Exceptional service in the national interest

Sandia National Laboratories

SAND2015-4333C

SubTER: Subsurface Technology & Engineering Research Development, & Demonstration Crosscut

American Association of Petroleum Geologists - Annual Meeting
Denver, Colorado

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Mastery of the Subsurface Needed for U. S. Energy Security

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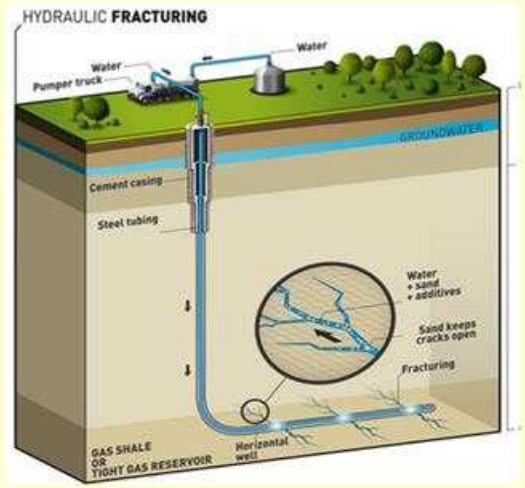
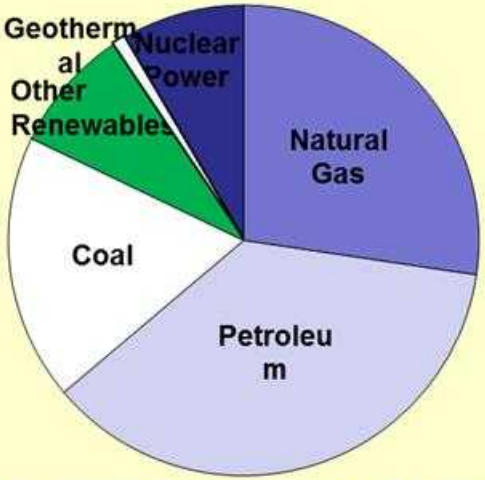
Shale hydrocarbon production

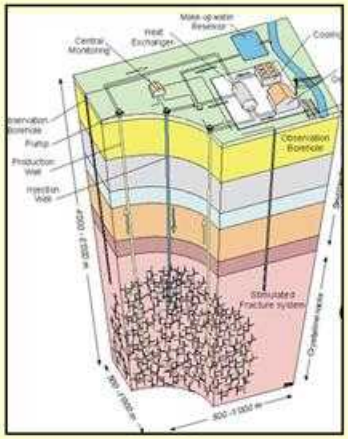




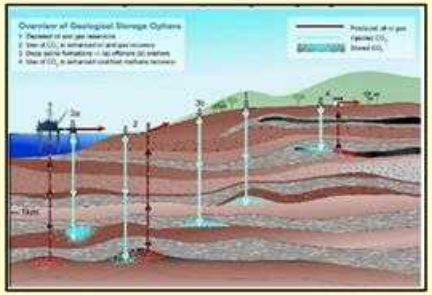
Primary Energy Use by Source, 2012

Quadrillion Btu [Total U.S. = 95.1 Quadrillion Btu]

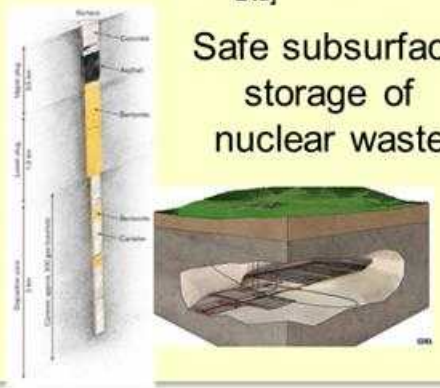
Enhanced geothermal energy



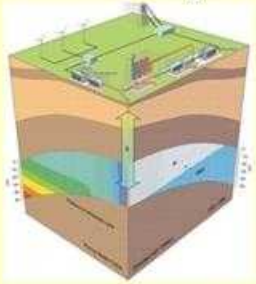
Safe subsurface storage of CO_2



Safe subsurface storage of nuclear waste



Compressed Air Energy Storage



Overview of Program Roles

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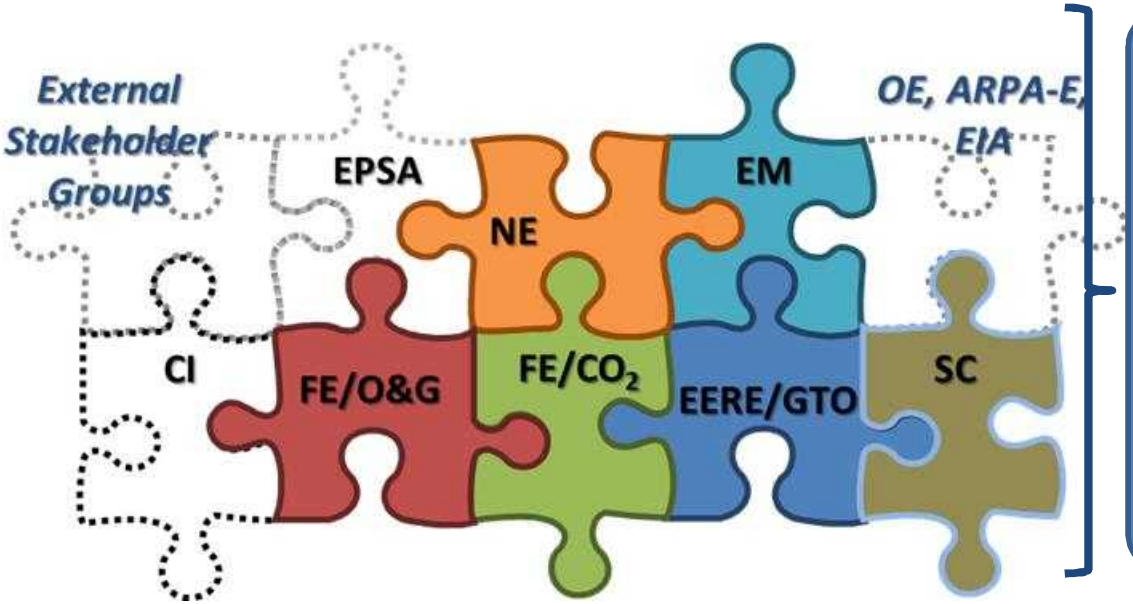
Energy Policy & Systems Analysis
- Advisement: Secretary of Energy
- Policy: low-carbon and secure energy economy
- Technical assistance: States and local entities

