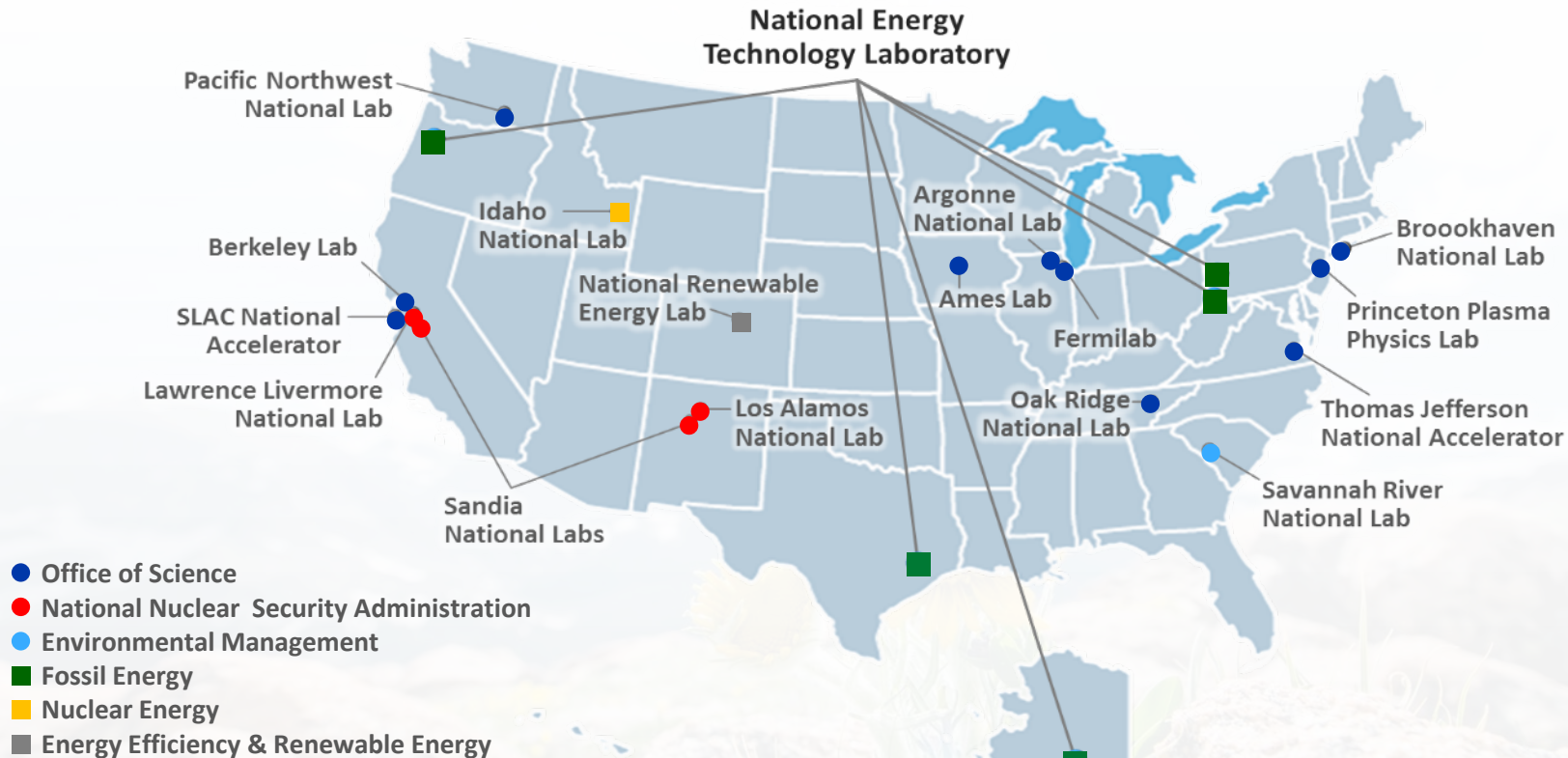
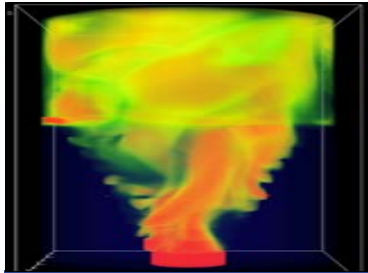


NETL: THE Fossil Energy Laboratory



NETL's mission is to discover, integrate, and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations

