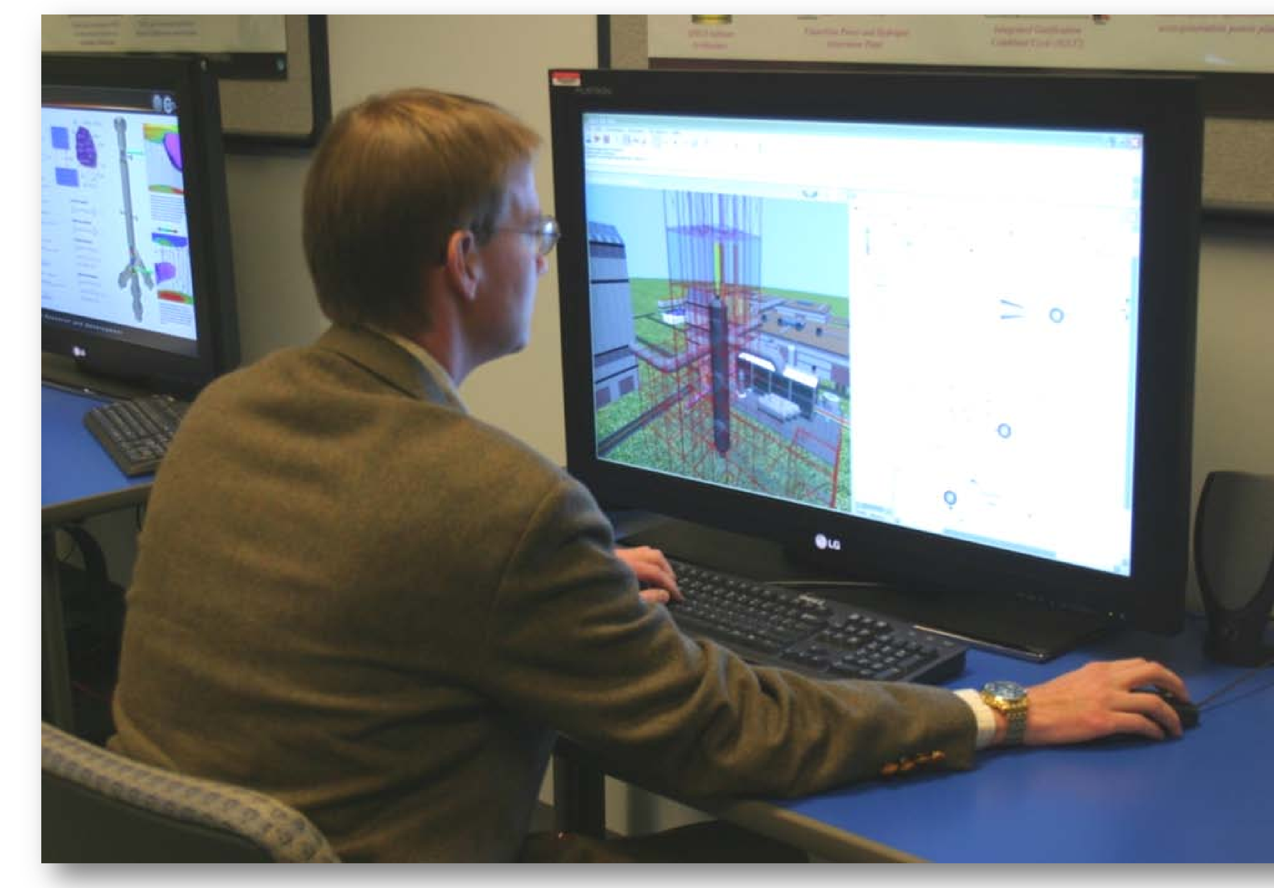
An R&D Alliance for Energy Technology Innovation

Carnegie Mellon · Penn State · University of Pittsburgh · Virginia Tech · West Virginia University

NETL-RUA
Regional University Alliance

Shared Laboratories

Shared Intellect



Shared Resources

Extreme Drilling Team

NETL-RUA Regional University Alliance

U.S. DEPARTMENT OF ENERGY

Challenge:

Enable energy companies to economically produce gas and oil trapped in reservoirs four to five miles beneath the earth surface where high pressures and temperatures prevail