Nuclear Energy
- Policy and technology: disposition of used nuclear fuel and waste
- R&D: deep borehole disposal concept

Environmental Management
- Modeling and tools: subsurface evaluation and characterization
- Cleanup: nuclear weapons legacy

Congressional & Inter-governmental Affairs
- Interactions: elected officials, regulators, and stakeholders
- Information access for change agents



SubTER Tech Team
- Encompasses relevant offices
- Reports to Under Secretary for Energy and Science
- Identifies and facilitates crosscutting subsurface R&D and policy priorities for DOE
- Develops collaborative spend plan and funding scenarios

Fossil Energy/Oil & Gas
- R&D and access: clean, affordable traditional fuel sources
- R&D: drilling, well construction and integrity, and hydraulic fracturing technologies

Fossil Energy/Carbon Storage
- Policy and technology: challenges of CO_2 storage to inform regulators, industry, and the public
- R&D: CO_2 offshore and onshore storage

Energy Efficiency & Renewable Energy/ Geothermal Technologies Office
- R&D: locate, access, and develop geothermal resources
- R&D: access, create, and sustain enhanced geothermal systems (EGS)

Science
- Basic research: geology, geophysics, and biogeochemistry
- Expertise: subsurface chemistry, complex fluid flow

2014: DOE Subsurface Tech Team: SubTER Common Subsurface Challenges

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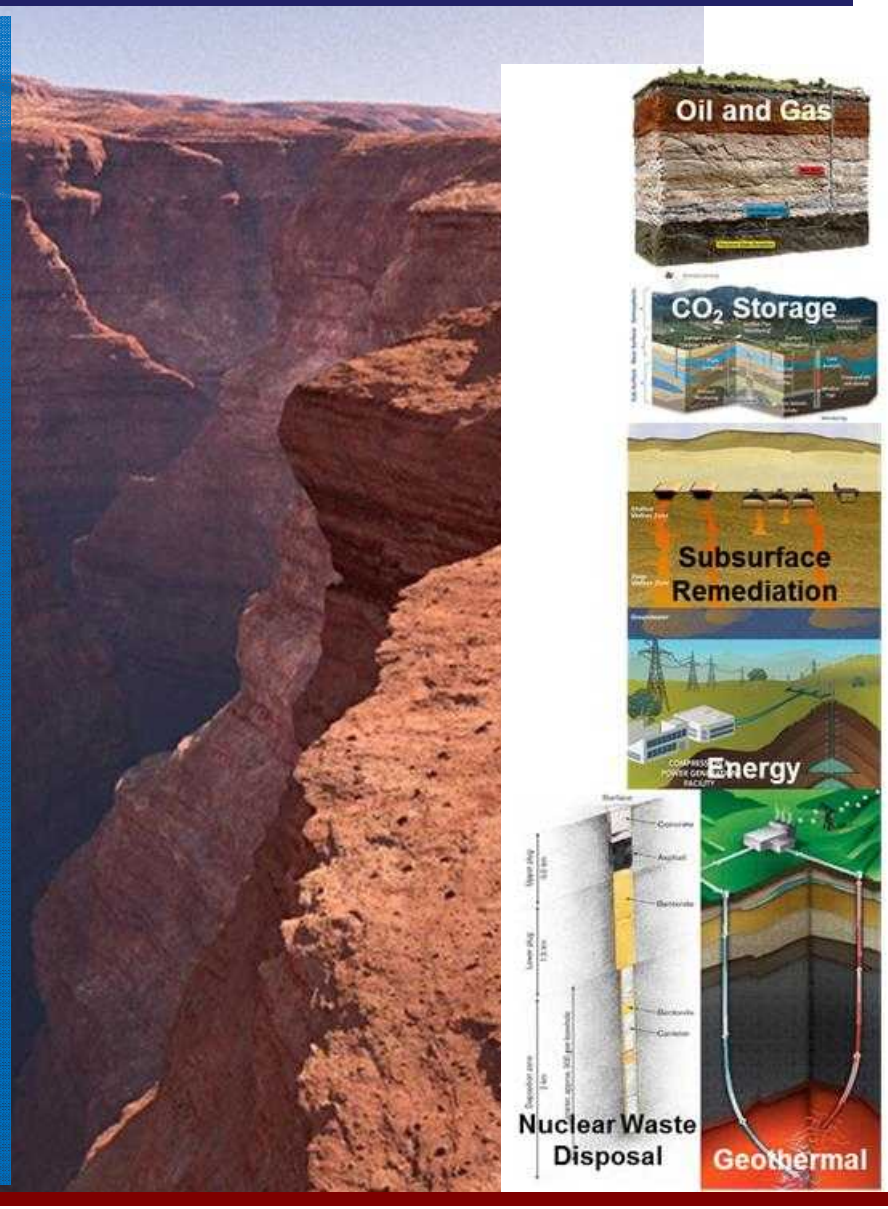
Discovering, Characterizing, and Predicting
Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resource, and quantitatively infer their evolution under future engineered conditions