World-Class Facilities

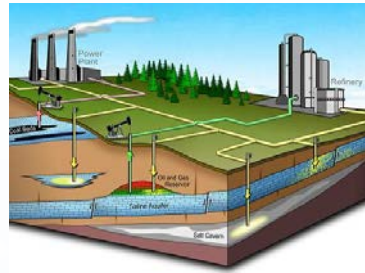


Computational Engineering

HPC – Joule



Materials Engineering & Manufacturing



Geological & Environmental Systems

Pilot-Scale Foundry



Energy Conversion Engineering

SOFC-Turbine Hybrid



Systems Analysis & Engineering

High-Pressure Combustor Water-Tunnel



Immersive Virtual Simulator

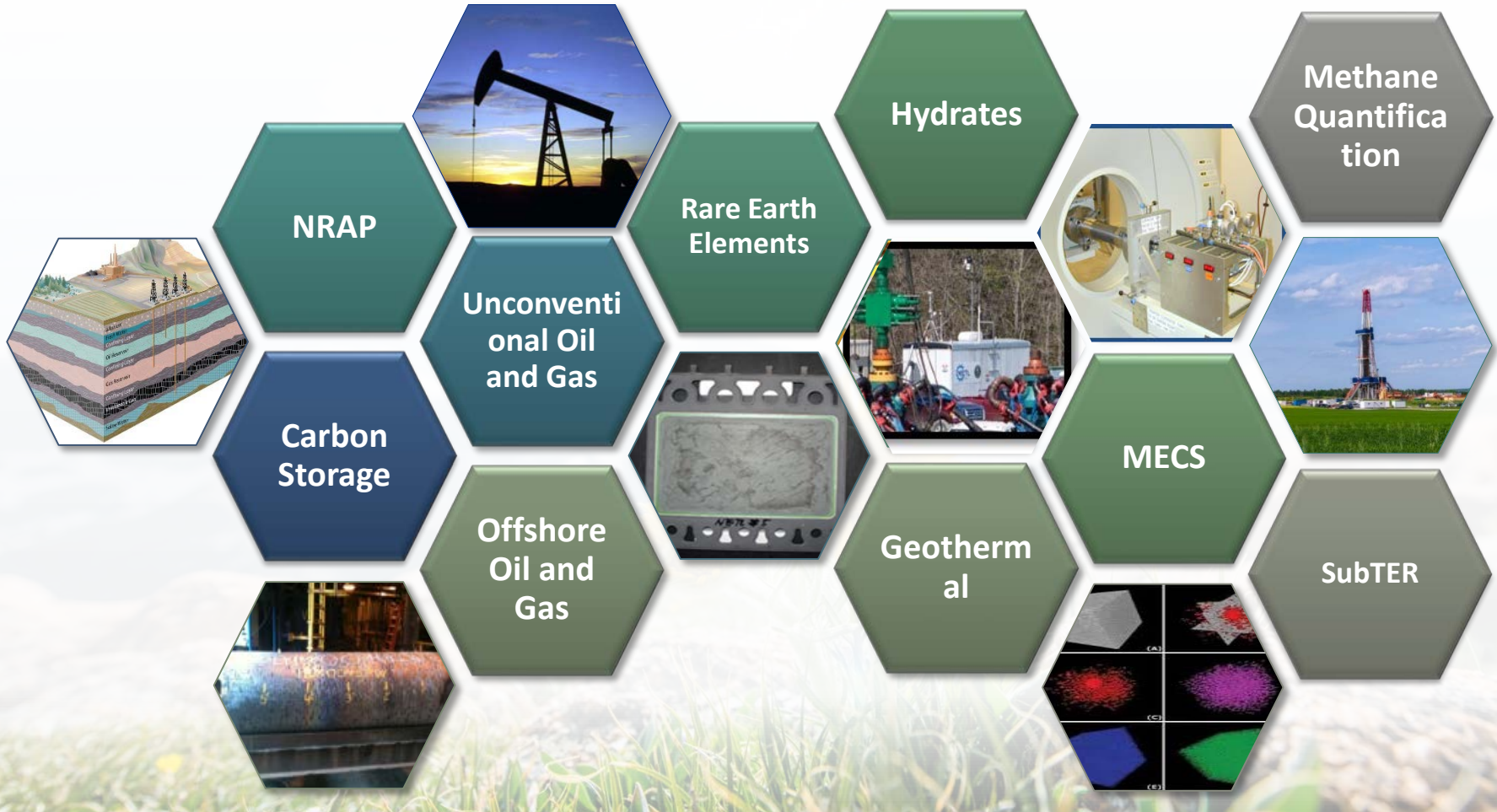


Portable Field Laboratory



In situ CT Scanning

Advancing Solutions in Geological and Environmental Sciences



Understanding ~ Materials ~ Processes ~ Tools ~ Technology

NETL RIC Subsurface Research

Engineering Solutions using an Integrated Approach

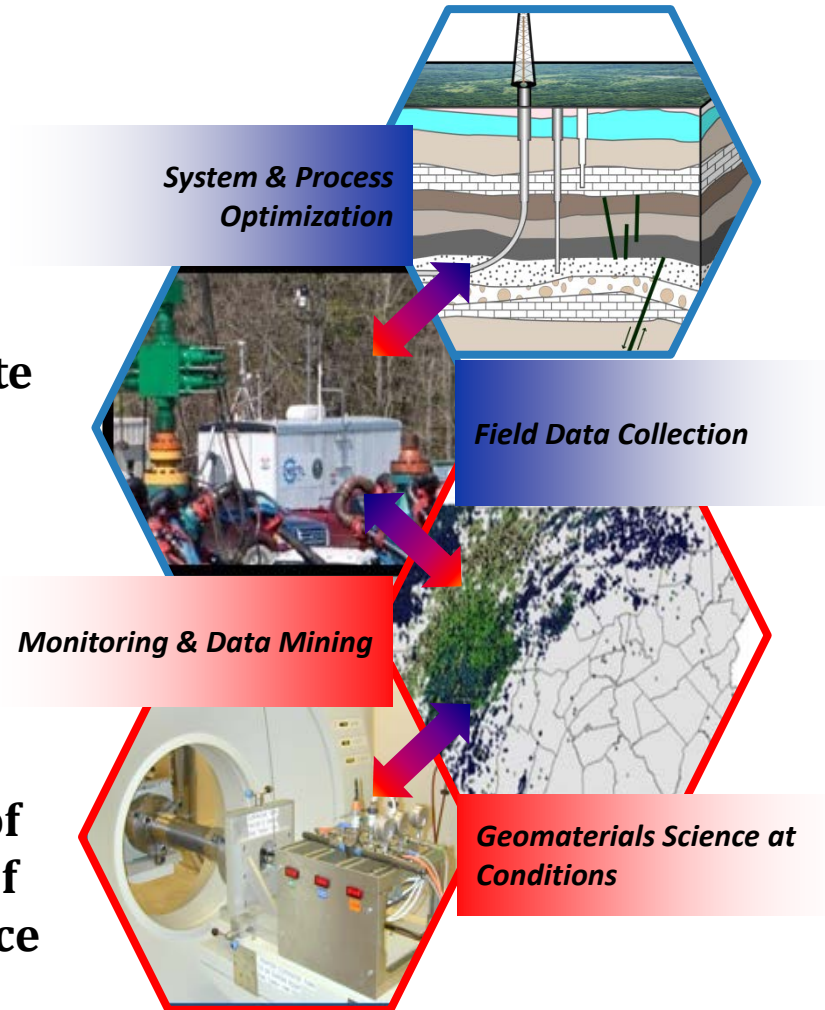


**Validated simulation tools
to predict behavior of
engineered natural systems:
reservoir to receptor**

**Field-scale data to calibrate
and validate predictions
and to establish baselines**

**Physical and computational
data analysis techniques to
identify key patterns**

**Scientific understanding of
the behavior/properties of
real materials at subsurface
conditions**



NETL Research Presentations and Posters

TUESDAY, AUGUST 16, 2016

- 12:40 PM Monitoring Groundwater Impacts - Christina Lopano
- 1:55 PM Multi Variate Examination of the Cause of Increasing Induced Seismicity – Kelly Rose
- 4:40 PM Exploring the Behavior of Shales as Seals and Storage Reservoirs for CO₂ – Ernest Lindner
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WEDNESDAY, AUGUST 17, 2016

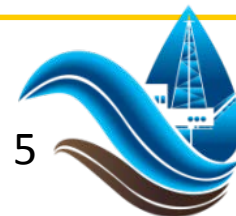
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<https://edx.netl.doe.gov/carbonstorage/>
<https://edx.netl.doe.gov/offshore/>
<https://edx.netl.doe.gov/ucr/>
<https://edx.netl.doe.gov/nrap>



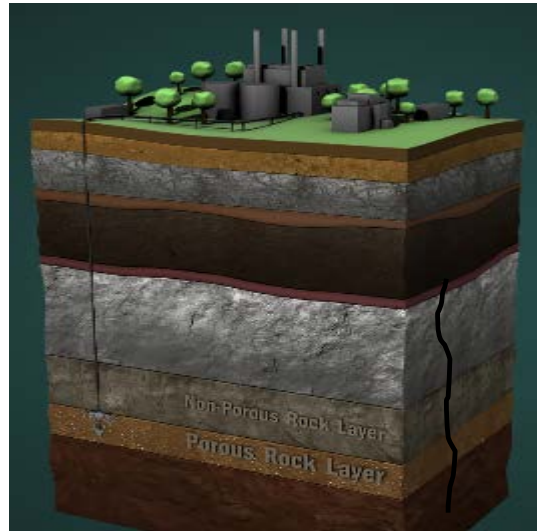
5



NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO₂ storage deployment.

Objective: Building tools and improving the science base to address key questions related to environmental impacts from potential release of CO₂ or brine from the storage reservoir, and potential ground-motion impacts due to injection of CO₂

Technical Team



Stakeholder Group



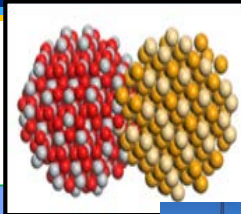
NETL RIC's Carbon Storage Portfolio

Enhancing Effectiveness and Reducing Uncertainty in Long-Term CO₂ Storage and Efficiency



