Impact:** *Is this a high-impact problem?*
2. **Additionality:** *Will the EERE funding make a large difference relative to what the private sector (and other funding entities) is already doing?*
3. **Openness:** *Have we made sure to focus on the broad problem we are trying to solve and be open to new ideas, new approaches, and new performers?*
4. **Enduring Economic Benefit:** *How will this EERE funding result in enduring economic benefit to the United States?*
5. **Proper Role of Government:** *Why is what you are doing a proper high-impact role of government versus something best left to the private sector to address on its own?*

DOE-GDR Data Submitters

2013 Peer Reviewed Projects

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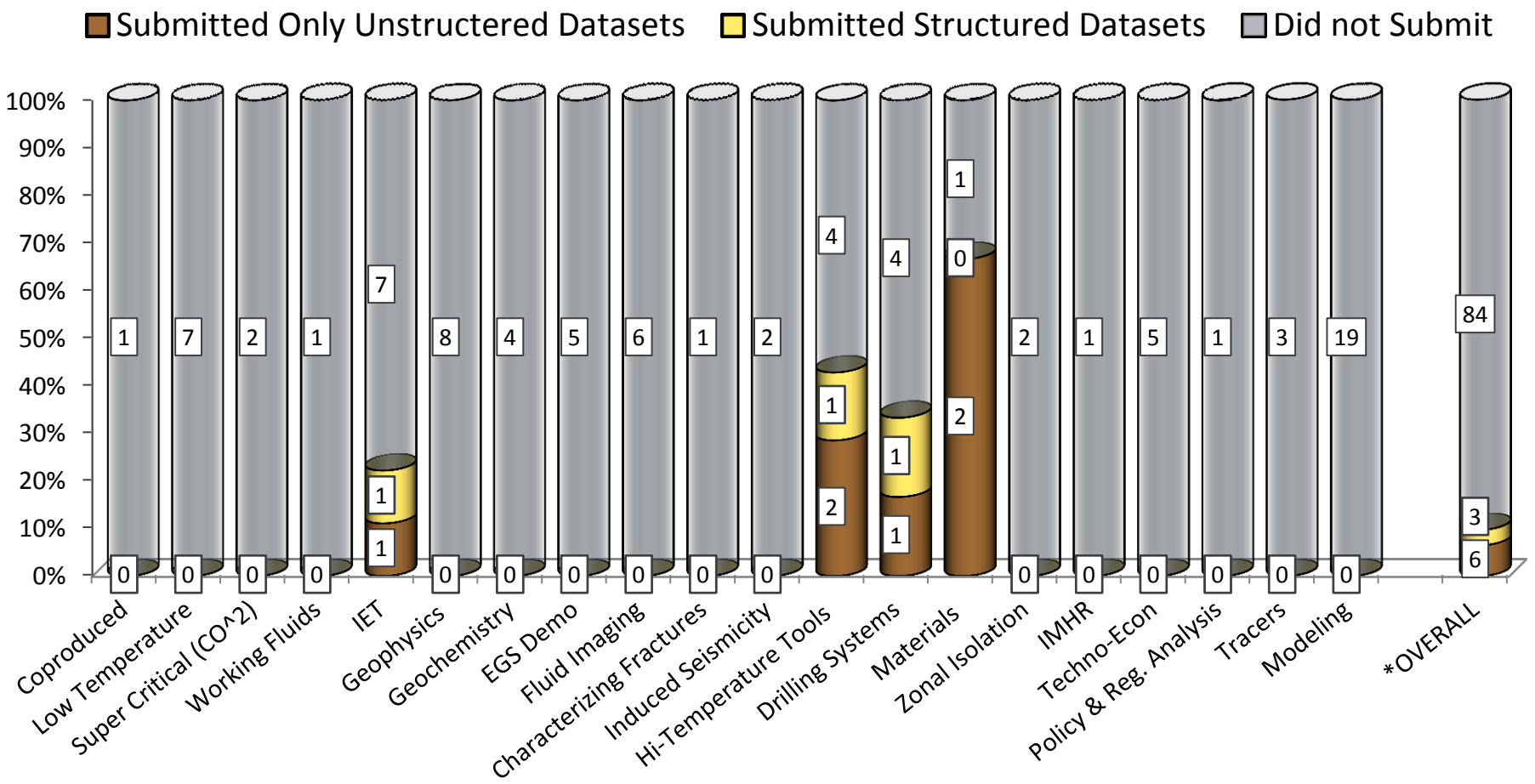


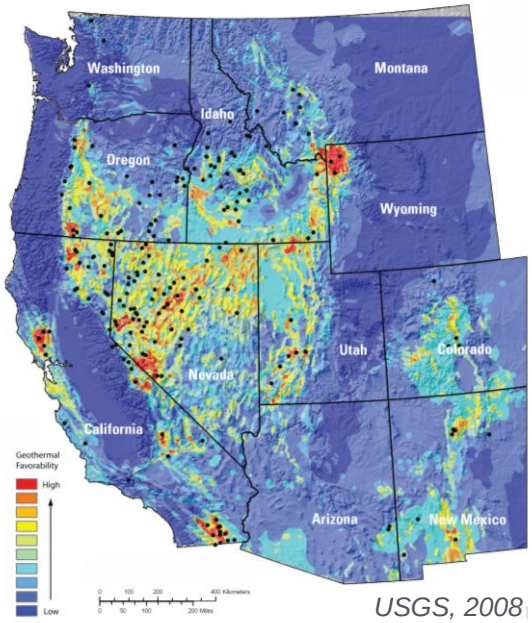
Technology Area

*OVERALL total number of submitters (93) in all technology areas compared to structured and unstructured datasets

Special thanks to Ava Coy, Sara Gonnion, and the Sentech team for all their hard work to make the 2013 Peer Review a success!

THANK YOU!