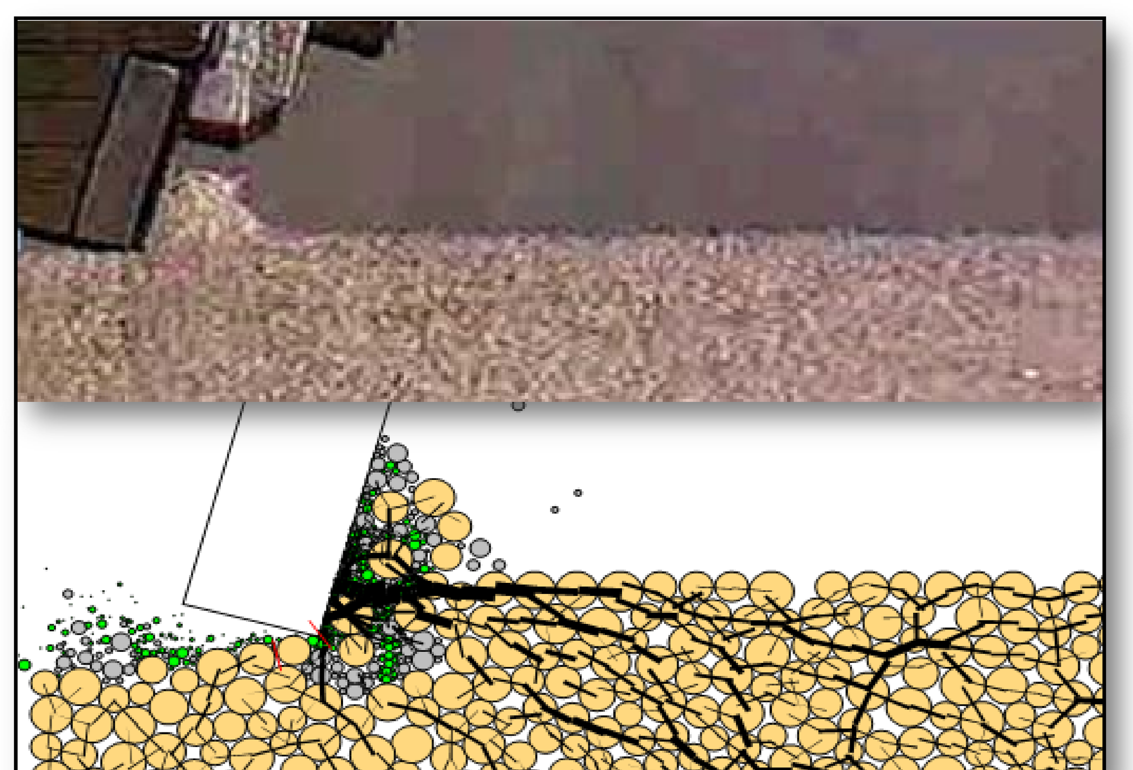
Research:

Integrate physical and numerical simulations to address low rate of penetration due to increased formation pressures enabling a safe, efficient, and economical supply of domestic oil and gas