CO₂ Reuse

- NOVEL SYSTEMS FOR CO₂ CONVERSION



Monitoring CO₂/Brine Plumes and Groundwater Impacts

- DEVELOP AND DEMONSTRATE TOOLS AND PROTOCOLS FOR DETECTION OF CO₂/BRINE INTERFACE AND GROUNDWATER MONITORING



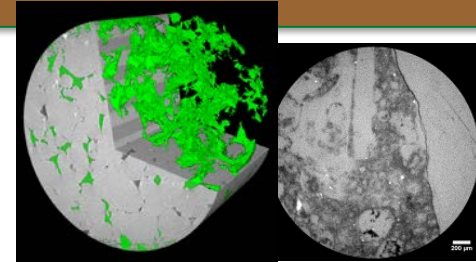
MVA Field Activities

- SUPPORT LARGE-SCALE FIELD ACTIVITIES



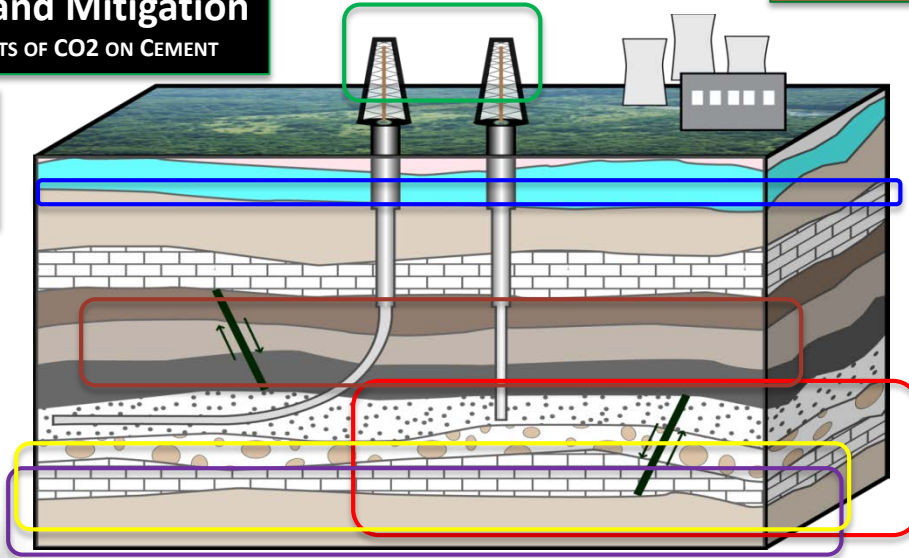
Reservoir Performance

- EXPERIMENTAL MEASUREMENTS OF RELATIVE PERMEABILITY, RESIDUAL SATURATION, AND POROSITY NEEDED FOR RESERVOIR SIMULATIONS



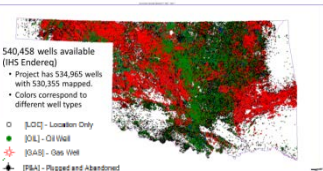
Wellbore Integrity and Mitigation

- EVALUATE GEOCHEMICAL IMPACTS OF CO₂ ON CEMENT



SubTER

- DOE CROSSCUTTING SUBSURFACE TECHNOLOGY



Shales as Seals and Unconventional Reservoirs

- IMPROVE CHARACTERIZATION OF SHALES AS SEALS AND STORAGE RESERVOIRS

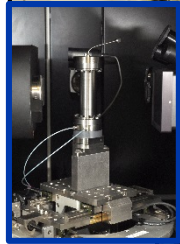
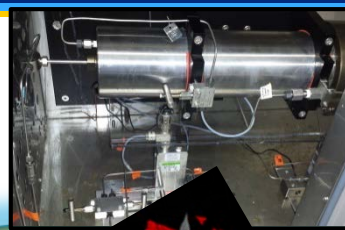


Resource Assessments and Geospatial Resources (EDX and NATCARB)

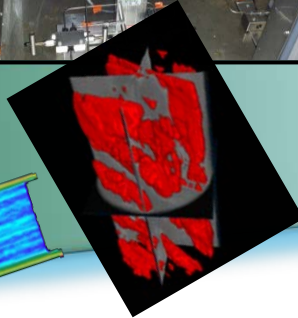
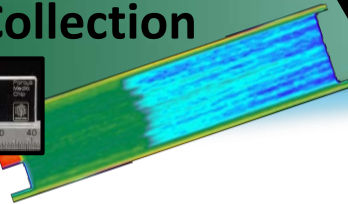
- DEVELOP DEFENSIBLE DOE STORAGE METHODS FOR THE ONSHORE AND OFFSHORE
- DEVELOP, MAINTAIN, AND UTILIZE GEOSPATIAL PLATFORMS TO SUPPORT CO₂ STORAGE RESEARCH



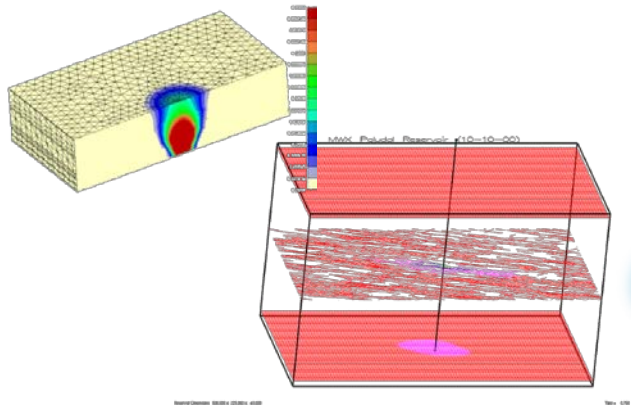
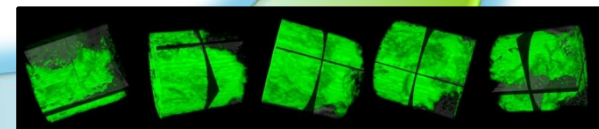
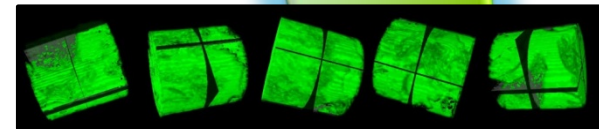
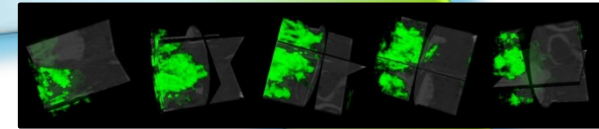
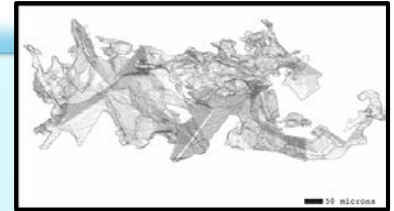
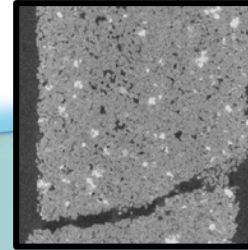
Approaches to scale from pore to reservoir



Micro-Scale Data Collection

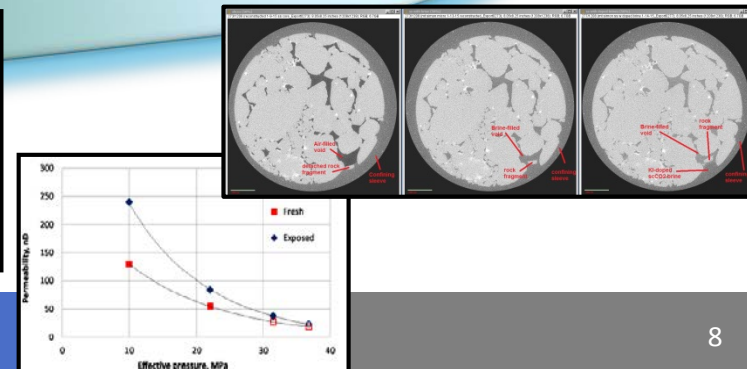
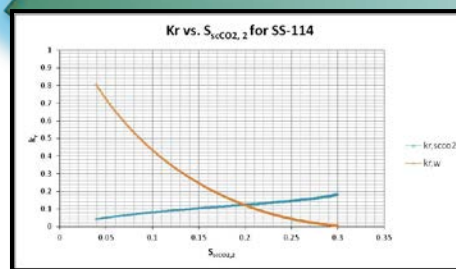


Data Conversion and CFD



Reservoir-Scale Application

Multiscale Data Analysis



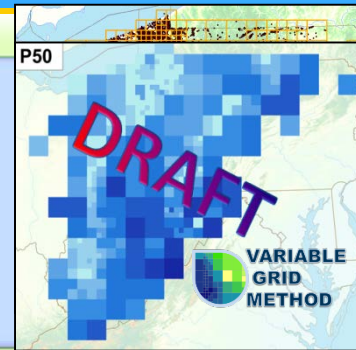
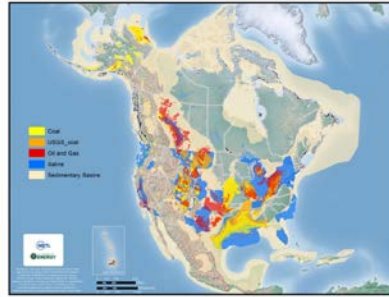
Resource Assessments and Geospatial Resources