Accessing
Safe and cost-effective drilling, with reservoir integrity

Engineering
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

Sustaining
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

Monitoring
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes



Many Common Subsurface Challenges

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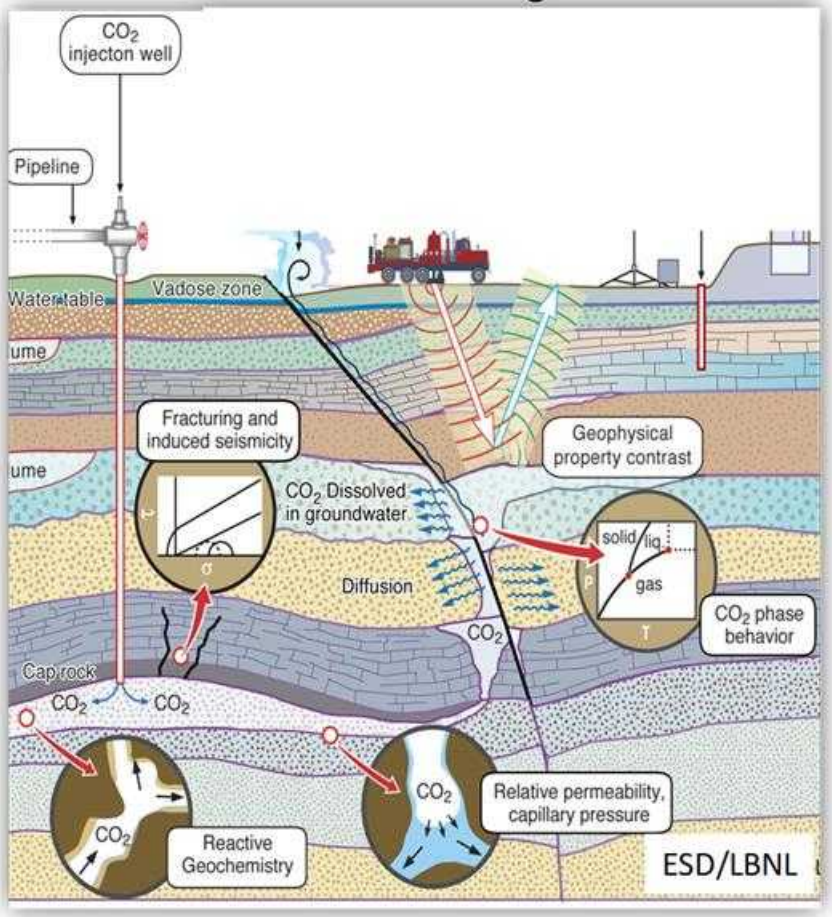
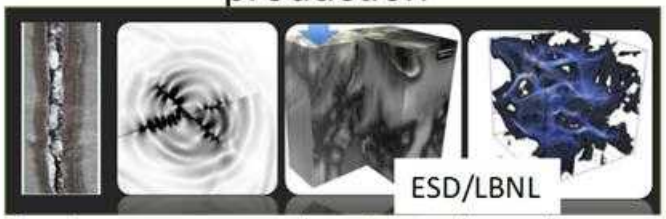
Reduce risk and cost of energy waste storage

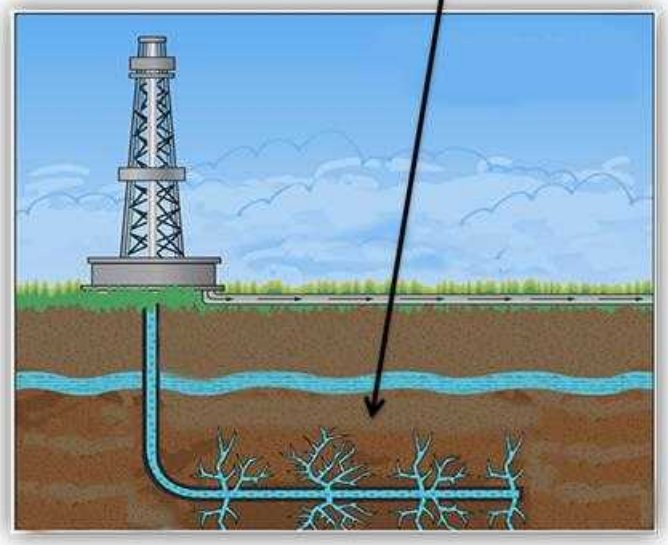


Geological Carbon Sequestration

More with Less: Improve efficiency & minimize environmental impact of energy production



Fracture processes mineral-organic interactions flow



Shale Gas Production

Adaptive Control of Subsurface Fractures and Fluid Flow

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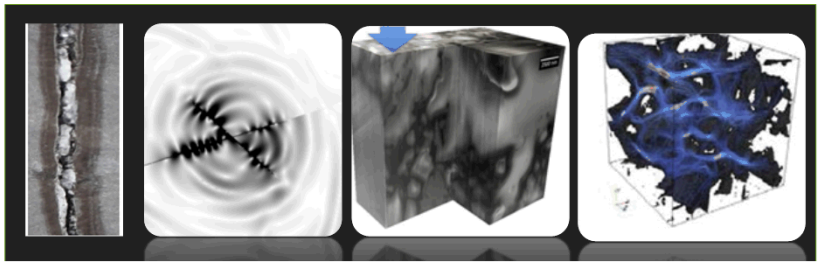
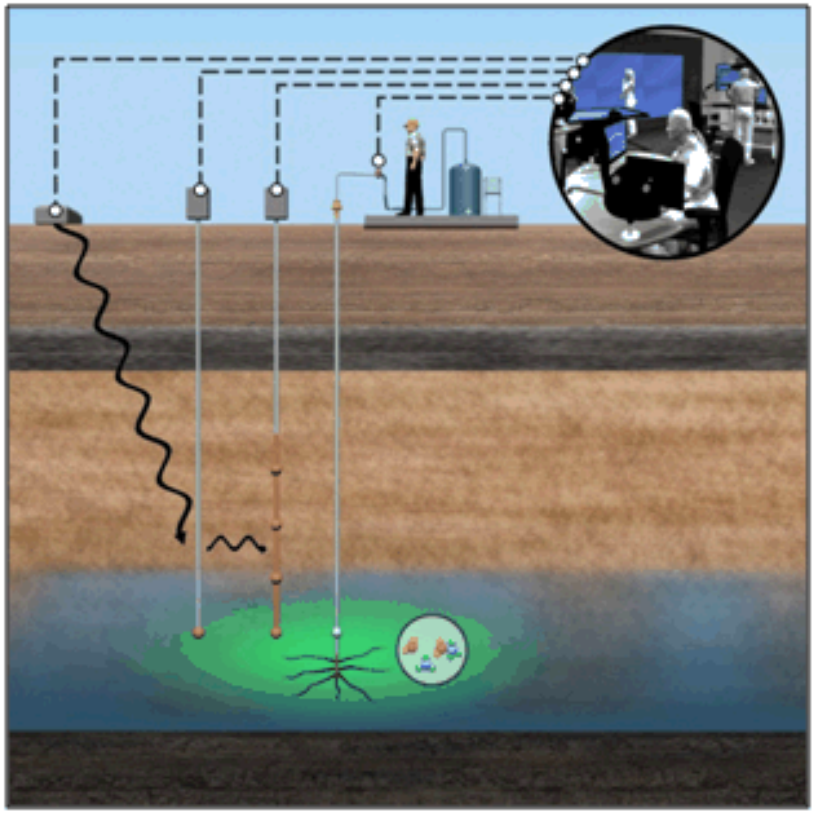
Ability to adaptively manipulate - with confidence and rapidly- subsurface fracture length, aperture, branching, connectivity and associated reactions and fluid flow.