A ROADMAP FOR STRATEGIC DEVELOPMENT OF GEOTHERMAL EXPLORATION TECHNOLOGIES



USGS, 2008

Eric Hass
U.S. DOE/GTO Hydrothermal Program Manager

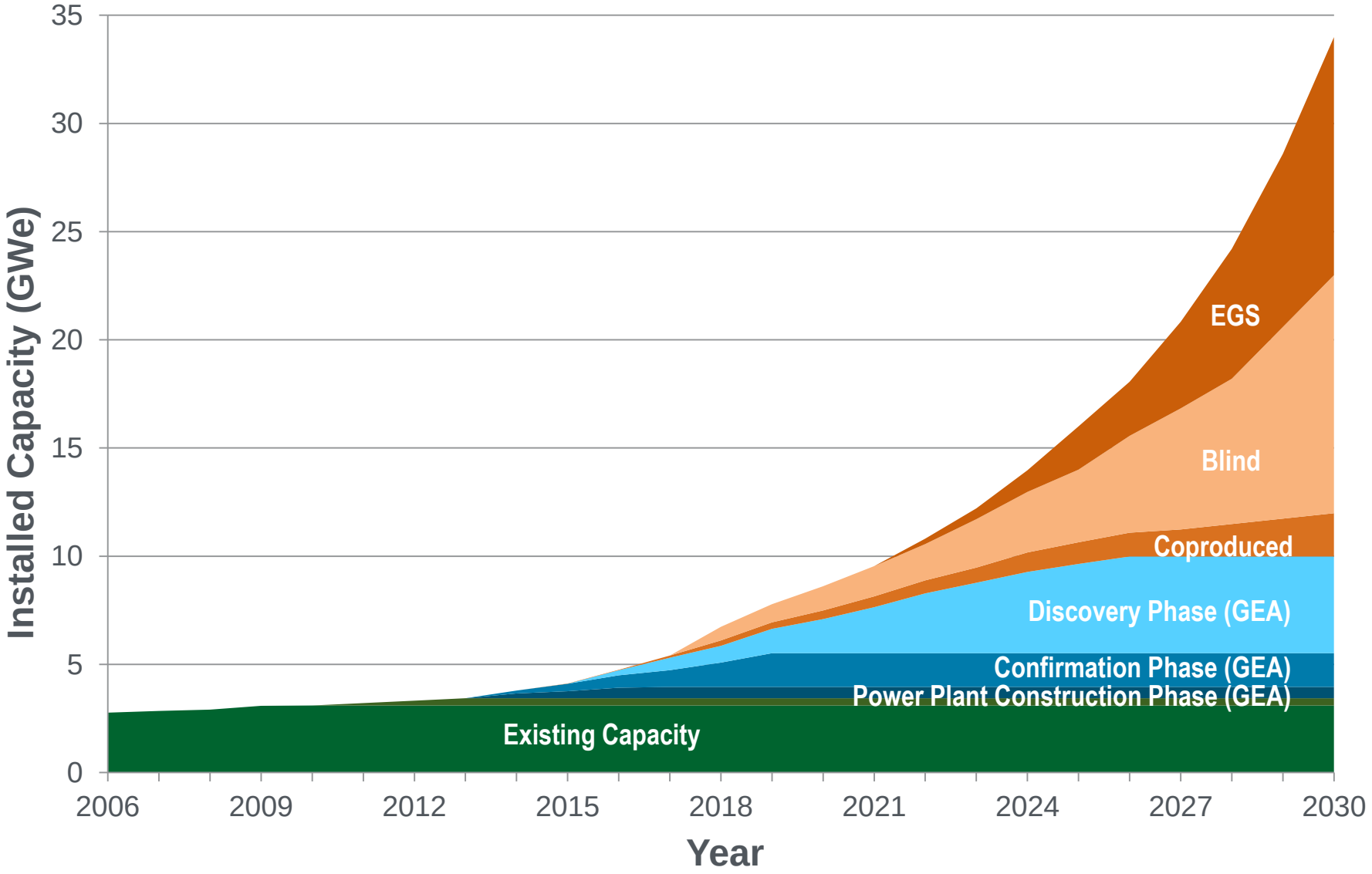
****

Dr. Benjamin R. Phillips
SRA International, Inc. and U.S. DOE

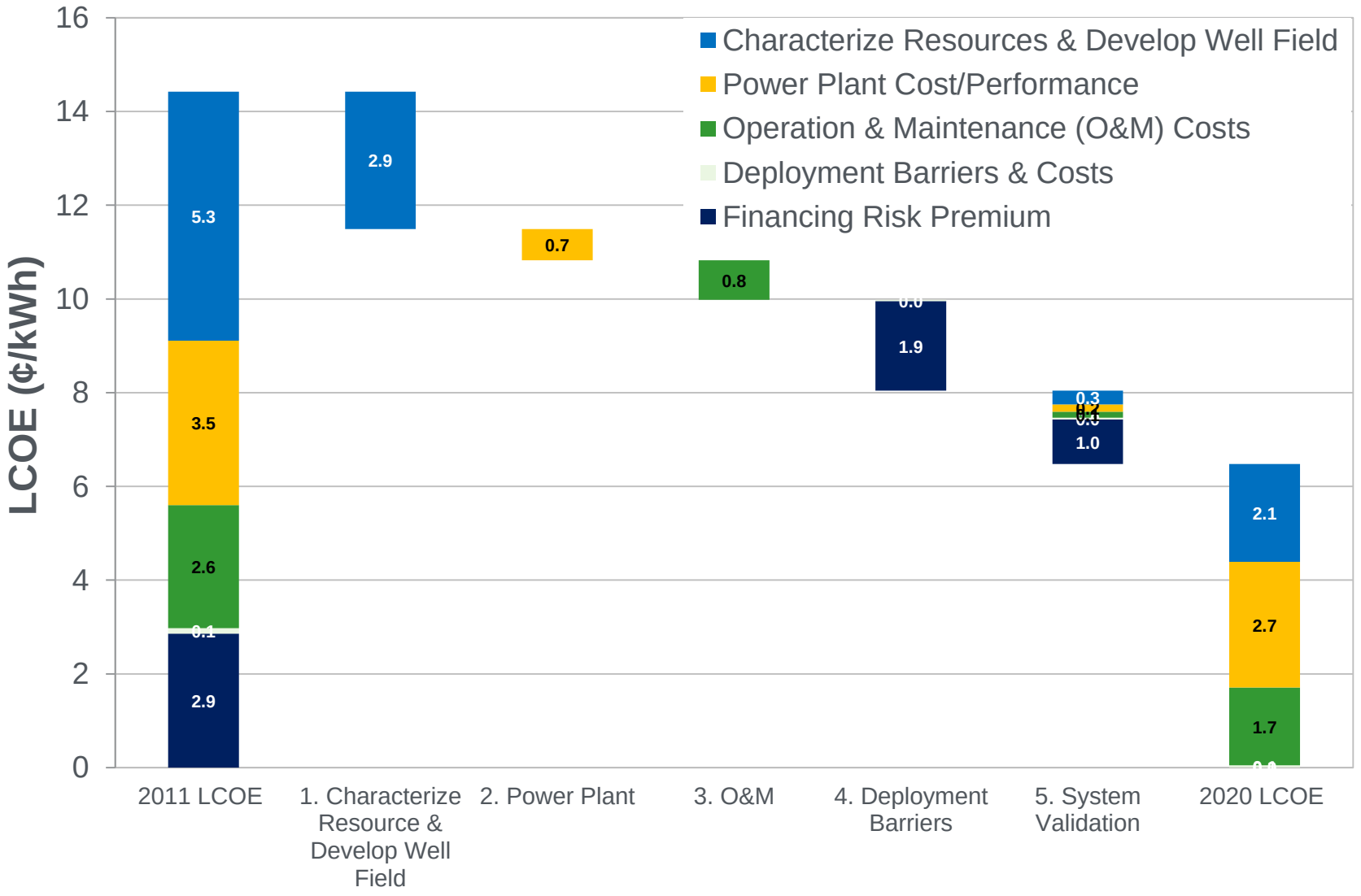
Dr. John Ziagos
Lawrence Livermore National Laboratory

Hildigunnur (Hidda) Thorsteinsson
U.S. DOE, now at Reykjavik Energy

Unlocking Geothermal



Hydrothermal Cost-Reduction Cascade



Roadmap purpose and process

- Goal of strategic roadmapping within DOE EERE is to define target metrics and guide investments for a given program
- Grow deployment through enabling commercialization in a competitive energy market
- Roadmaps constructed around performance drivers critical to meeting overall cost targets
- Engage the R&D community and the private sector for guidance on needs and viable pathways
- Develop a plan to inform funding opportunities and program progress
- Continuously gather input and periodically revise

GTO Planning Process

10/2010 Technology Planning Workshop, Sacramento, CA

06/2011 Workshop Report

http://www1.eere.energy.gov/geothermal/pdfs/iet_needs_assessment_draft.pdf

07/2011 Metrics and Milestones Roadmapping Info Exchange, LBNL

02/2012 Results distributed for comment at 2012 Stanford Workshop

GEOTHERMAL TECHNOLOGIES PROGRAM

MT/EM Tools/AFMAG

Improve or develop new measurement tools and devices

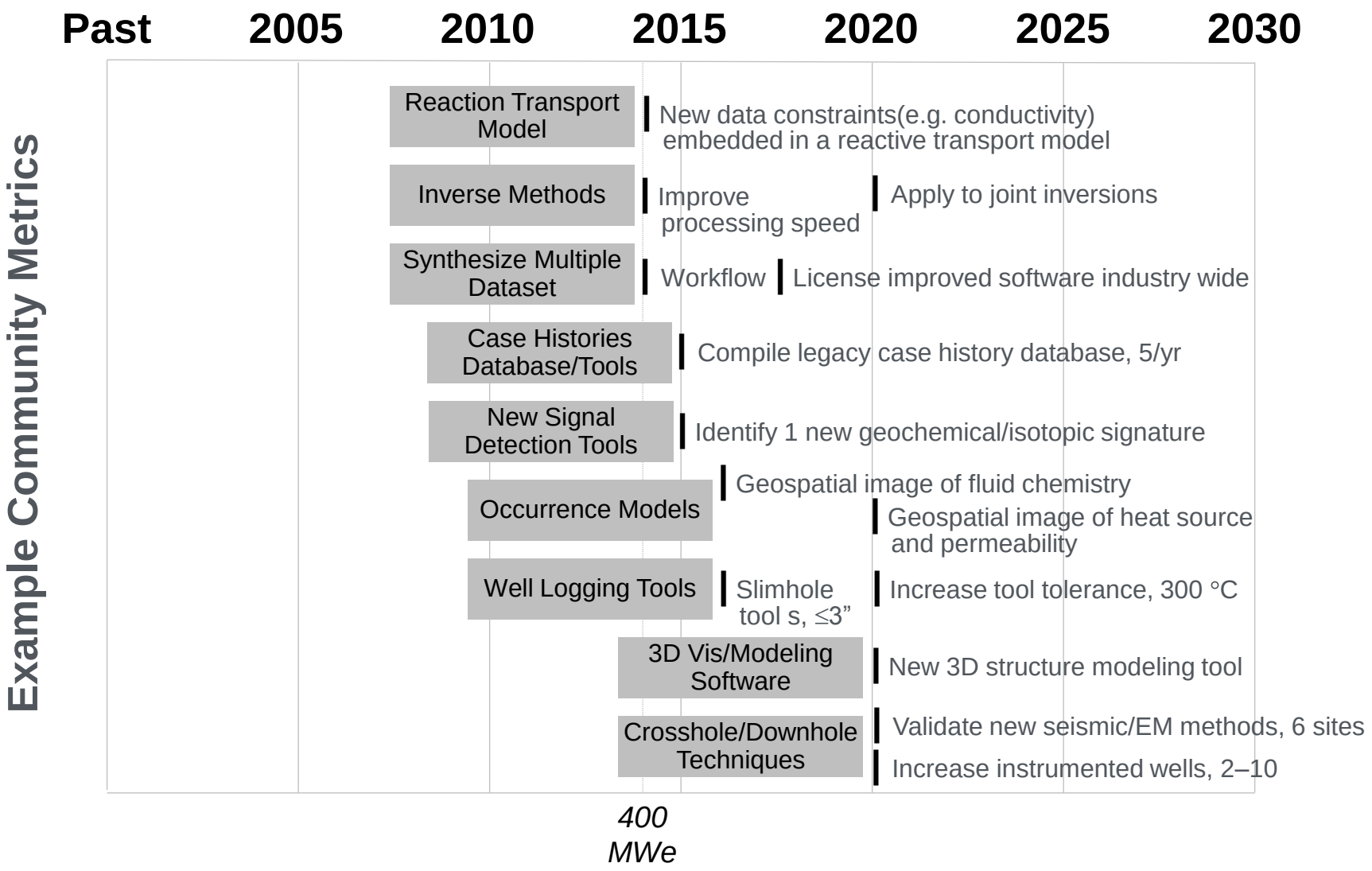
Technology Advancement	Technology Metrics			
	Metric Unit for Advancement	2011 Status	Target	When
Model study to determine what is required to build an airborne system (EM, MT) with sufficient power and sensitivity to access geothermal systems	New system	Not available	1 Done	2012
Based on results above with a partner build a prototype system and test (EM)	New systems	NADA	Complete	2015
Innovative platforms for airborne systems; e.g., blimps (EM)	Depth of penetration	400 m	2Km	2020