Extreme Drilling Laboratory

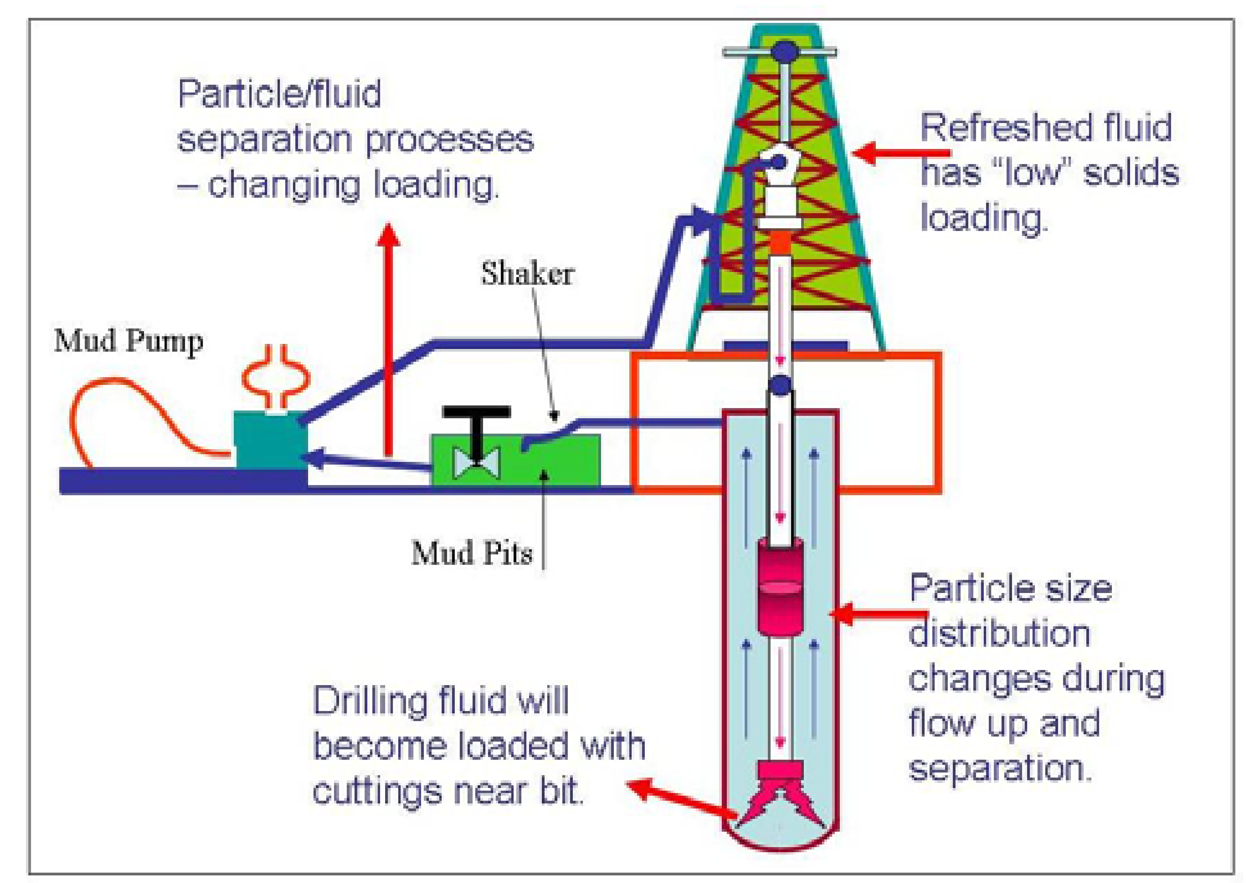
NETL Ultra-Deep Drilling Simulator mimics drilling at pressures up to 30,000 psi and temperatures up to 250 ^{o}C

Extreme Drilling Modeling



Computer simulation of drilling in ultra-deep conditions

High Temperature High Pressure Drilling Fluid



Nanoparticle-based drilling fluid improve the rate of penetration in deep drilling systems

Materials

Focus on the conditions under which catastrophic failure of drill alloy occurs

Collaborators:

NETL · Carnegie Mellon · PennState 1855 · University of Pittsburgh · URS · West Virginia University

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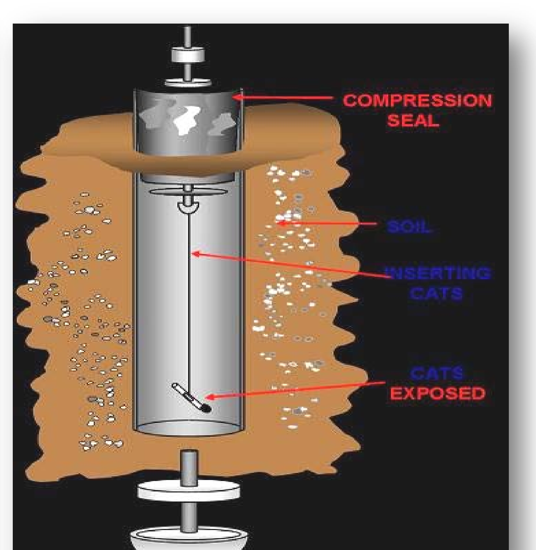
Quantitative MVA Team

Challenge:
Carbon capture and sequestration requires development of tools to monitor, verify and measure the CO_2 fate and behavior underground to ensure safe, permanent storage

Research:
Utilize lab and field studies for geochemical modeling, thermodynamics and kinetics studies, reactive transport and computational chemistry, to determine measureable and predictable properties of CO_2 in geologic formations