A "Grand Challenge"



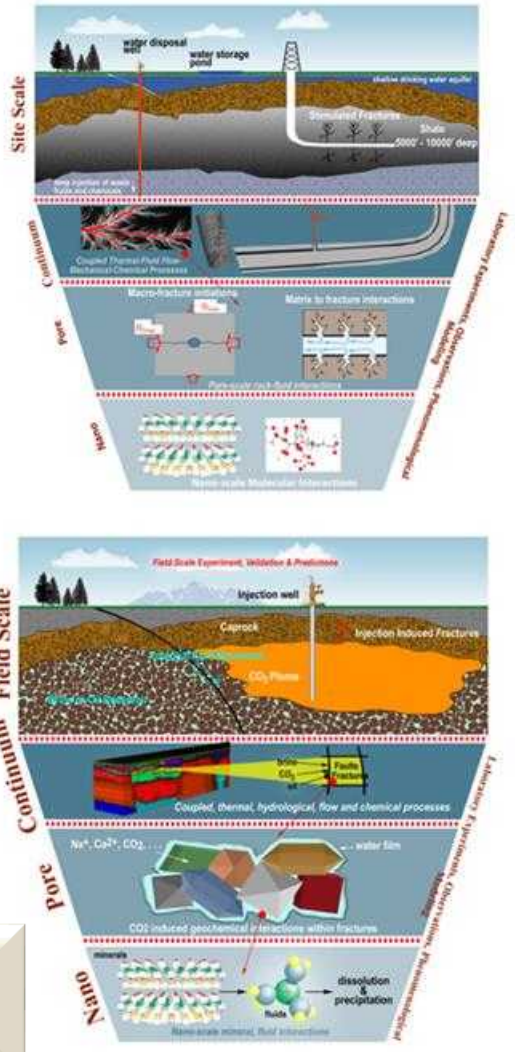
Range of RD^3 Challenges:

Fundamental Science to Engineering Application



General Technical Baseline: State of Knowledge & Practice

- Reservoir stress distribution and material properties are highly heterogeneous and largely unknown
- Mechanistic understanding of multi-scale processes that influence stress distribution and thus fracture formation and flow is lacking - limits both production and subsurface storage
- Industry is developing approaches to improve fracture creation, commonly guided by empirical field evidence. Industry not attempting 'real time' control
- Significant public concern and uncertainty associated with environmental risks



Today we cannot accurately image, predict, or control fractures with confidence or in real-time.

Subsurface Crosscut Research Framework

Adaptive Control of Subsurface Fractures and Fluid Flow

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Intelligent Wellbore Systems	Subsurface Stress & Induced Seismicity	Permeability Manipulation	New Subsurface Signals
Improved well construction materials and techniques	Measurement of stress and induced seismicity	Physicochemical fluid-rock interactions	New sensing approaches
Autonomous completions for well integrity modeling	Manipulation of stress and induced seismicity	Manipulating flowpaths	Integration of multi-scale, multi-type data
New diagnostics for wellbore integrity	Relating stress manipulation and induced seismicity to permeability	Characterizing fractures, dynamics, and flows	Adaptive control processes
Remediation tools and technologies	Applied risk analysis of subsurface manipulation	Novel stimulation methods	Diagnostic signatures and critical thresholds
Fit-for-purpose drilling and completion tools (e.g. anticipative drilling, centralizers, monitoring)			
HT/HP well construction / completion technologies			

Energy Field Observatories

Fit For Purpose Simulation Capabilities

The Crosscut Team and the Big Idea come together

13 National Laboratories

Argonne NATIONAL LABORATORY
BERKELEY LAB
BROOKHAVEN NATIONAL LABORATORY
INL Idaho National Laboratory
Lawrence Livermore National Laboratory
Los Alamos NATIONAL LABORATORY
NETL
NREL
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
Sandia National Laboratories
SLAC NATIONAL ACCELERATOR LABORATORY
SRNL

SubTER Progress

Sandia National Laboratories

National Labs

White Papers May 2014

Big Ideas Summit March 12-13 2014

FY14 Seed projects initiated

Lab Rep Scoping Meeting Nov 2014

FY15 project proposals

Town Hall

AGU American Geophysical Union

2014

2015

SubTER Workshop
Subsurface Technology and Engineering R&D Crosscut
March 14, 2014
SRA, International, 1801 K Street, Suite 460