Ongoing NREL anal[illegible]

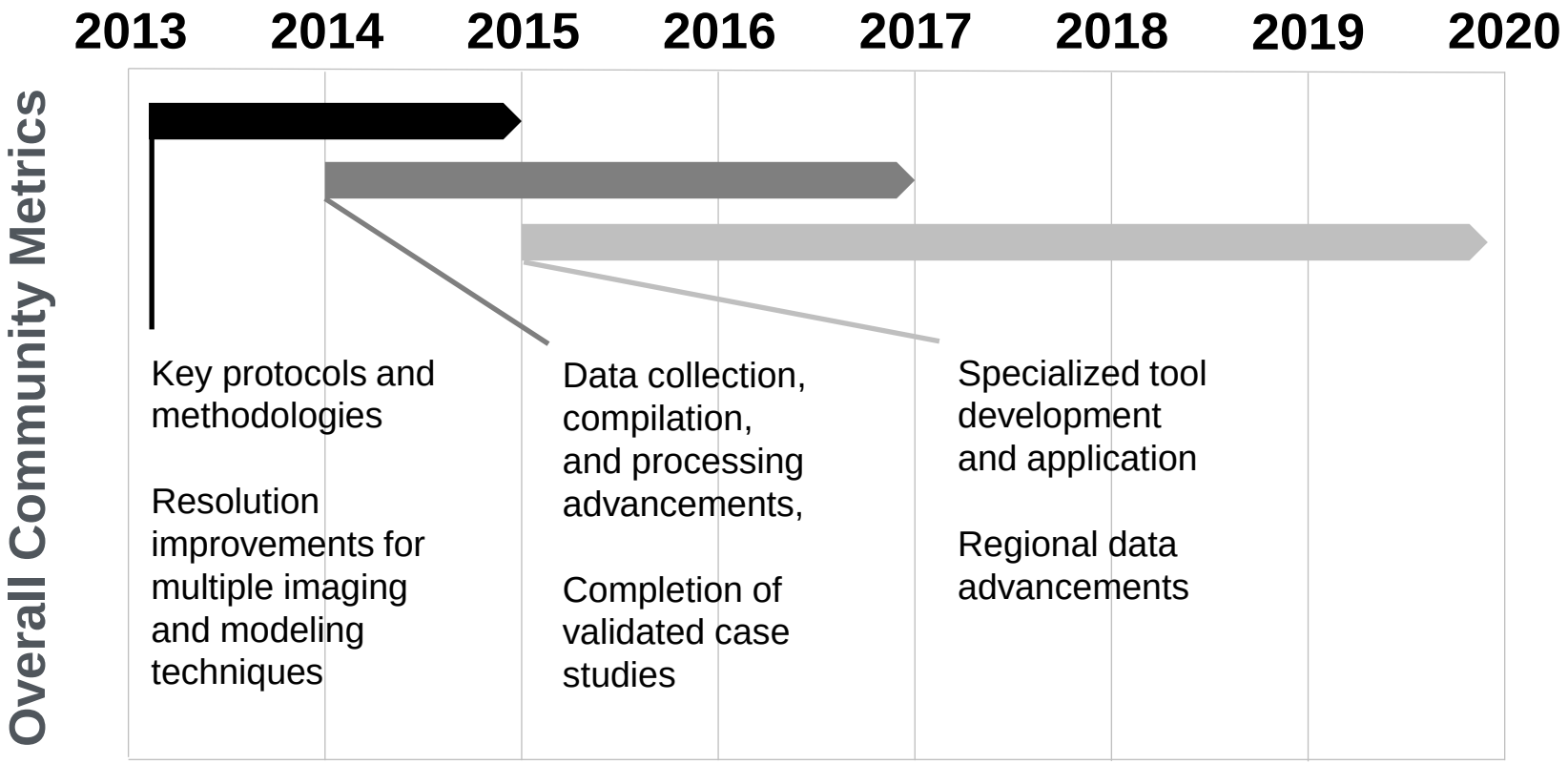
Workshop Results
Priority technology needs

Cross-Cutting	• Conceptual Models • Structural Evaluation of Geothermal Systems • 3D Visualization and Modeling Software • Database of Case Histories and Analysis Tools • Geothermal Potential Maps*
Geology/Structure Stress/Strain	• Core Log Analysis • Stress/Strain Data Mapping • Basic Geologic Setting and Permeability • Coupled Transport Modeling • District Mapping* • Rock Property Data-Data Set*
Non-Invasive Geophysics	• Gravity Tools and Techniques • Inverse Methods • Seismic (reflection seismic, passive, source) • EM Improvements* • 3D EM Interpretation Techniques* • High Density Data Acquisition Instruments*
Invasive Geophysics	• Well Logging Tools • Crosshole/Downhole Techniques • Vertical Seismic Profiling (VSP) • EM Improvements* • Heat Flow Logging*
Airborne Exploration	• MT/EM Tools/AFMAG • Gravity Tools • Regional Remote Sensing Data Collection • Synthesis of Multiple Data Sets • Processing Methods* • Single Source Database*
Geochemistry	• Reaction Transport Modeling • Isotopic Exchange/Permeability Distribution • New Signal Detection Tools • Geothermometers* • Fracture Detection Tools* • Improved Consistent Thermodynamic and Kinetic Database*