DEVELOP DEFENSIBLE DOE METHODOLOGY FOR REGIONAL ASSESSMENTS

$$G_{CO_2} = A_t h_g \phi_{tot} \rho E_{saline}$$

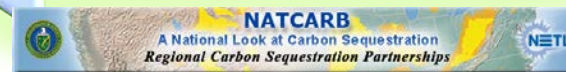
Petroleum Industry	CO ₂ Geological Storage
Reserves	Capacity
On Production	Active Injection
Approved for Development	Approved for Development
Justified for Development	Justified for Development
Contingent Resources	Contingent Storage Resources
Development Pending	Development Pending
Development Unclassified or On Hold	Development Unclassified or On Hold
Development Not Viable	Development Not Viable
Prospective Resources	Prospective Storage Resources
Prospect	Qualified Site(s)
Lead	Selected Areas
Play	Potential Sub-Regions



Pair-wise Differences	Formation													
	A	B	C	D	E	F	G	H	I	J	K	L	M	
USGS - CSLF														
USGS - AtlasII														
USGS - AtlasIII,IV														
USGS - Szulc														
USGS - Zhou														
CSLF - AtlasI,II														
CSLF - AtlasIII,IV														
CSLF - Szulc														
CSLF - Zhou														
AtlasI,II - AtlasIII,IV														
AtlasI,II - Szulc														
AtlasI,II - Zhou														
AtlasIII,IV - Szulc														
AtlasIII,IV - Zhou														
Szulc - Zhou														

SPATIAL STATISTICAL DATA ANALYSIS

Develop methods to aid broad energy-related government policy and business decisions; Develop, refine, and evaluate a suite of methodologies/methods to quantitatively assess CO₂ storage resource potential



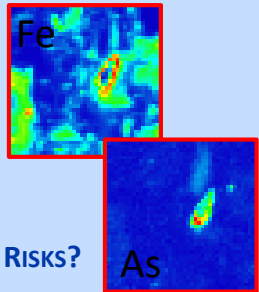
GEOSPATIAL PLATFORMS

Monitoring Groundwater Impacts

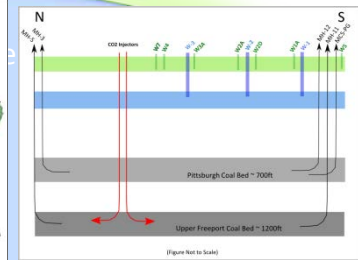
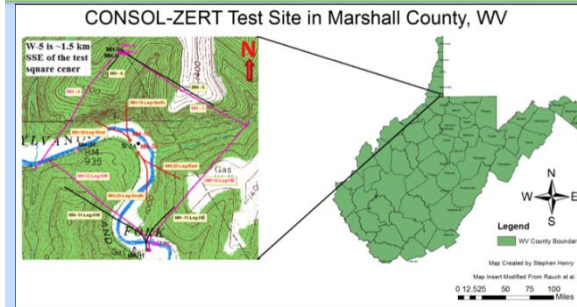


ESTABLISH THE UTILITY OF STABLE ISOTOPES TO TRACK MIGRATION OF A

UNDERSTAND NATURAL BACKGROUND VARIABILITY



METHODS?



CO₂ PLUME

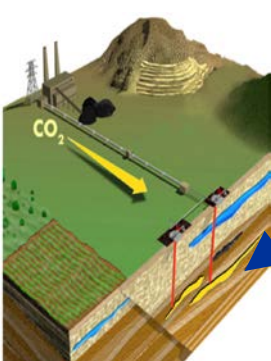
Developing and demonstrating a suite of geochemically-based monitoring strategies for groundwater systems, and developing a statistical understanding of natural groundwater variability in CO₂ storage systems.



Thermal springs (Natural Analog)



EOR Field Site



Migration into Shallow Aquifers

Migration into other Deep Formations

Fiber Optics

Continuous CO₂ Monitoring Devices

LIBS

NETL: A Multi-Variate Examination of the Cause(s) of Increasing Induced Seismicity Events with Geoscience Computing & Big Data

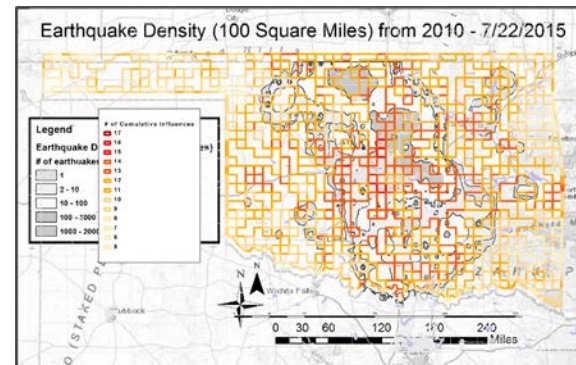
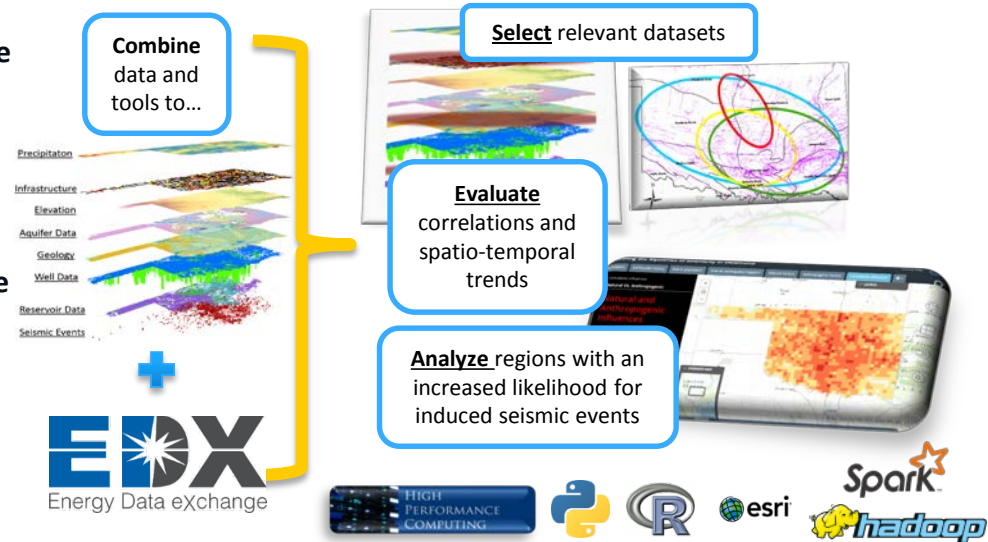


Main Objectives:

- Address the need for rapid, repeatable evaluations to reduce induced seismicity risk
- Developing tool/method using probabilistic & big data approach
- Develop approaches to reduce uncertainty and constrain subsurface trends
- Improve discovery, integration, and joint analysis of multiple datasets using advanced "Big Data" computing algorithms

Current Work:

- Gathered & using over 150 dataset volumes, containing >200 million data fields
- Testing custom probabilistic analytical algorithms & data mining capabilities using Hadoop cluster
 - Faster data mining and analytical processing times by 60x's
- Merging GIS and Big Data computing for advanced 3D/4D geospatial analysis
 - Offloading intensive geometric operations from desktop to a Hadoop cluster
- Released [Storymap](#) summarizing induced seismicity evaluation problem and beta spatial analyses using common risk factors
- Completed meta analysis evaluating seismicity risk factors
- Developing phase 2 probabilistic analytical work flow using combination of existing and custom methods