RFI: Grand challenges in subsurface engineering

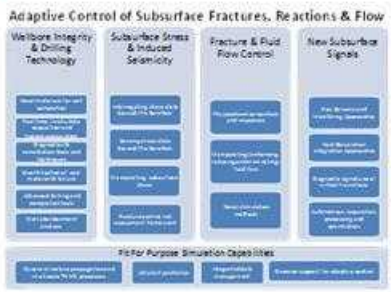
Stakeholder Outreach Events

USEA United States Energy Association

THE GEOLOGICAL SOCIETY OF AMERICA®

Jason Reports

QTR



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DOE

Crosscut framework identified

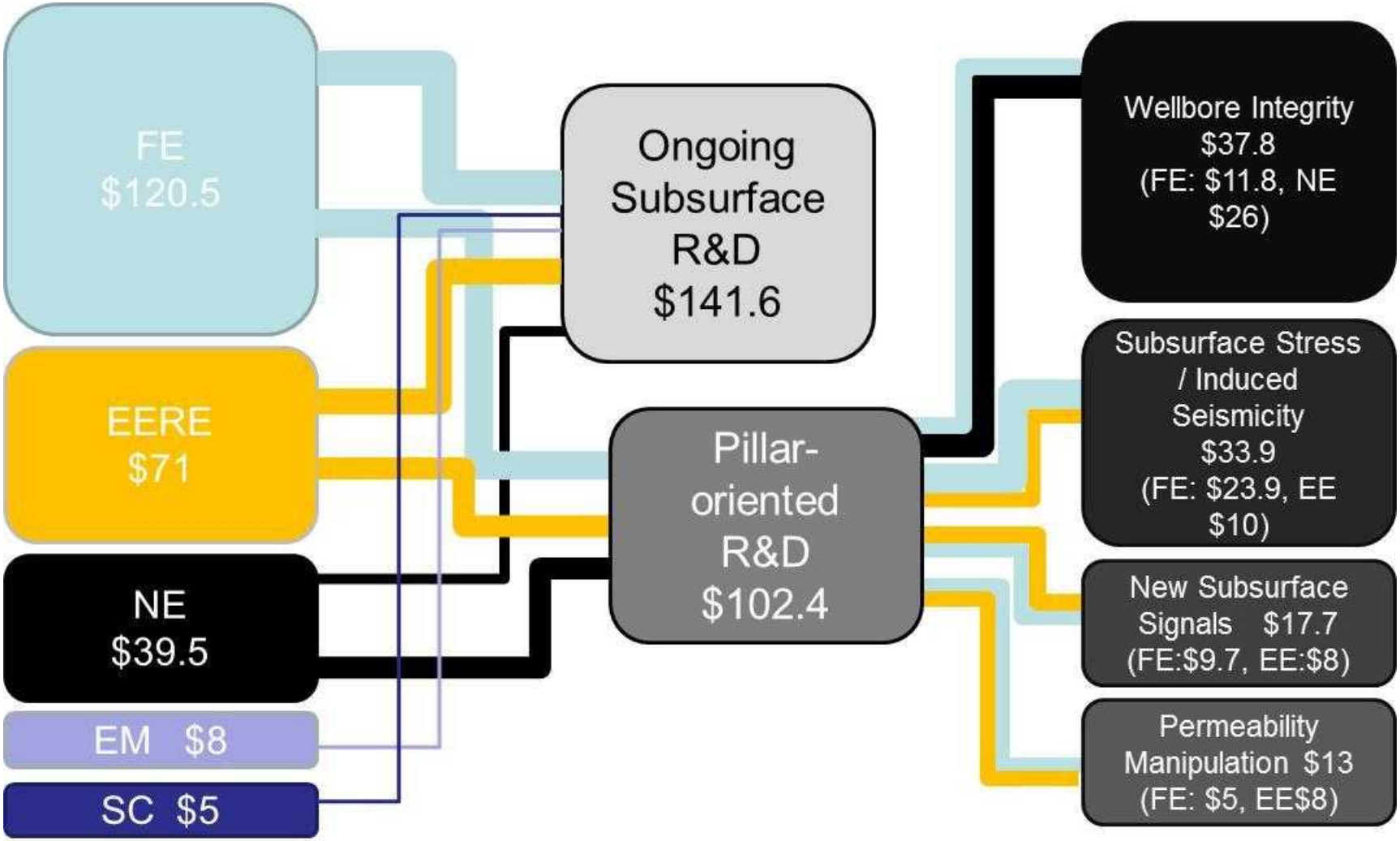
Subsurface Briefings to Staffers

FORGE FOA released

Ramping Up SubTER

- FY14 Kickstart: $2M investment in 9 seedling projects
- FY15 ~$6M opportunity to propose high priority, integrated and collaborative projects that build on 10 seedlings
- FY16 expected launch: President's Budget Request includes $244M for SubTER; ~$100M new funds

SubTER in FY2016
President's Budget Request ($M)



FY 2015 Schedule

Sandia National Laboratories

Activities	Nov-Dec 2014	Jan-Feb 2015	Mar-Apr 2015	May-Jun 2015	Jul-Aug 2015	Sep-Oct 2015	Nov 2015
Subsurface Crosscut Scoping Meeting • 13 labs and DOE participated • Technical planning for program elements							
Labs support DOE on SubTER elements in QTR • Substantive narrative for web appendix							
FY15 AOP Opportunity for Labs ($6M, multi-lab projects)							
Interim Report on Program Elements							
Outreach: Professional Societies, universities, industry							
2nd Subsurface Crosscut Scoping Meeting							
Develop Technical Plan for FY16 and beyond							
SubTER Community Workshop (Academia and Industry) • Includes published workshop report							
SubTER Launch							

How can the Community be Involved?

- **Your input now can contribute to shaping the scope of SubTER.**
- **Funding opportunities will be announced leading up to and/or after the full launch of this initiative in FY16 (pending appropriations).**
- **Partnerships with National Labs can facilitate involvement in other aspects of the Subsurface Crosscut starting in FY15.**

Please Provide Feedback . . .