Workshop Results
Metrics proposed



Workshop Results
Metrics summarized

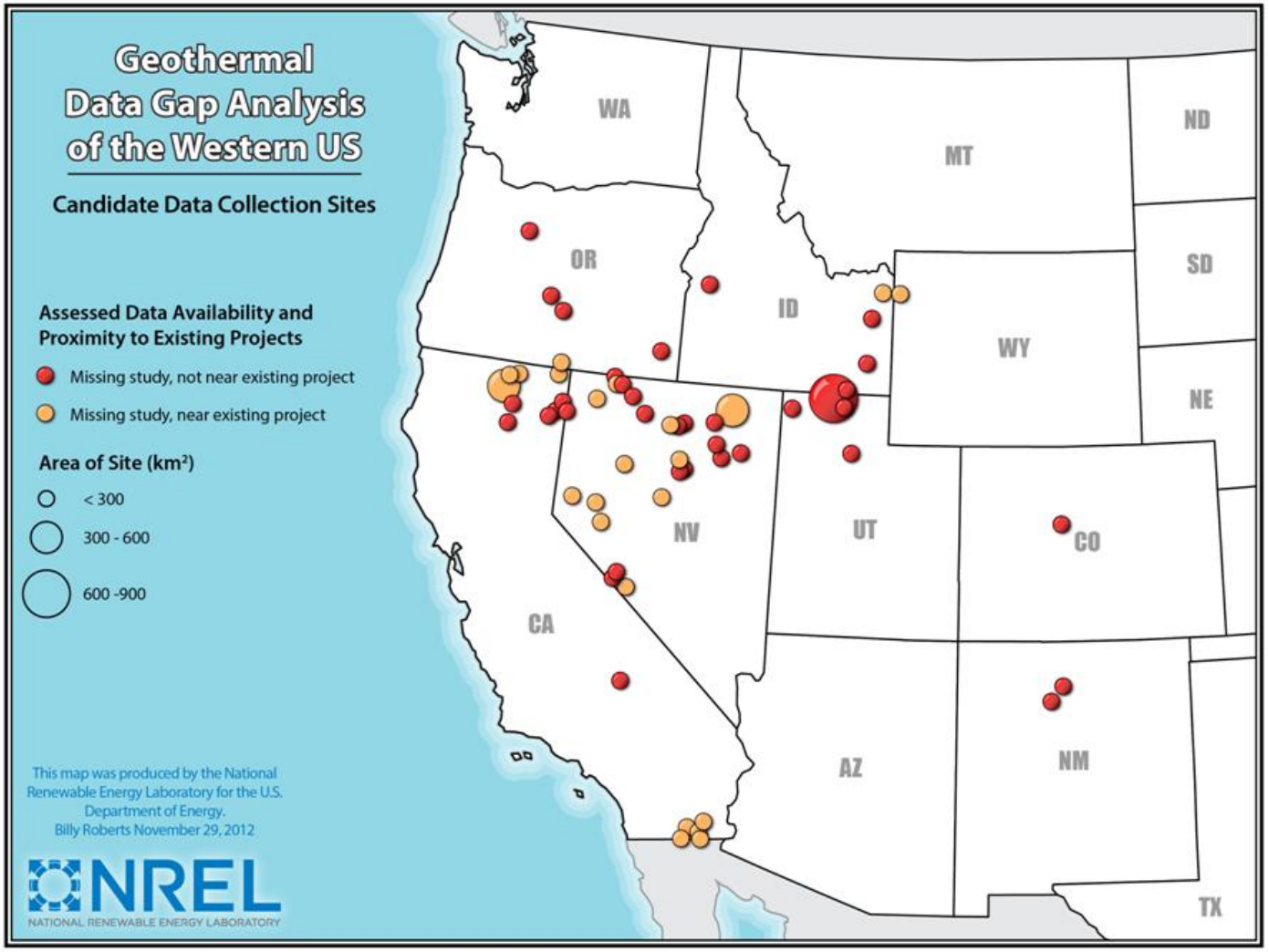


NREL Baseline Exploration Suite Spatial-operational phases

	Input Cells							
	Output/Calculation cells			Initial Reference	(Walker, et. Al. GRC 2005)			
	Phase Total							
	Project Total							
	Target Power Sales	30	MW					
	Typical Area Covered Based on MW	6	sq. miles					
	Method	Notes	Unit Cost	Unit	Cost Source	# of Units	Well Multiplier	Total Cost
Phase I (no site visit)	Regional Reconnaissance							
	Geothermal Literature Review	Seismic, regional tectonics, mining history, past expl	$ 200.00	hour	Database	80		$ 16,000.00
	Geothermometry	Initial Geothermometry	$ 30.00	sample	Database	20		$ 600.00
	Multispectral Imaging	Collect available data for aerial photos, satellite ph	$ 370.23	sq. mile	Database	40		$ 14,809.00
	Data Acquisition-Manipulation	Conceptual Model 1	$ 250.00	hour	Database	60		$ 15,000.00
							Phase 1 Total $	$46,409
Phase II (no permit required)	Prospect Evaluation							
	Hyperspectral Imaging	Hydrothermal Alteration and Mineral Map	$ 1,337.56	sq. mile	Database	40		$ 53,502.58
	Compound and Elemental Analysis	Ground water/hot spring lab analysis	$ 30.00	compound	Database	50		$ 1,500.00
	Geothermometry	Detailed Geothermometry	$ 30.00	sample	Database	50		$ 1,500.00
	Field Mapping	Geologic Mapping I	$ 600.00	hour	Database	40		$ 24,000.00
	Modeling-Computer Simulations	Mineral Model, Conceptual Model 1	$ 195.00	hour	Database	40		$ 7,800.00
							Phase 2 Total $	$88,303
Phase III (permit required)	Project Appraisal							
	Ground Gravity Survey		$ 68.31	station	Database	500		$ 34,155.56
	Aeromagnetic Survey		$ 167.34	mile	Database	200		$ 33,467.20
	Magnetotellurics		$ 1,738.83	station	Database	75		$ 130,412.20
	Reflection Survey		$ 44,946.67	sq. mile	Database	6		$ 269,680.00
	Field Mapping	Geologic Mapping II	$ 600.00	hour	Database	40		$ 24,000.00
	Modeling-Computer Simulations	Conceptual Model 2	$ 195.00	hour	Database	40		$ 7,800.00
							Phase 3 Total $	$499,515
Phase IV (Initial Drilling)	Project Appraisal							
	Thermal Gradient Holes	500 foot rotary holes	$ 16.50	foot	Database	500	20	$ 165,000.00
	Core Hole Drilling	small diameter well to determine temp	$ 200.00	foot	Interview	3500	5	$ 3,500,000.00
	Cutting Analysis		$ 4,000.00	100 feet cut	Database	15		$ 60,000.00
	Core Analysis	Stress regime	$ 10,000.00	30 foot core	Database	10		$ 100,000.00
	Slim Holes	Min 3.5" bottom hole diameter	$ 169.90	foot	Database	7000	2	$ 2,378,530.00
	Compound and Elemental Analysis		$ 30.00	compound	Database	50		$ 1,500.00
	Modeling-Computer Simulations	Conceptual Model 3	$ 195.00	hour	Database	80		$ 15,600.00
							Phase 4 Total $	$6,220,630
Phase V (Confirmation Drilling)	Development							
	Deveopment Drilling	Full Diameter Well	$ 1,000.00	foot	Interview	7000	1	$ 7,000,000.00
							Phase 5 Total $	$7,000,000
Phase VI (Final Drilling)	Development							
	Production/Injection Wells	Production/Injection Wells	$ 1,000.00	foot	Interview	7000	5	$ 35,000,000.00
							Phase 5 Total $	$35,000,000
							Total Exploration (Pre Phase V)	$ 6,854,856.53

Jenne et al., 2013

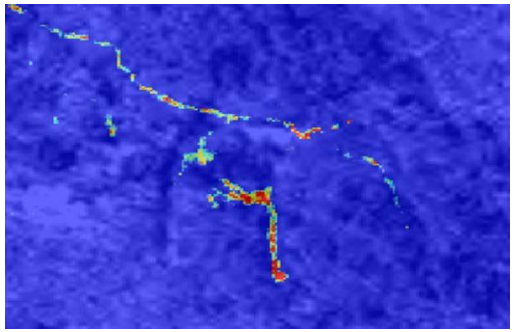
NREL Data Gap Analysis
Priority areas for data collection