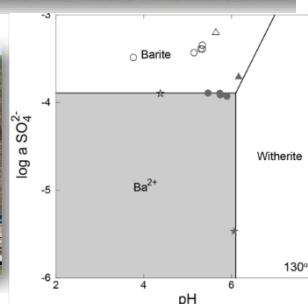
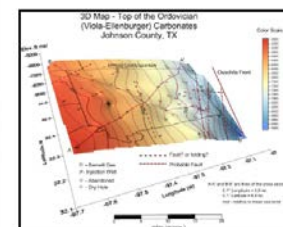
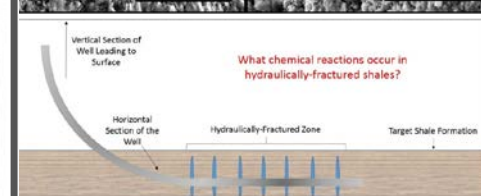
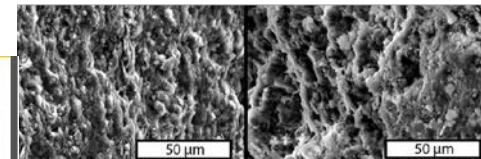
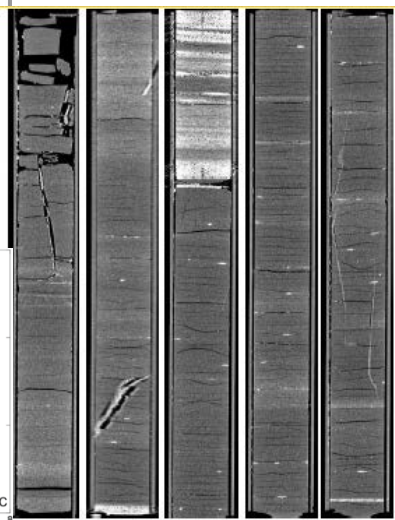


Beta analysis of 18 key datasets related to natural and anthropogenic earthquake factors –

Shows broad alignment between geospatial assessment of risk factors & earthquake activity in OK

NETL RIC's Unconventional Portfolio

Investigating and reducing environmental impacts from unconventional HC production



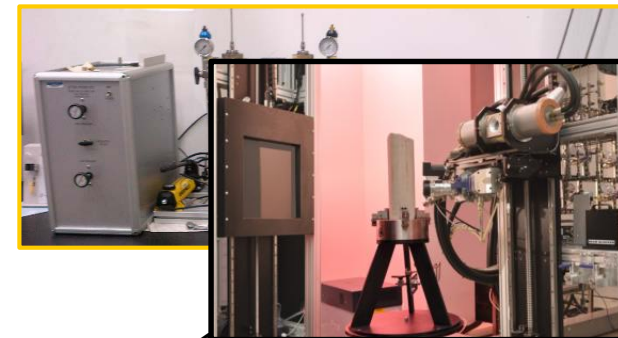
- Fluid interactions with shale
- Geomechanics and induced seismicity
- Field monitoring
- Analytical approaches for source determination
- Atmospheric monitoring and emissions quantification

- **Portfolio Manger: Alexandra Hakala**
- **Team Technical Coordinators: Dustin Crandall, Barbara Kutchko, Richard Hammack, Alexandra Hakala, Natalie Pekney, Mark McKoy, Donald Remson**

Changes to Reservoir Rocks and Seals



- 6 month exposure in high-pressure vessels
 - 23.8 Mpa (3450 psi)
 - 85 °C (185 °F)
- CT, XRD, SEM, petrography, porosity, and permeability analyses were conducted before and after the six month exposure experiment.



NETL's Assessment of Shale Gas Development's Air Quality Impacts



Problem:

- Uncertain/inaccurate values for emission factors associated with large contributors to life-cycle emissions

Objectives:

- To collect field data of representative ambient and point source air emissions

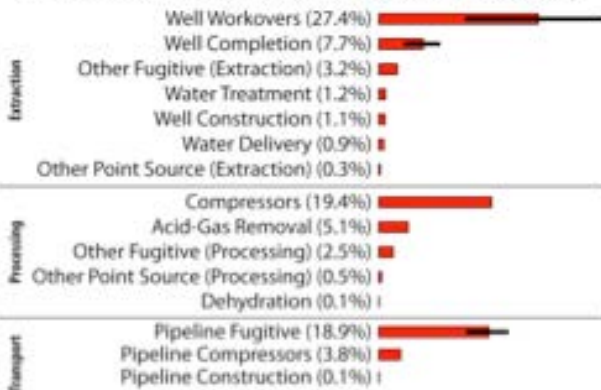


Emissions of methane, volatile organic compounds, particulate matter, reactive nitrogen, carbon dioxide



NETL's Mobile Air Monitoring Laboratory

Drivers for GHG Emissions in LCA of Shale-Gas Activities
(GHG emissions include CH₄, CO₂, and N₂O, converted to CO₂ eq.)



NETL's Use of Multiple Measurement Approaches:

Ambient	Point-Source
Values integrated over an area	Values for a specific location and/or operation
Plume interception dependent on local meteorology	Determination of background concentrations not necessary
Continuous measurements capture variations in operator/equipment activity	Provides a "snapshot" or short-term measurement

NETL Facilities/Capabilities



NETL's Mobile Air Monitoring Laboratory



VOCs, NO_x, ozone,
CH₄ + $\delta^{13}\text{C}_{\text{CH}_4}$, CO₂
+ $\delta^{13}\text{C}_{\text{CO}_2}$, PM₁₀,
PM_{2.5},
Meteorological
Data

Unattended,
remote operation
via satellite link

- Source Emissions Measurements:
HiFlow Sampler, Dynamic Flux Chamber
- Tracer Release for Indirect Methane
Emissions Measurements





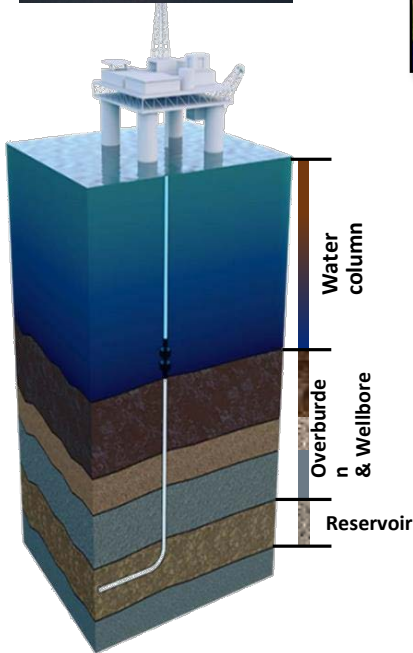
Natural Disasters also a growing consideration...



NETL's Offshore Portfolio Target Key E&P Risks:

- Cementing Failures
- Equipment & Casing Failures
- Reducing geologic uncertainty
- Higher risk targets, "exploratory" systems

Through use of novel tools, models and big data



Wellbore Integrity – Improved Science Base for Materials

- Characterizing the Behavior of Metal-Based Systems Used for Control Devices in Extreme Environments
- Improving Science-Base for Wellbore Integrity, Foam Cements
- Evaluation of Lithology:Cement:Casing Barrier Integrity under UDW Subsurface Conditions