- Do these challenges and related R&D directions, accurately represent the technology landscape related to fracture propagation and fluid flow in the subsurface?
- Are there additional areas or themes within this topic, which should be considered?
- Is this a high-impact problem or challenge?
- Is the topic sufficiently open, i.e., does it address the broad problem, and is it appropriately open to new ideas, approaches, directions?
- Does solution of this problem, result in enduring benefit to the United States – economic, environment, etc.? What could be the impact?
- What are the gaps between what is being pursued in the private sector, vs. publicly funded R&D?

subsurface@hq.doe.gov

energy.gov/subsurface-tech-team

Thank You

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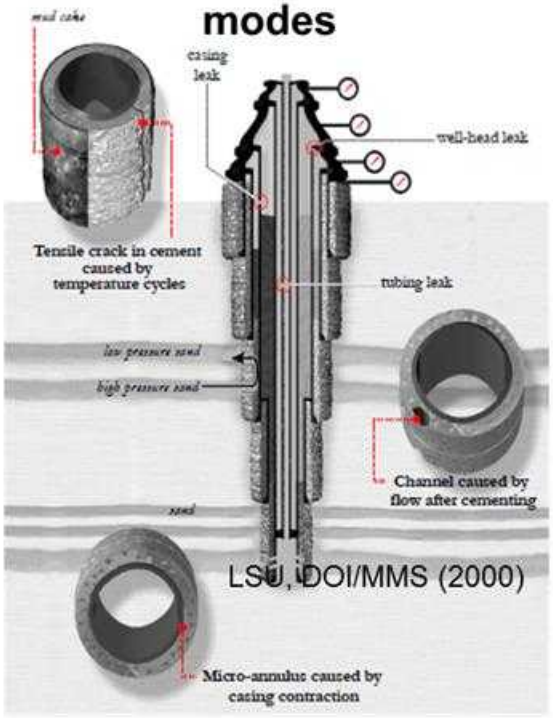
Pillar: Intelligent Wellbore Systems

Intelligent Wellbores: Self-healing cements and integrated-casing monitoring systems for enhanced wellbore performance assurance

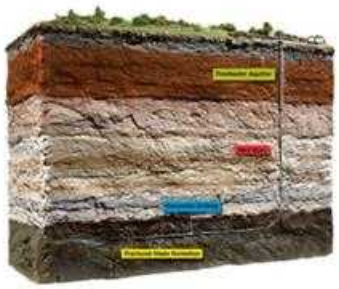
wide band gap semiconductors + advanced manufacturing + HT electronics and sensors + materials science industry + national labs + academia

Casing/cement failure modes



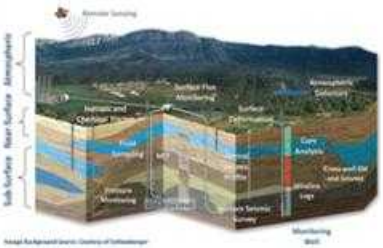
LSU, DOI/MMS (2000)

multi-decadal — REQUIRED LIFETIME — millennial

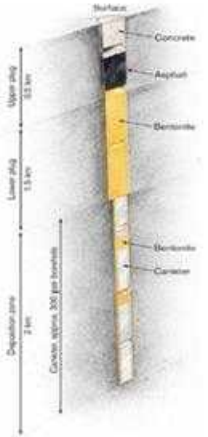


Oil and Gas

Geothermal



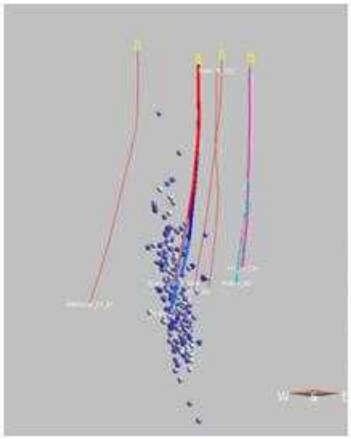
CO_2 Storage



Nuclear Waste Deep-Borehole Disposal

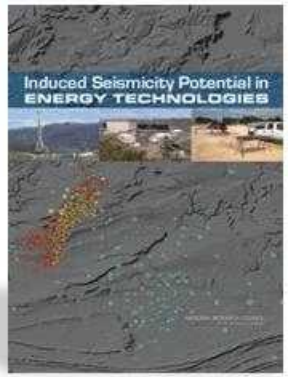
Class VI permit process, used-fuel disposition regulatory framework…

Pillar: Subsurface Stress and Induced Seismicity



Induced Seismicity at The Geysers Geothermal Field (Calpine)

Approach to Date: Geothermal sector has proactively developed its own induced seismicity management protocol. CO_2 storage developing new risk assessment tools through NRAP.



Increasing societal relevance of induced seismicity as EGS deployment and CO_2 storage grow, akin to oil and gas today

Subsurface Stress and Induced Seismicity Program:

- Improved stress measurements
- Broader data acquisition and sharing
- Advanced risk assessment tools

Permeability *Manipulation* and ***New Subsurface Signals*** are also critical components of overall effective reservoir management that are essential for scaling up EGS and CO_2 storage safely and effectively

Outcomes:

- Improved understanding of the subsurface
- Mitigation and reduced risk
- Safe scale up
- Improved resource identification and development

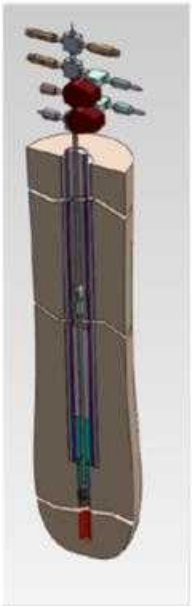
Pillar: Permeability Manipulation

Sandia National Laboratories

Precise control over fracturing and fluid flow is critical for efficient extraction of energy resources, as well as for containment of CO_2 and waste streams.