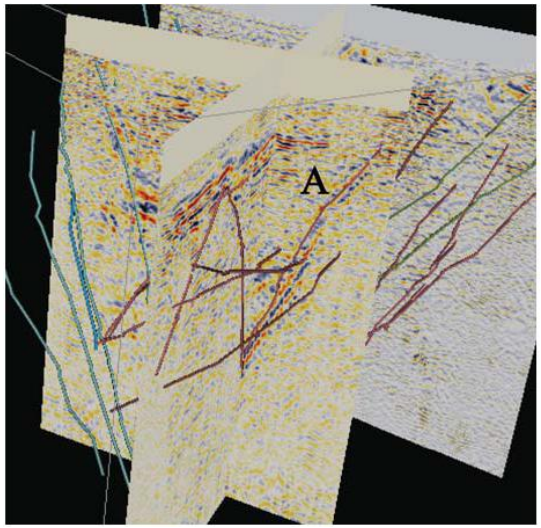
Esposito et al., 2013

Technology Pathways

Temperature



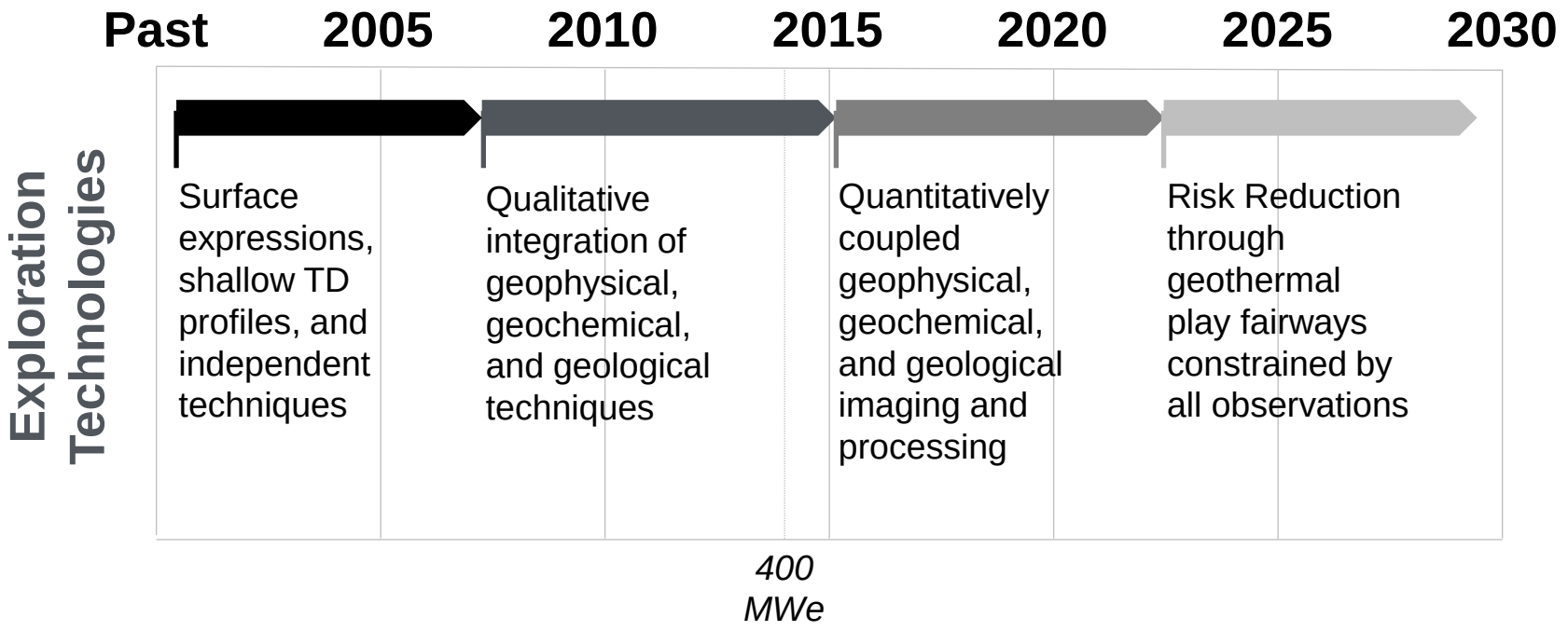
Permeability



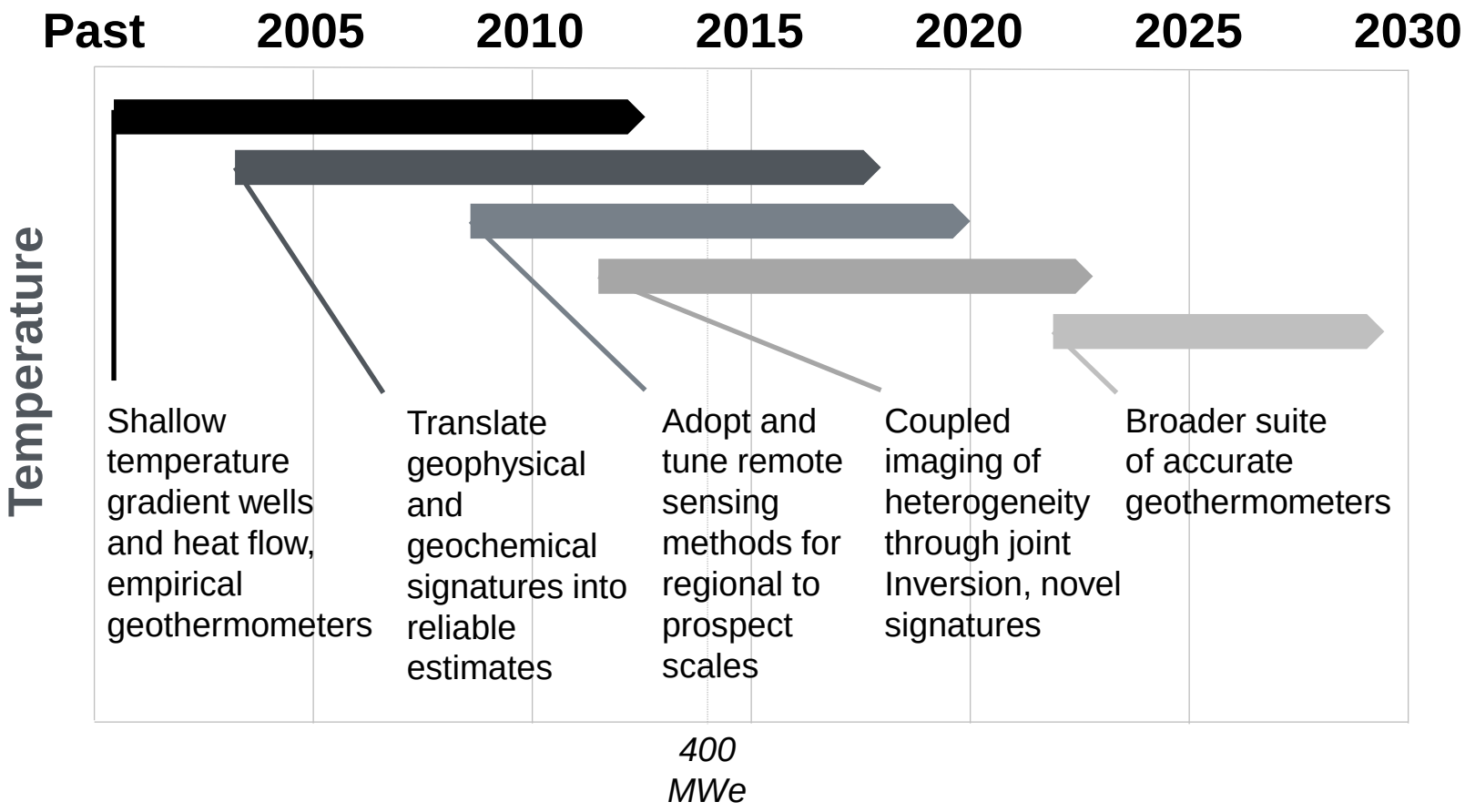
Frary et al., 2011

Fluids

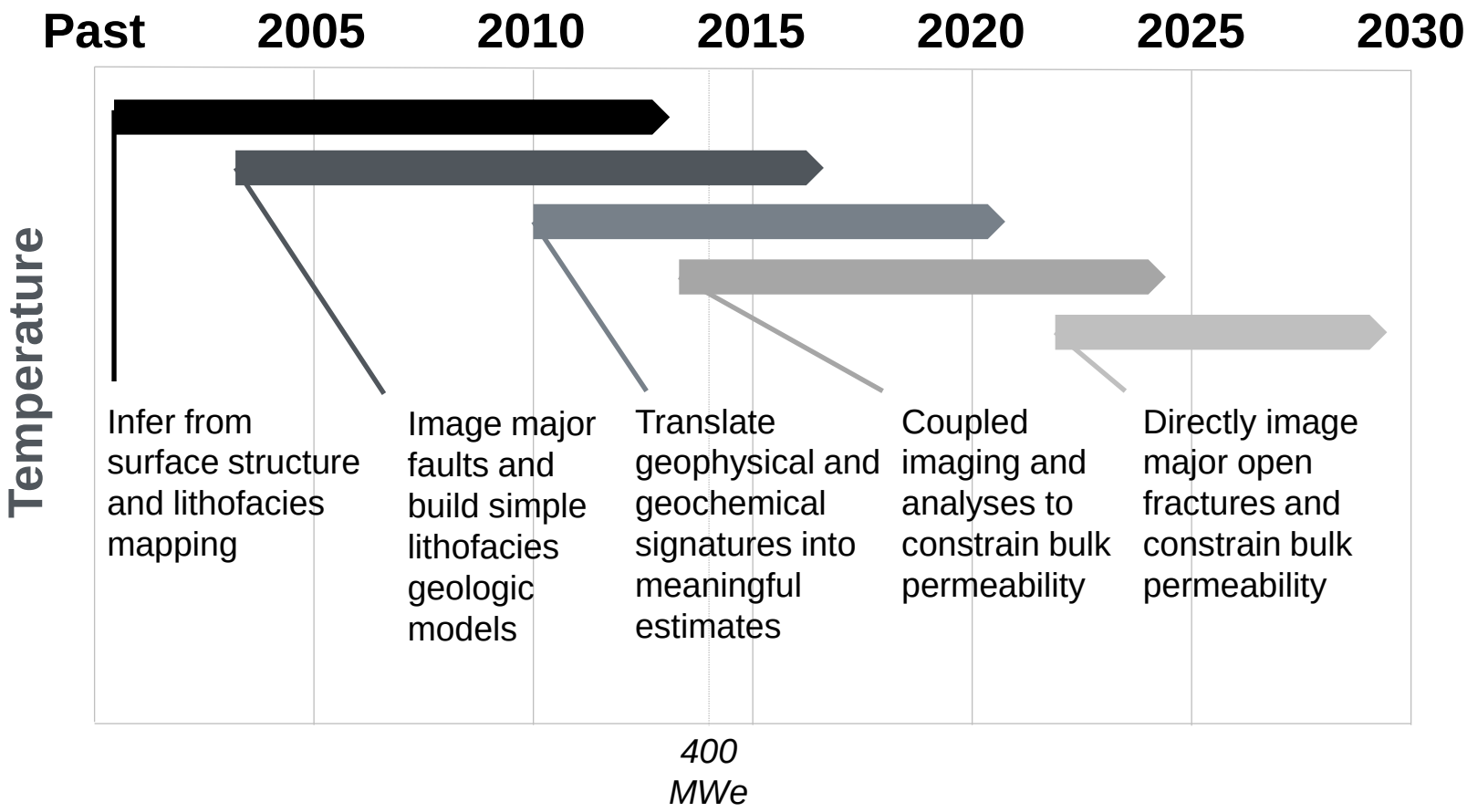
Exploration Overall
Technology Evolution Timeline



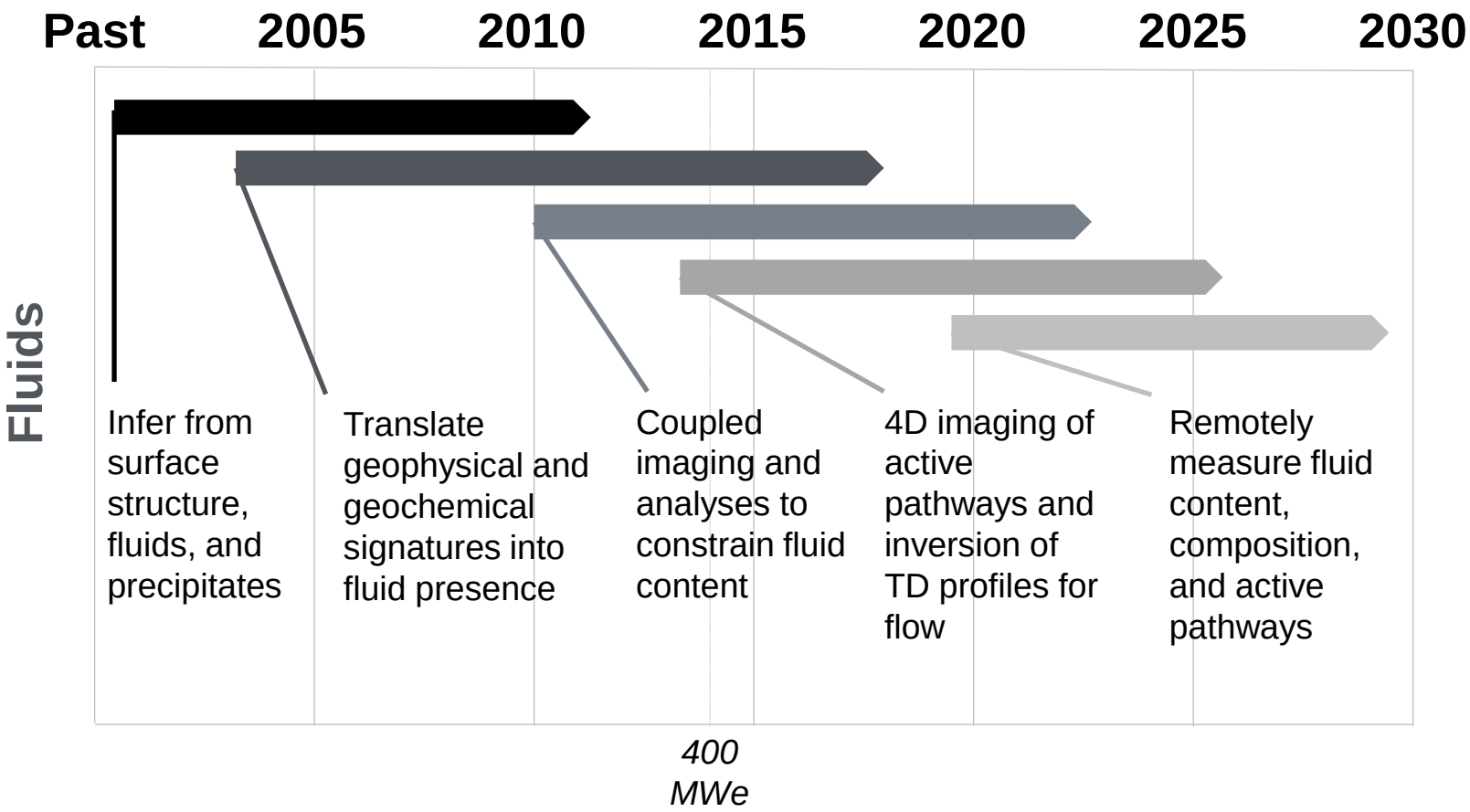
Temperature
Technology Evolution Timeline