Rapid Detection and *In Situ* Characterization – Improving Safety

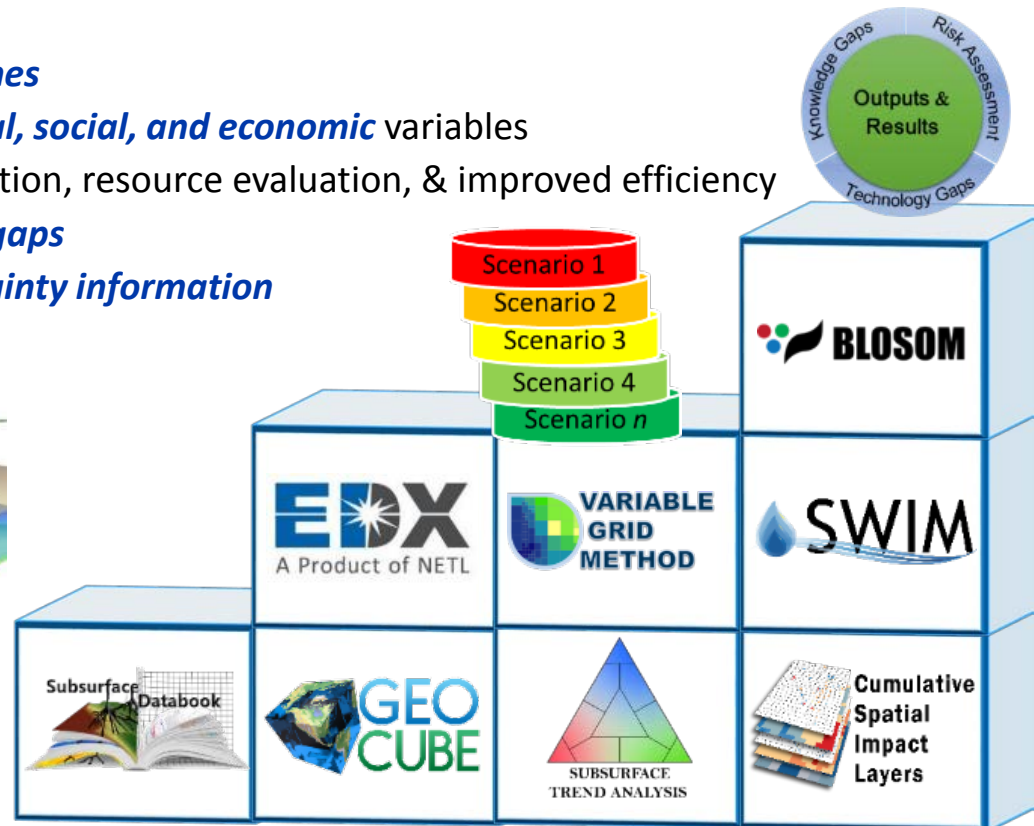
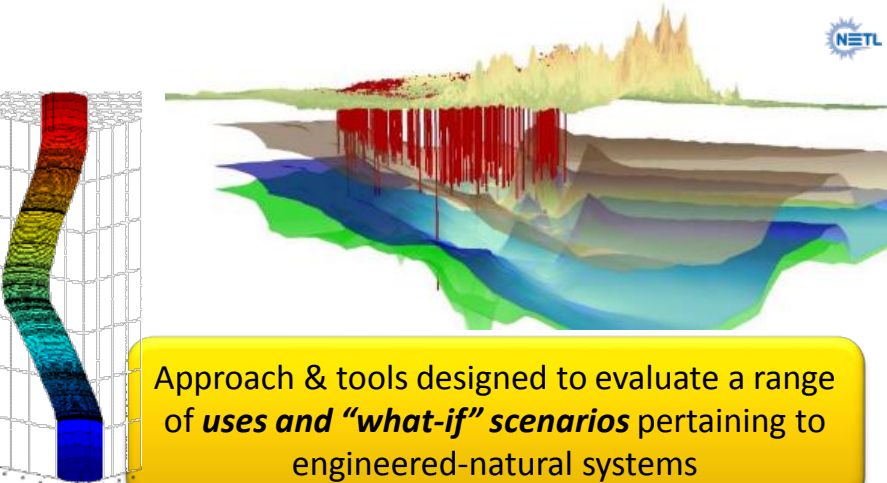
- Kick Detection at the Drill Bit - Adaptation of Existing Technology to Reduce Risks Associated with Deep and Ultra-Deep Drilling
- **Completed:** Improving Flow Assurance, Expediting Well Control, and Reducing Environmental Impacts Resulting from Blow-Outs in HPLT Environments

Risk Reduction - Mitigating Knowledge & Technology Gaps in Offshore Systems-

- Quantifying Complex Fluid-Phase Properties at High Pressure/High Temperature (HPHT)
- Assessing Risks and the Potential for Environmental Impacts for Offshore GOM Resources

Focused on creating tools & analyses that:

- Combine data from *different scales and disciplines*
- Help evaluate a range of potential *environmental, social, and economic* variables
- Evaluate various *energy scenarios*, for risk reduction, resource evaluation, & improved efficiency
- Use to highlight *knowledge and/or technology gaps*
- Improve understanding by incorporating *uncertainty information*



In Situ Predictions & Evaluation



Characterize, predict/identify, and understand areas with significant gas hydrate occurrences.

Field Studies in the Natural Environment



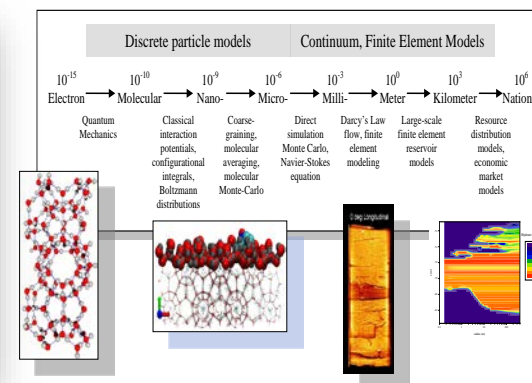
Collect and perform geologic, geochemical, and microbiologic analyses of samples from natural gas hydrate systems

Experimental Studies



Study gas hydrate formation/dissociation and mixed-gases hydrate phenomena

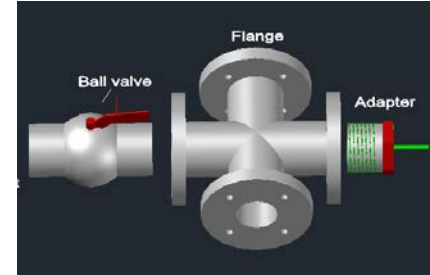
Numerical Analyses



Simulate natural gas hydrate behavior in porous media and sediments to evaluate their stability in the natural environment as well as future production potential.

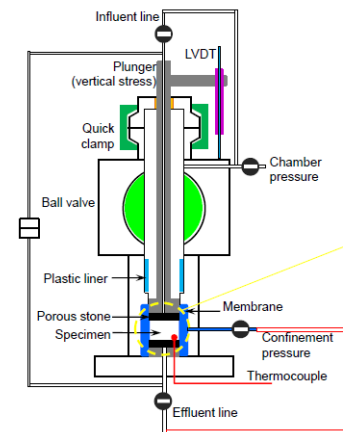
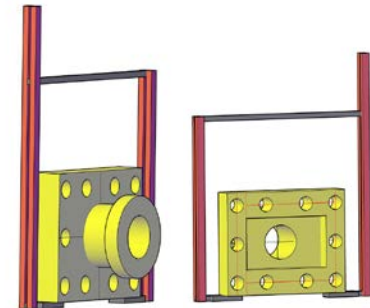
- **Developing Pressure Core Handling and Testing Chambers**

- Pore-scale visualization technique will be combined with new pressure core characterization chambers for hydrate pore habits in natural samples
- Geomechanical/hydrological property measurements under in-situ conditions



- **Four Newly Designed Chambers under Development**

- Core handler, cutter, sub-sample corer, and multi-property testing chamber (consolidation, acoustic, permeability)
- All four units will be connected seamlessly without disturbing the internal pressure, which will be controlled, maintained, and monitored at all times.
- Preliminary designs completed and currently under detailed design and hazard/safety review