Approach to Date:

- Geometry-based approaches
- Chemical manipulation
- Incomplete physical treatment in models



Gas phase bi-propellant energetic stimulation design (Sandia National Laboratories)

***SubTER Permeability Manipulation objectives*:**

- Novel stimulation techniques (e.g., water-free energetics, shape-memory alloys)
- Advances in reservoir and seal performance mechanisms for contaminant flow and trapping
- In-situ, real time imaging, modeling, and analysis of flow

Outcomes:

- Improved control over fluid migration and reservoir integrity
- Mitigation and reduced risk
- Safe scale up of EGS, carbon storage, and high-level waste disposal

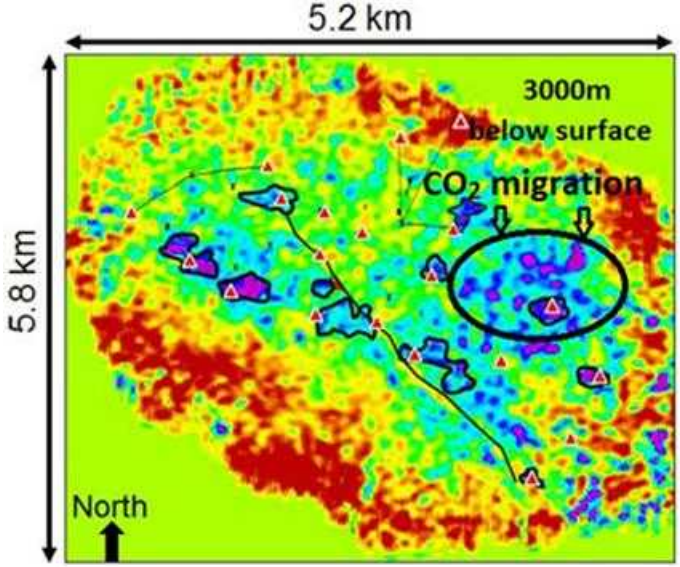
Pillar: New Subsurface Signals

Sandia National Laboratories

High fidelity characterization of subsurface environments is critical to successful subsurface engineering efforts.

Approach to Date:

- Seismic, electromagnetic, and gravity methods from the surface and the
...



High resolution inverted seismic images of CO_2 migration at the Cranfield injection site

***SubTER Subsurface Signals Objectives*:**

- R&D on small-scale deployable sensors
- Autonomous acquisition, processing and assimilation
- Identification of critical system transitions

Outcomes:

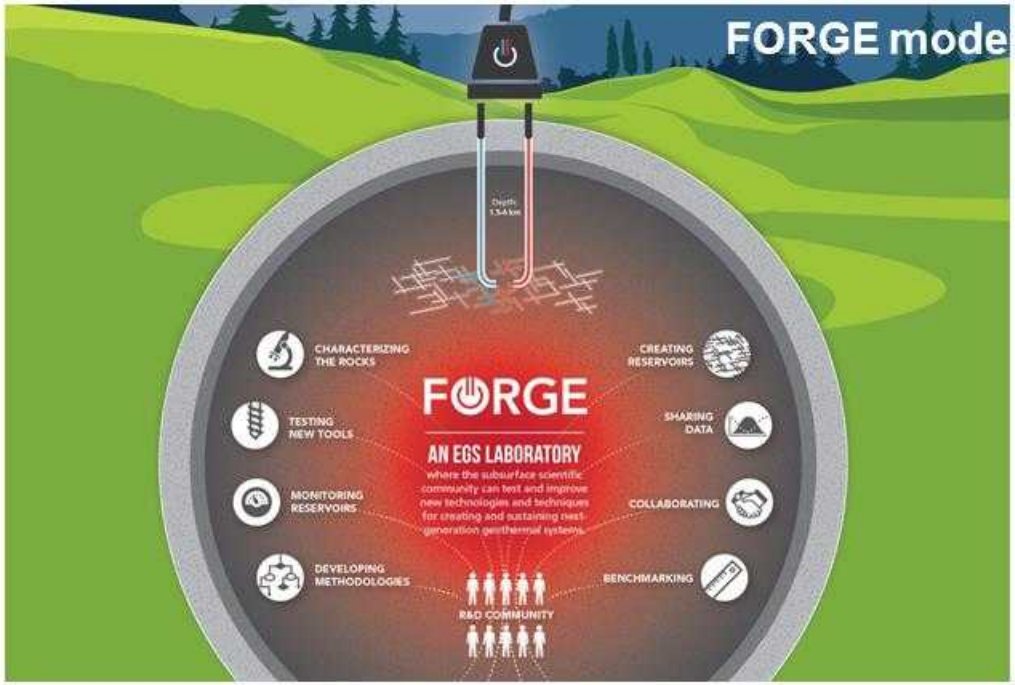
- New ways to "see" subsurface fractures and fluid pathways.
- Acquisition of data necessary for adaptive control of subsurface fractures and fluid flow.

Approach: Field observatories are critically important to SubTER efforts

Sandia National Laboratories

Required for fundamental subsurface progress

- Validation through monitoring/production
- Site-specific conditions
- Strong industry engagement
- Multiple business models:
  - Fit-for-purpose, dedicated site (FORGE, RMOTC)
  - Isolated, targeted effort (Frio CCS pilot)
  - Opportunistic (Weyburn)
- Expensive: individual sites = $10-35M/year commitment