Permeability
Technology Evolution Timeline



Technology Evolution Timeline



Technology Needs
Categories and Priorities

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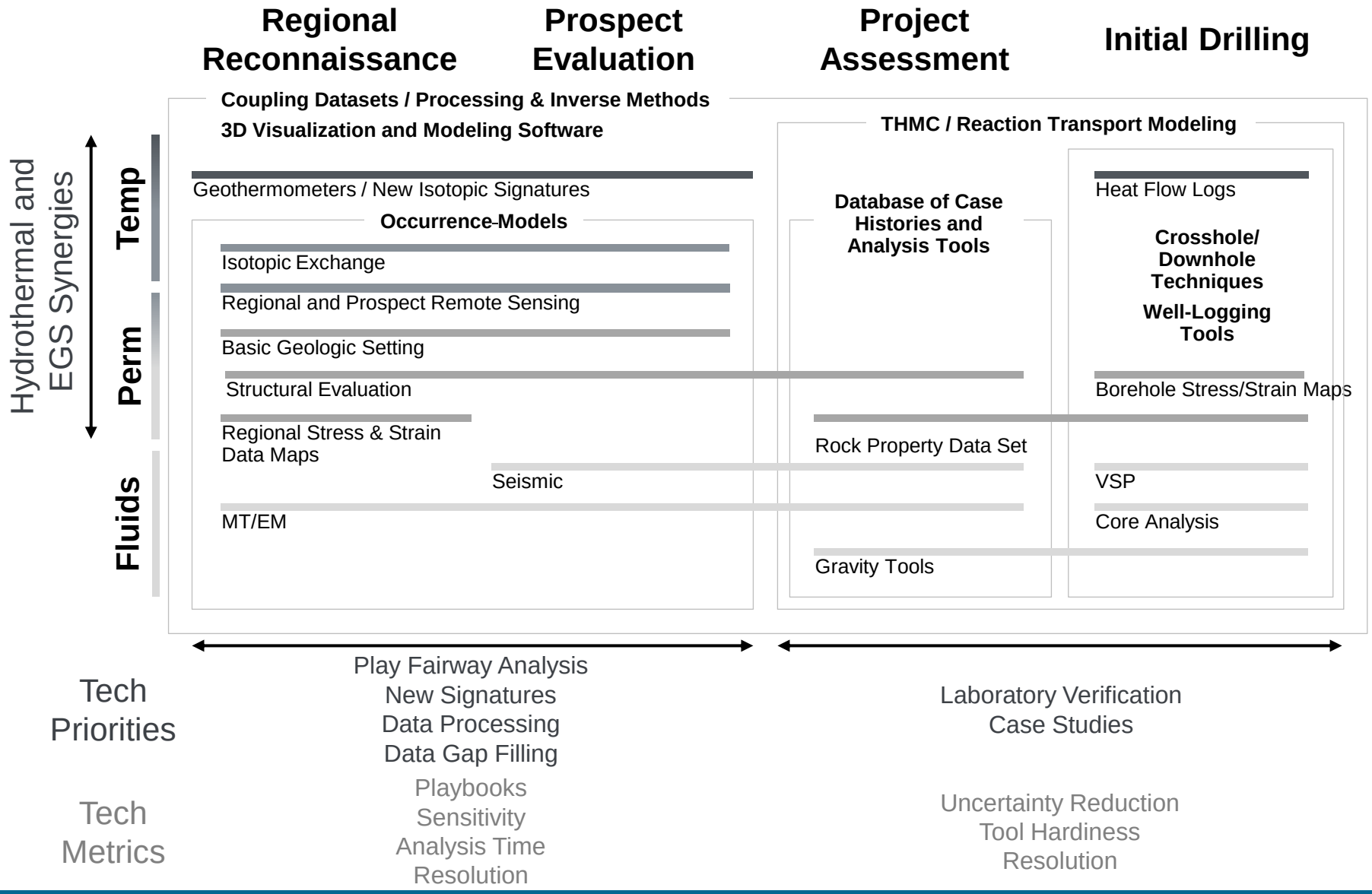
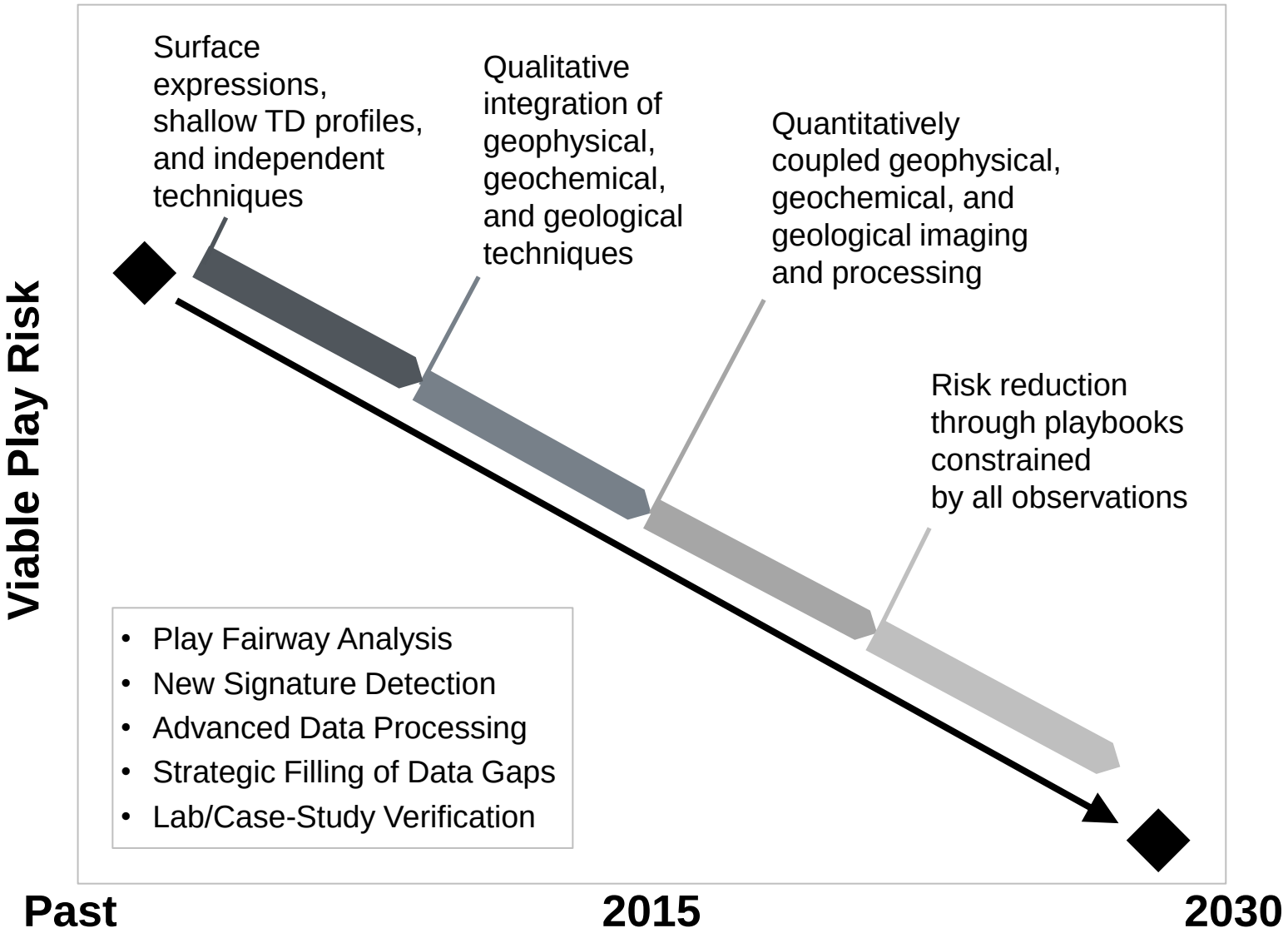


Overall Exploration Goals



Feedback Welcome

- This is a fluid, living document
- Talk to us:
  - Hydrothermal Team Members
    - Ava Coy, Mark Ziegenbein
    - Brittany Segneri, Erik Swanton
  - GTO Team Members
  - Roadmap authors

Hydrothermal Program

Other Focus Areas

- Co-Production / Low Temp Applications
- Strategic Minerals
  - Tim Reinhardt / Sara Gonnion