Biogasification Micro Field Laboratory Study

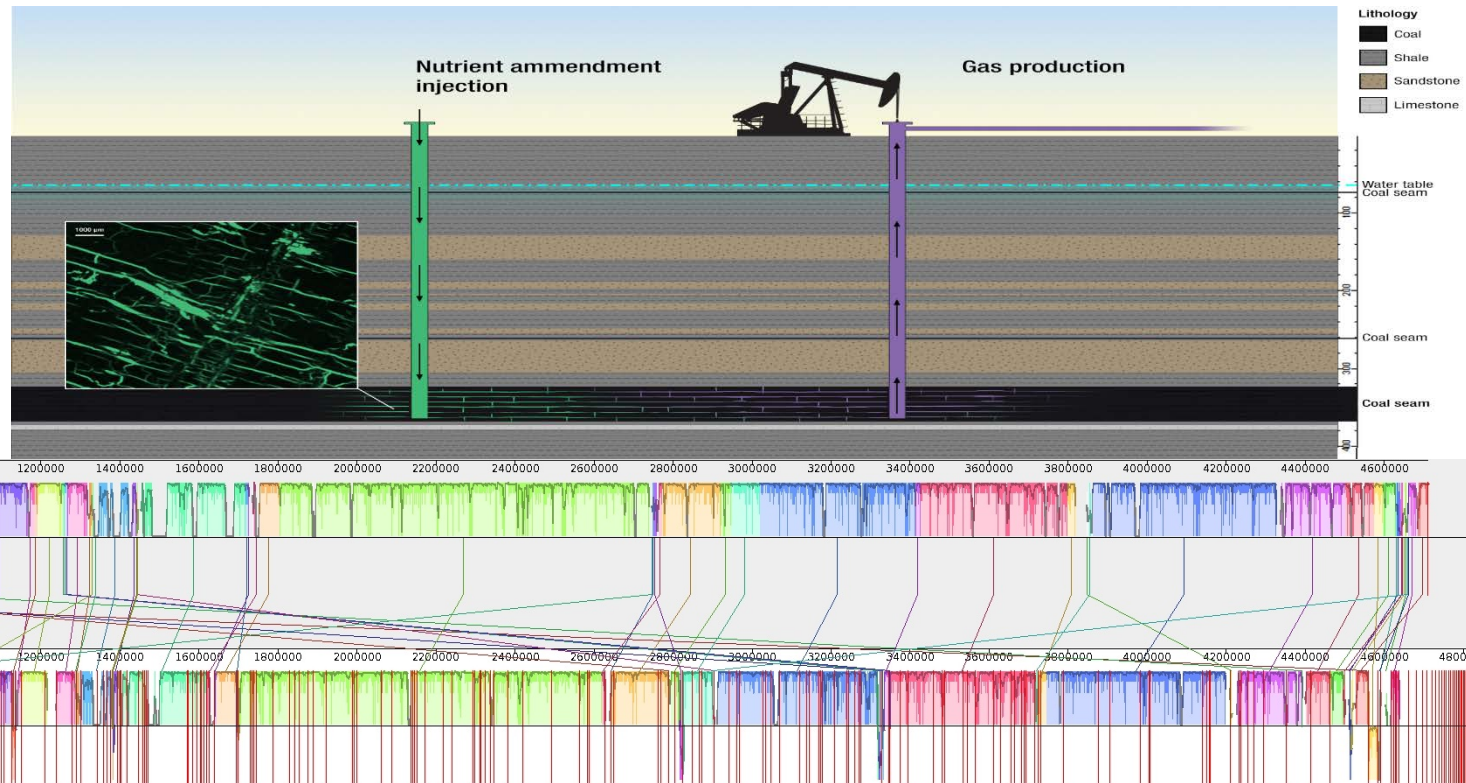


Phase 1:

- Wells will be cored/ drilled and permeability will be studied.
- Lab studies conducted with cores and fluids

Phase 2:

- Baseline conditions will be monitored
- Nutrients will be added to the injection well and increased methane production will be monitored.



Pseudomonas_stutzeri_K35_updated_051516.fasta



ENERGY

National Energy
Technology Laboratory

Thank you!

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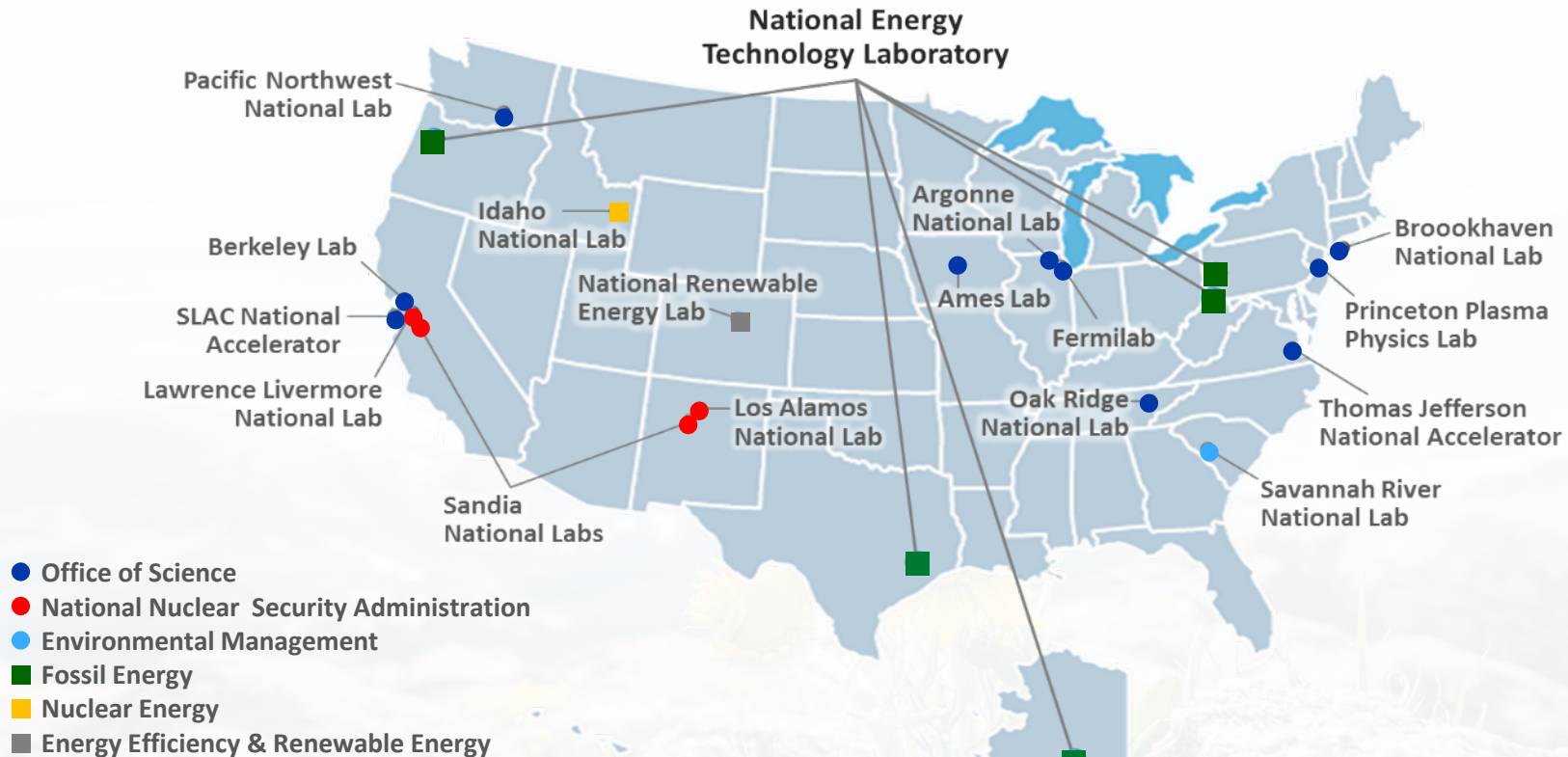
<https://edx.netl.doe.gov/carbonstorage/>
<https://edx.netl.doe.gov/offshore/>
<https://edx.netl.doe.gov/ucr/>
<https://edx.netl.doe.gov/nrap>



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NETL: THE Fossil Energy Laboratory



NETL's mission is to discover, integrate, and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations

History of Enabling Fossil Fuels



Technology Readiness...Maturing Technology



EXTRAMURAL

INTRAMURAL & EXTRAMURAL



Technology Demonstration
TRL 8-9



Process Engineering
& Integration
TRL 5-7



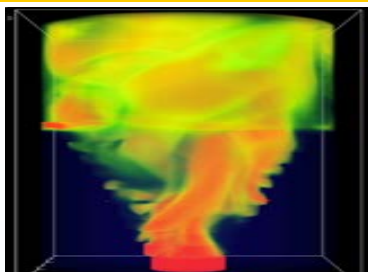
Applied Research
TRL 2-4

*Energy Solutions
for Today*

*Energy Options
for Tomorrow*

TRL=Technology Readiness Level

Enduring Core Competencies



**Computational
Engineering**

High Performance
Computing

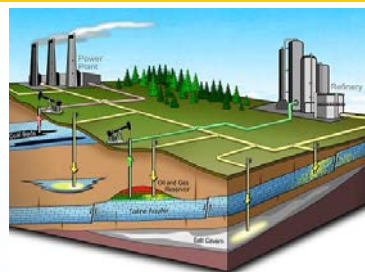
Data Analytics



**Materials Engineering
& Manufacturing**

Structural & Functional

Design, Synthesis &
Performance



**Geological &
Environmental Systems**

Air, Water & Geology

Understanding &
Mitigation



**Energy
Conversion
Engineering**

Component & Device

Design & Validation



**Systems
Analysis & Engineering**

Process &
System

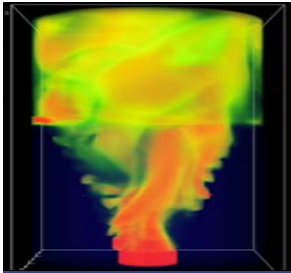
Optimization,
Validation & Economics

Effective Resource Development

Efficient Energy Conversion

Environmental Sustainability

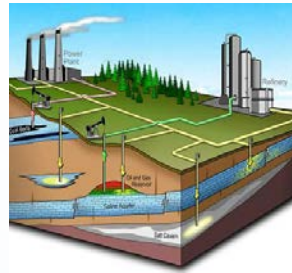
Core Competencies & Technical Thrusts



Computational Engineering



Materials Engineering



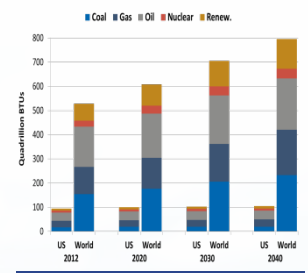
Environmental Engineering



Energy Conversion



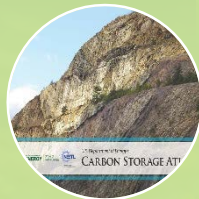
System Engineering



Markets & Benefits



Carbon Storage



Carbon Capture



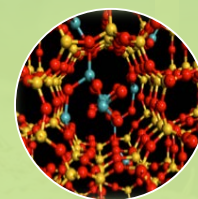
Sensors



Advanced Materials



Advanced Computing



Advanced Energy Systems



Enhanced Resource Production



Environmentally Prudent Development



Transmission & Delivery



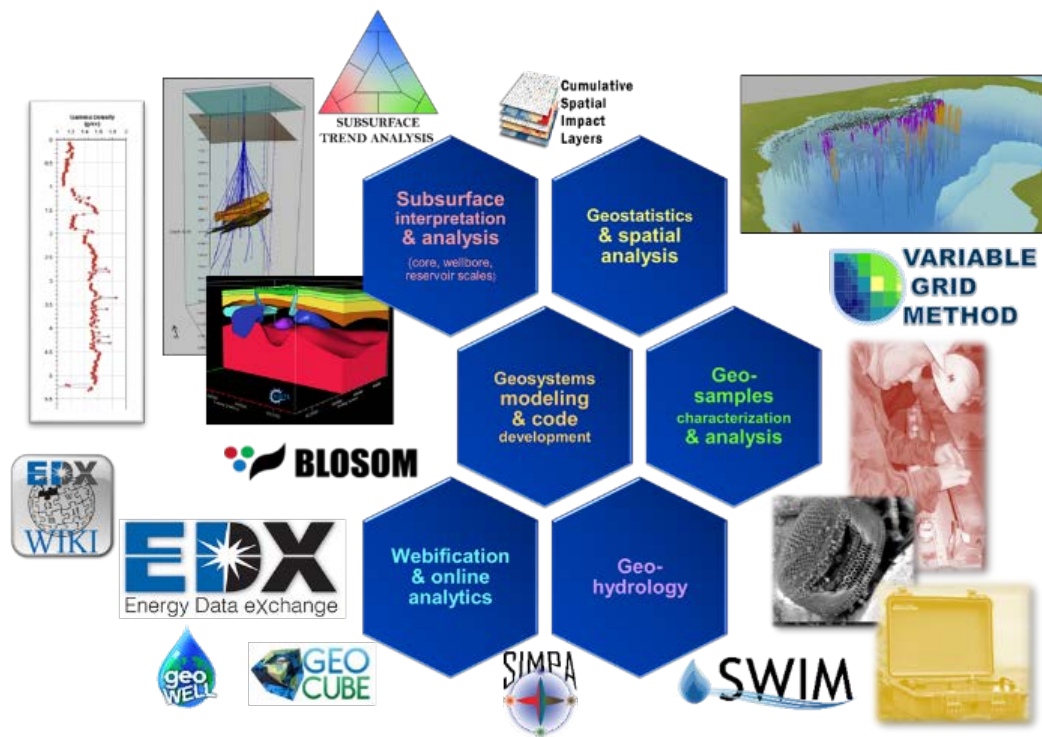
Methane Hydrates



Geology & Geospatial Analytical Team (G&G Team)

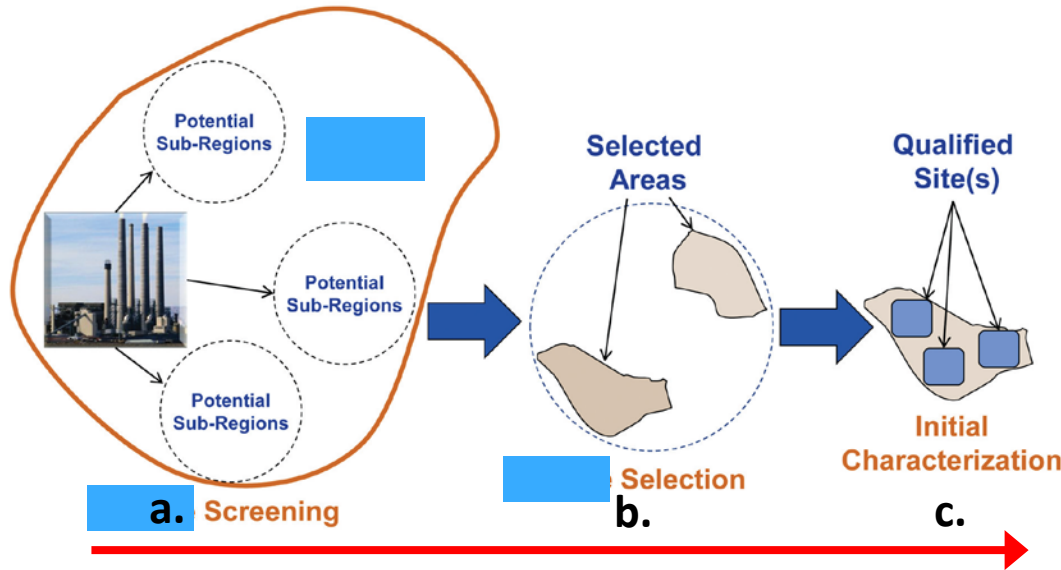


MISSION: The Geology & Geospatial Analytical Team seeks to **reduce uncertainty about, and provide data to characterize engineered-natural energy systems** through development of data, information, approaches and numerical simulations **spanning the micron to regional scale.**



DEVELOP DEFENSIBLE DOE METHODOLOGY FOR REGIONAL ASSESSMENTS

Prospective Storage Resource for CO₂ storage reservoirs



“Project Site Maturation” through the Exploration Phase.

Petroleum Industry		CO ₂ Geological Storage
Reserves	Implementation	Capacity
On Production		Active Injection
Approved for Development		Approved for Development
Justified for Development		Justified for Development
Contingent Resources	Site Characterization	Contingent Storage Resources
Development Pending		Development Pending
Development Unclearified or On Hold		Development Unclearified or On Hold
Development Not Viable		Development Not Viable
Prospective Resources	Exploration	Prospective Storage Resources
Prospect		Qualified Site(s)
Lead		Selected Areas
Play		Potential Sub-Regions

Exploration		Prospective Storage Resources	
c.	Project Sub-class	Evaluation Process	
b.	Qualified Site(s)	Initial Characterization	
a.	Selected Areas	Site Selection	
	Potential Sub-Regions	Site Screening	



the ENERGY lab

BEST PRACTICES for:

Site Screening, Site Selection, and Initial Characterization for Storage of CO₂ in Deep Geologic Formations