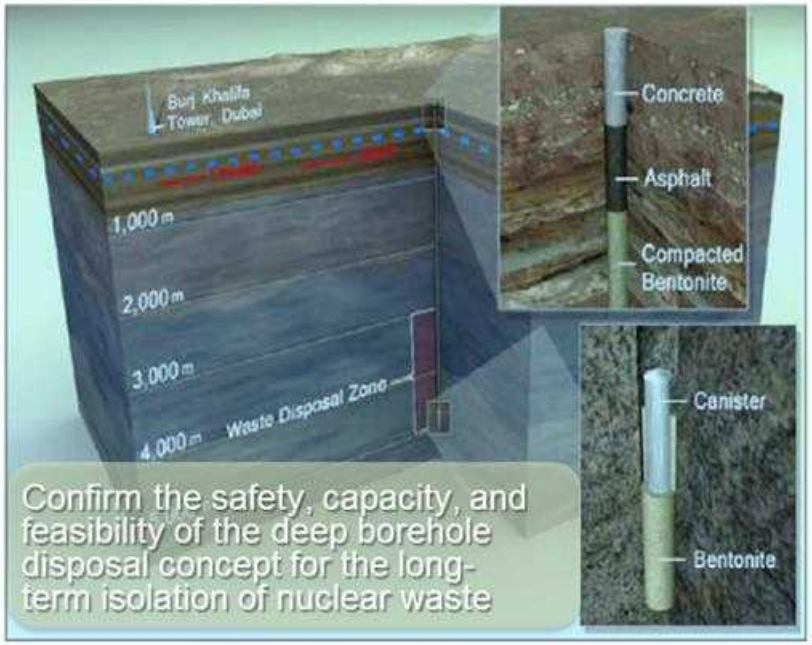


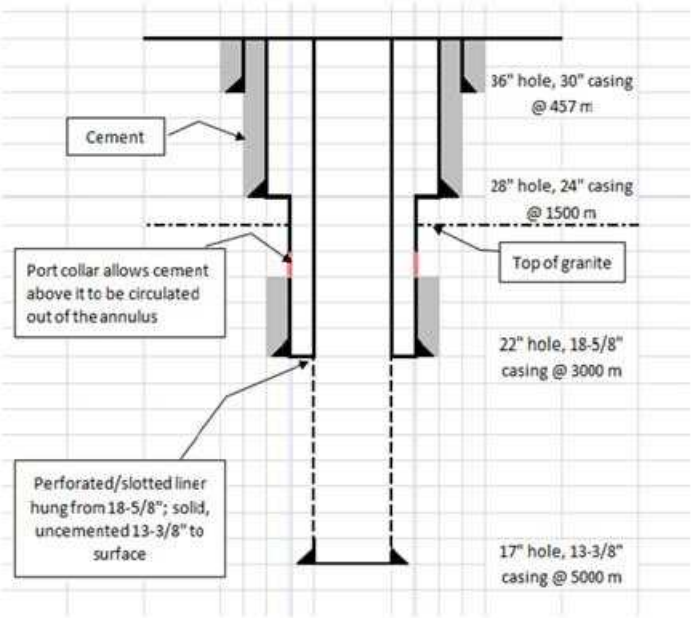
Phase 1	Phase 2	Phase 3	
$2 M	$29 M		
Site Selection	*Site preparation & characterization*	*R&D testing, monitoring, innovative drilling, advanced stimulation, sustainability testing*	*Decommission/ Transfer site*
PHASE 1	PHASE 2	PHASE 3	Closeout

Validation of new results and approaches at commercial scale;
Road-test monitoring, stimulation, and permeability- and flow-control tools

Approach: Deep Borehole Field Test

- Demonstrate the feasibility of characterizing and engineering deep boreholes (no actual waste disposal)
- Demonstrate safe processes and operations for safe waste emplacement downhole





Crosscut Benefit: *Drilling technology, well construction and integrity, and subsurface characterization.*

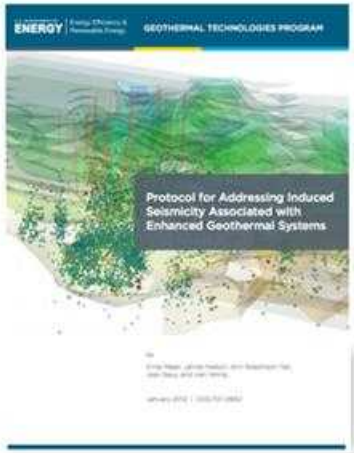
Approach: "Virtual" Field Observatory

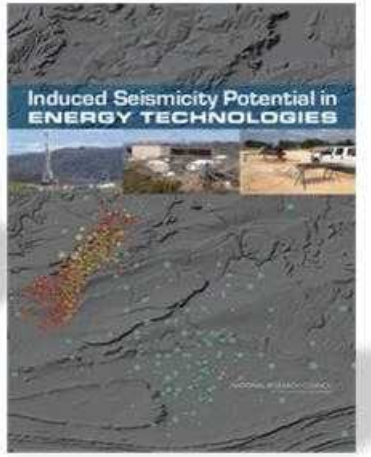
Sandia National Laboratories

Increasing societal relevance of induced seismicity as wastewater injection associated with natural gas extraction continues to expand and as EGS deployment grows.

Approach to Date:

- Induced seismicity management protocol





***SubTER Subsurface Stress and Induced Seismicity Program*:**

- Improved stress measurements
- Broader data acquisition and sharing
- Advanced risk assessment tools

Permeability *Manipulation* and ***New Subsurface Signals*** are also critical components of overall effective reservoir management that are essential for ensuring safe and effective subsurface operations.

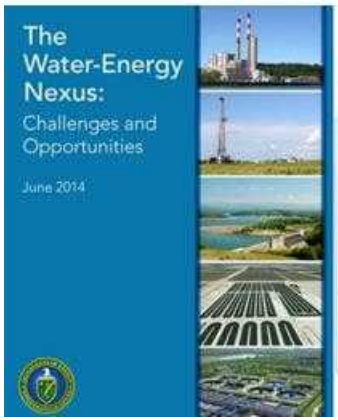
Outcomes:

- Improved understanding of the subsurface
- Mitigation and reduced risk
- Safe scale up of EGS and carbon storage
- Improved resource identification and development

New DOE Structure and Emphasis

- **Secretary Moniz created:**
  - Undersecretary for Science and Energy position: better integration of Energy Technology Programs with Fundamental Research
  - 6 crosscutting "Tech Teams"
    - **Grid***
    - Water-Energy (WETT)
    - Supercritical CO_2 Brayton Cycle
    - Advanced Computing
    - Manufacturing
    - **Subsurface Technology and Engineering RD&D (SubTER)***

***Large FY16 programs proposed**



Laboratory Roles