EGS is High Impact

Unlocking Geothermal Potential

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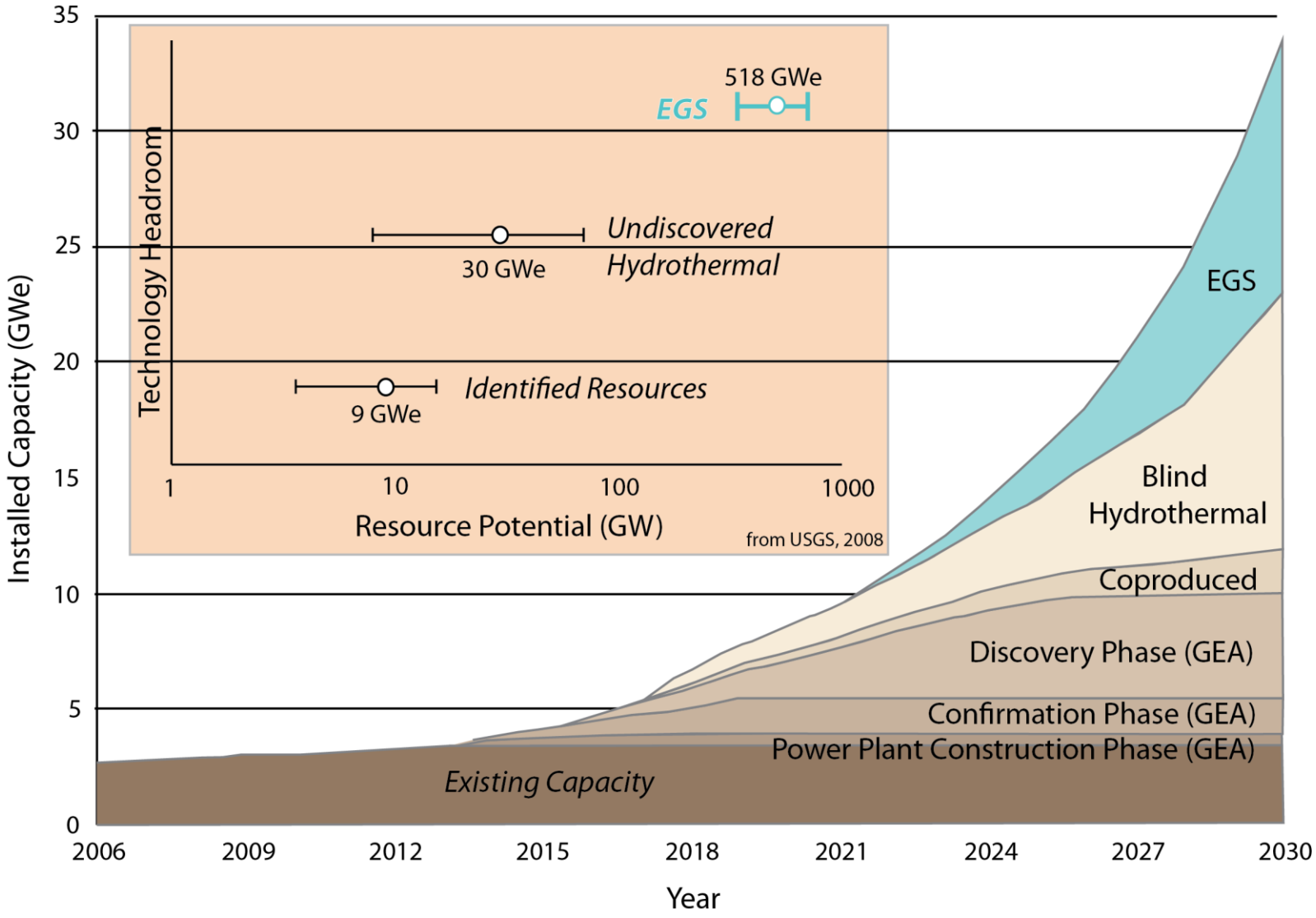

Enhanced Geothermal Systems

State of the Technology – 40 yrs of progress

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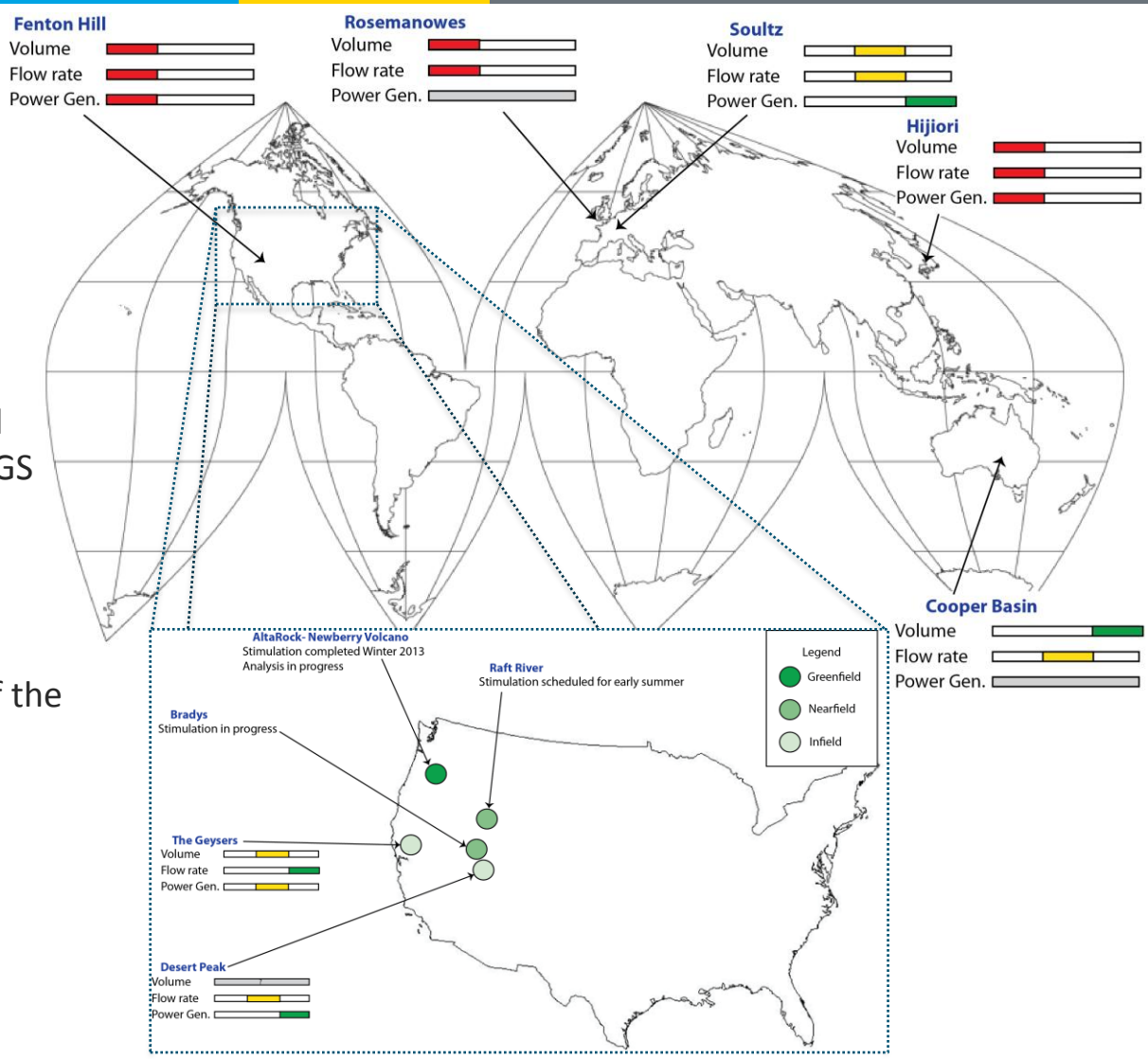
Critical Needs:

- ***Characterization*** of ***local stress***, ***chemical potential***, and ***thermal pathways***

- Achieving ***sufficient productivity*** (and stimulated volume) for commercial EGS power generation

Path Forward:

- Remaining gaps are the foundation of the EGS portfolio
- Most ***technology needs*** are ***evolutionary- not revolutionary!***



Concept proven but not yet commercial scale

EERE Strategic Planning
GTO's EGS Technology Roadmap

WHY

To support visions, goals, and missions articulated in strategic plans.

- To present a ***strategy*** for ***promoting technology advancements*** necessary to optimize EGS.
- Forms the basis for current and future ***EGS R&D investment strategies***.
- ***Communicate*** the EGS Program R&D strategy to:
  - stakeholders, members of other subsurface science and energy sectors
  - legislative and policy administrators.

HOW

Drafted in collaboration with experts and stakeholders

- Informed by ***expert feedback*** and ***multiple workshops*** with industry, academia, national laboratories, trade associations.

WHAT

Represent the consensus thinking on major barriers and potential avenues of research to address barriers.

- Illustrates technical research paths over time:
  - ***Past*** practices
  - ***current*** GTO efforts
  - ***desired future capabilities and outcomes***

Workshop Results

EGS Technology Needs

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3 high-level EGS R&D topics & 8 unique tech paths identified to communicate EGS research needs

CHARACTERIZE	CREATE	OPERATE
- Identify natural fractures and flow paths	- Create new fractures and flow paths	- Manage fractures and flow paths
	- Monitor flow paths	- Monitor flow paths
	- Zonal Isolation	- Zonal Isolation
- Drilling	- Drilling	- Drilling
- Modeling	- Modeling	- Modeling
- Tools	- Tools	- Tools

EGS Technology Evolution

Characterize, Create and Operate

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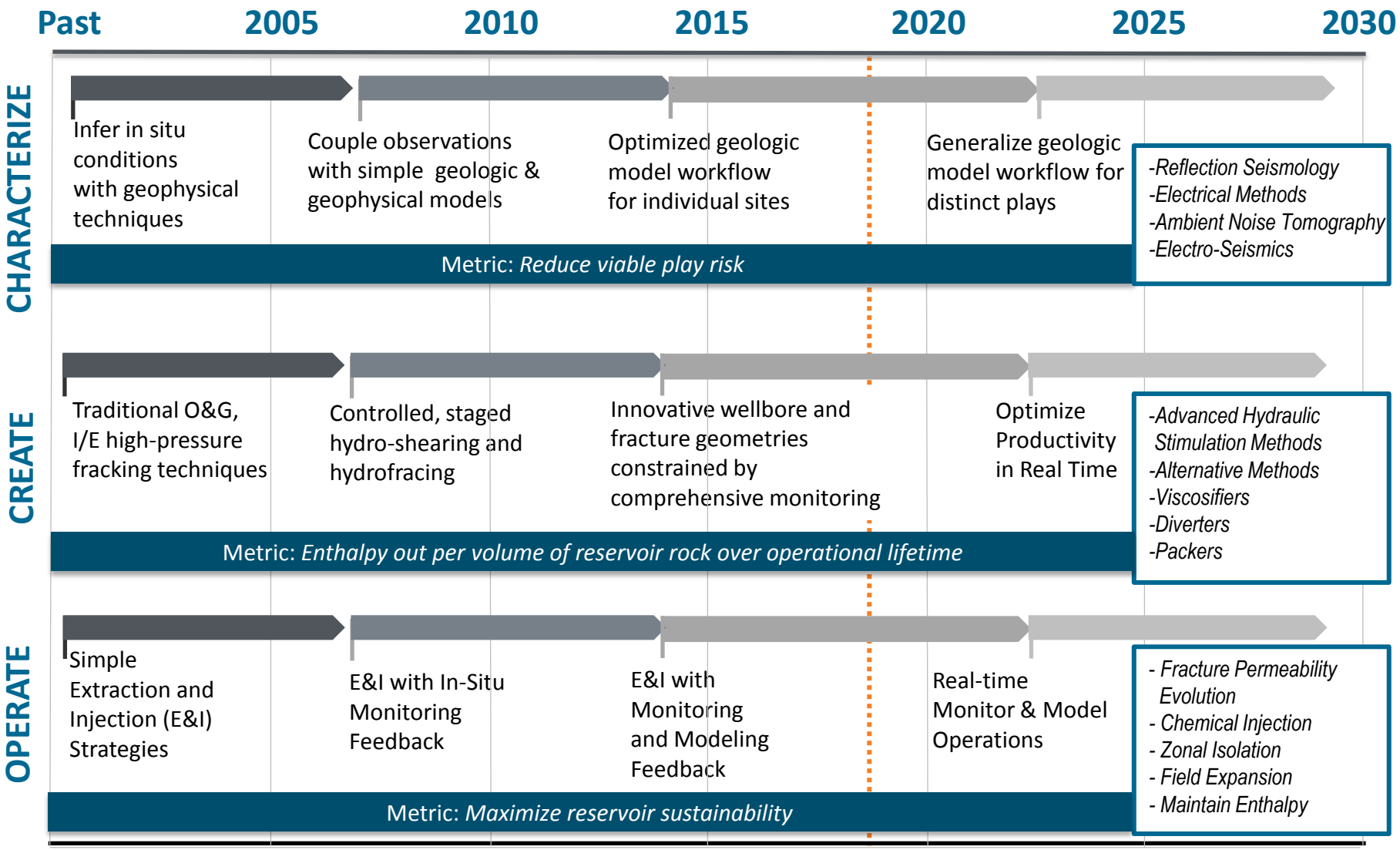

EGS Technology Pathway Metrics

Measuring R&D Progress

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Topic	Metric	Technology Pathway	Metric	Description
Characterize	Risk Reduction	Identify Natural Fractures and Flow Paths	Spatial resolution and ability to predict a priori reservoir performance	Develop precision geophysical methods, validated play books, and improved tools for subsurface.
Create	Reservoir Performance	Create New Fractures and Flow Paths	Fractured rock volume ability to predict a priori reservoir performance	Develop techniques to maximize heat extraction from a given volume of reservoir rock with a minimum of boreholes.
Create/Operate	Reservoir Performance	Monitor Flow Paths	Enthalpy and/or fractured rock volume	Develop ability to more accurately monitor and control flow paths in the reservoir.
Create/Operate	Reservoir Performance	Zonal Isolation	Enthalpy and/or fractured rock volume	Demonstrate the ability to isolate sections of the wellbore and reservoir.
Operate	Reservoir Performance	Manage Fractures and Flow Paths	Thermal drawdown and reservoir sustainability	Develop the ability to manage EGS reservoirs improving reservoir lifetime and productivity.
All	RR and RP	Drilling	ROP/Costs	Develop next generation rock reduction, drilling and well completion technologies.
All	RR and RP	Modeling	Ability to predict a priori and manage in real time reservoir performance	Develop robust, capable, and validated models of the subsurface.
All	RR and RP	Tools	T/P limits, sensitivity and durability	Develop tools that can withstand hostile EGS environments.

FORGE

Frontier Observatory for Geothermal Energy

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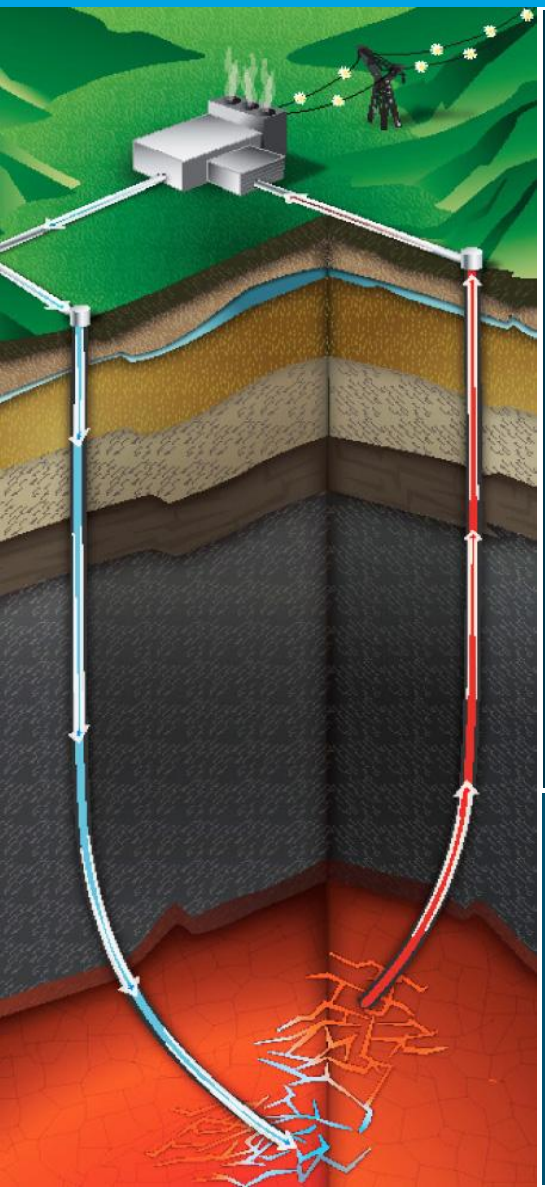


WHY?

Promote transformative science and engineering to:

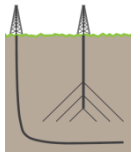
- Address key barriers
- Validate and optimize EGS technology
- Capture high fidelity data
- Ensure deep understanding and reproducibility for commercial scale-up

Federal Role:

- Test technologies/take technical risks not possible in private sector
- Work under aggressive timeframe
- Gather and disseminate comprehensive data sets

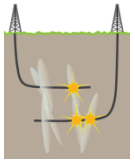
Direct benefits to all areas of research in the geothermal space

TECHNICAL CHALLENGES



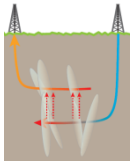
Reservoir Access

New well geometries and concepts, optimized drilling



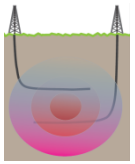
Reservoir Creation

Characterize local stress, zonal isolation, increase fractured volume per well



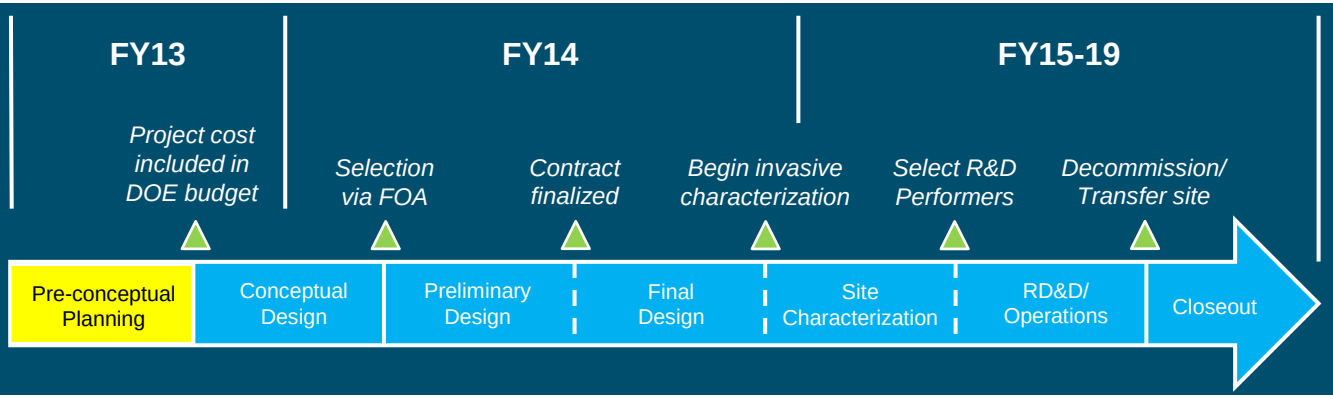
Productivity

Increase flow rates without excessive pressure needs or flow localization



Sustainability

Maintain productivity with minimal thermal drawdown and water losses



Thank you!