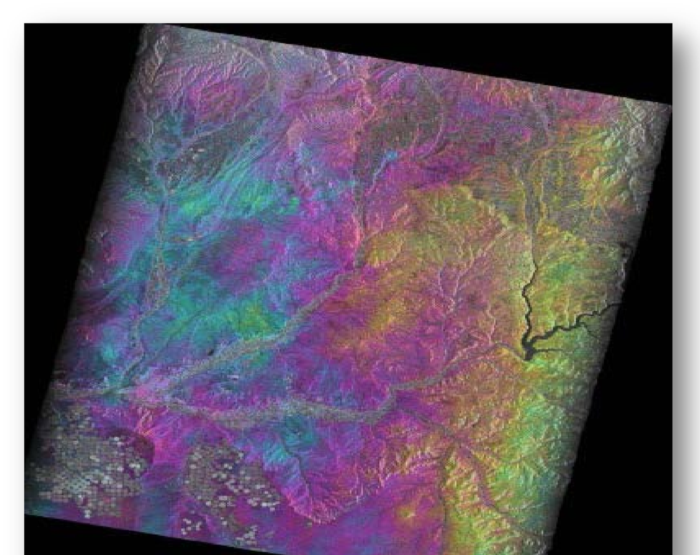
Quantitative Monitoring, Verification and Accounting

Geochemical Signals and Sensors



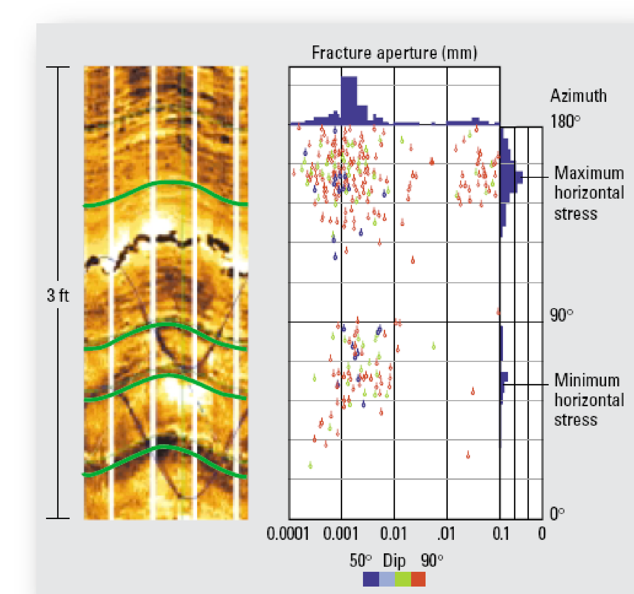
Develop natural geochemical indicators and signals that can be applied to monitor, verify and account for CO_2 and brine in geologic systems

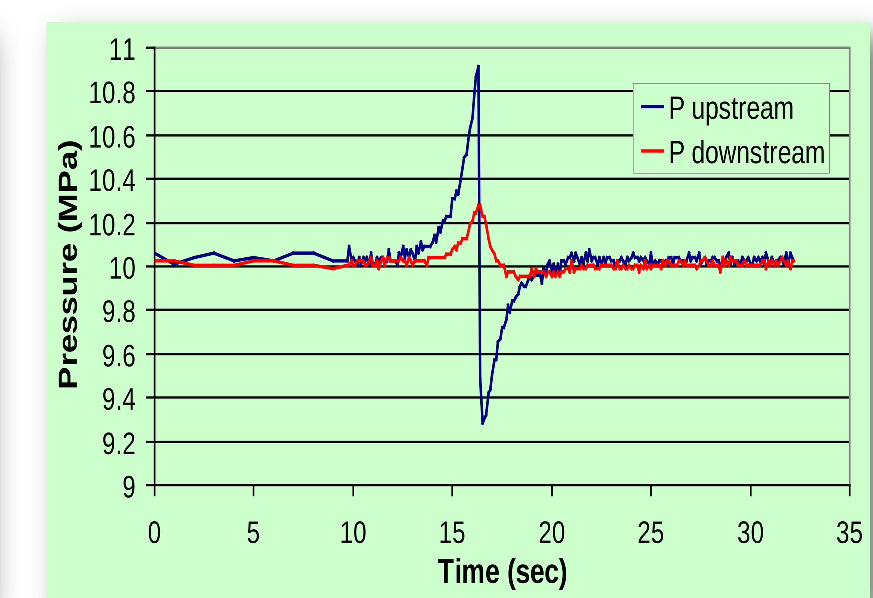
Integrated Modeling



Develop means to interpret near-surface monitoring results and optimize implementation of monitoring techniques

Quantitative Geophysical Properties





Integrate laboratory and field observations using geophysical techniques

Collaborators:

NETL Carnegie Mellon PENNSTATE University of Pittsburgh URS VirginiaTech WestVirginiaUniversity

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0057 – CR – 10/10 – Martello

Environmental Team

Challenge:

Reduce the environmental footprint of oil and natural gas production while reducing the cost of environmental compliance

Research:

Focus on technologies and methods to minimize environmental impacts of domestic oil and gas production

Produced Water Treatment

Develop new, more effective treatment for waters produced during oil and gas drilling

Oil and Gas Production Waste Characterization

Determine characteristics of wastes generated by oil/gas production activities

Ecological Impacts

Establish best practices in the oil and gas industry that maximize protection of ecological resources

Air Emissions

Measure air emissions from oil and gas production activities to enable environmentally responsible development of domestic supplies

Collaborators:

NETL, Carnegie Mellon, Clarion University, Penn State, University of Pittsburgh, URS, Virginia Tech

Membranes Team

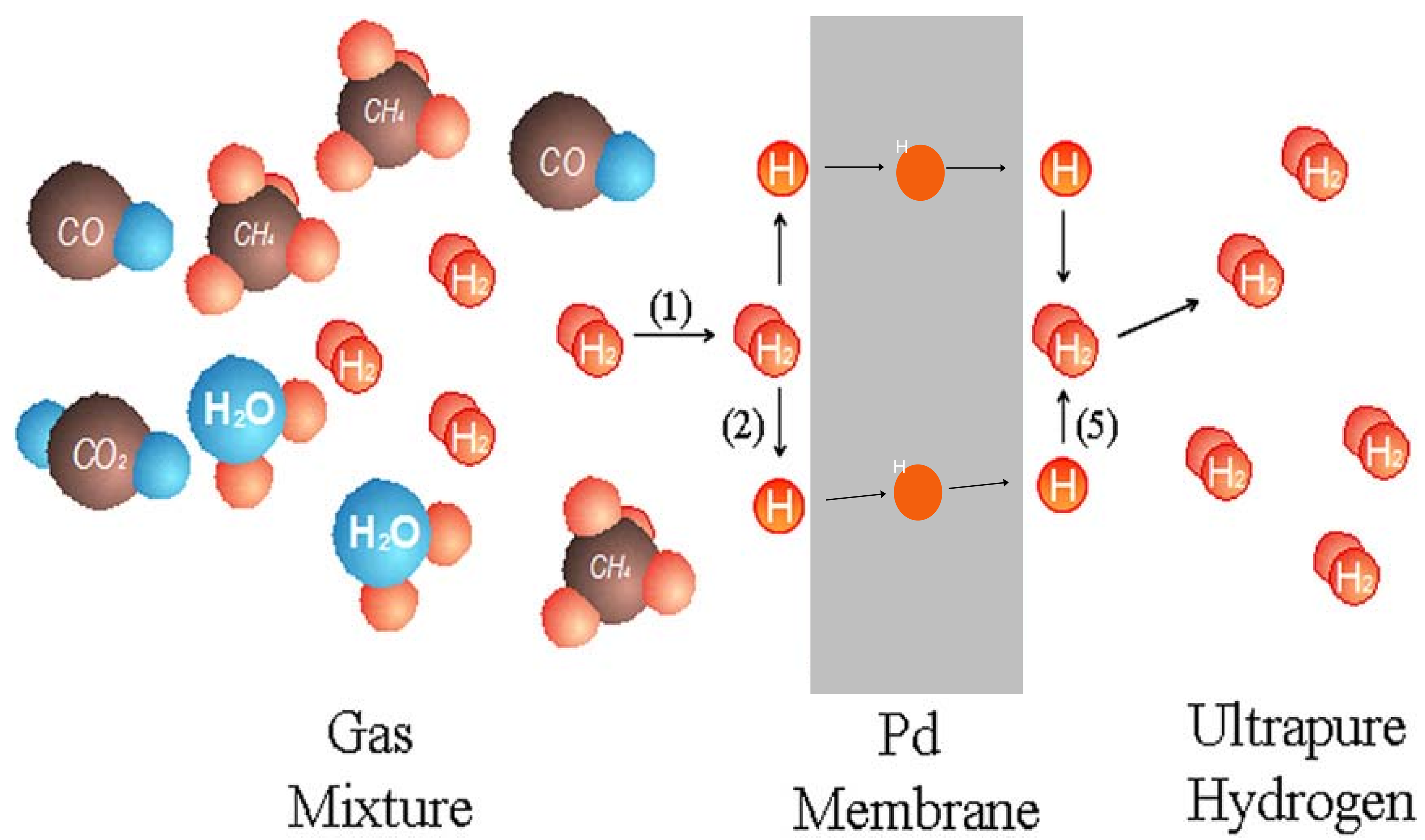
Challenge:

Develop effective gas separation technologies for carbon capture and hydrogen

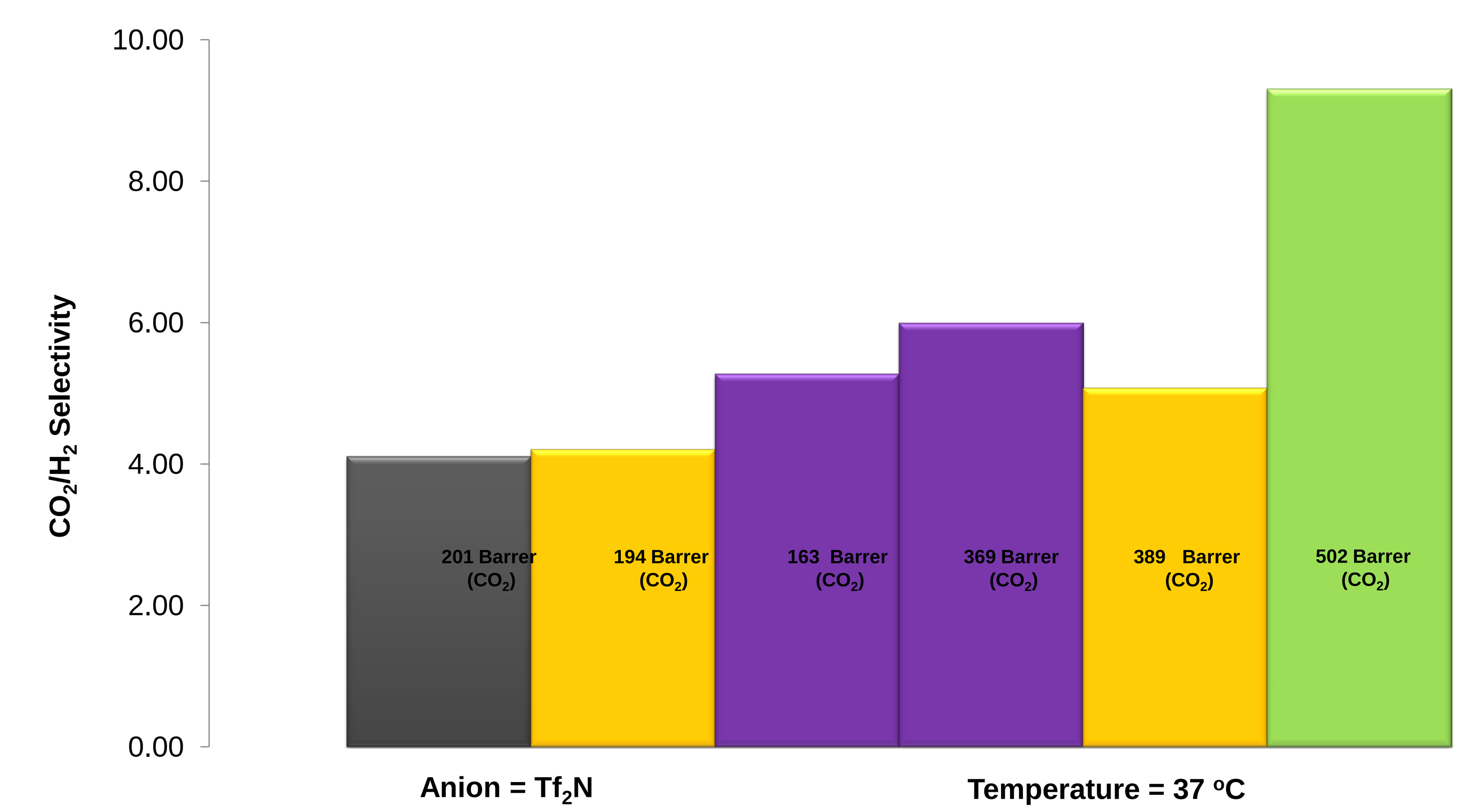
Research:

Focuses on computational and experimental work to develop affordable and efficient membranes for separation of CO_2, hydrogen, and other gases

Synthesis, processing, fabrication, and performance evaluation of membranes



Membranes for Hydrogen Separation



Ionic Liquids for CO_2 Separation

Collaborators: NETL, Carnegie Mellon, University of Pittsburgh, URS, Virginia Tech

Energy Storage Team

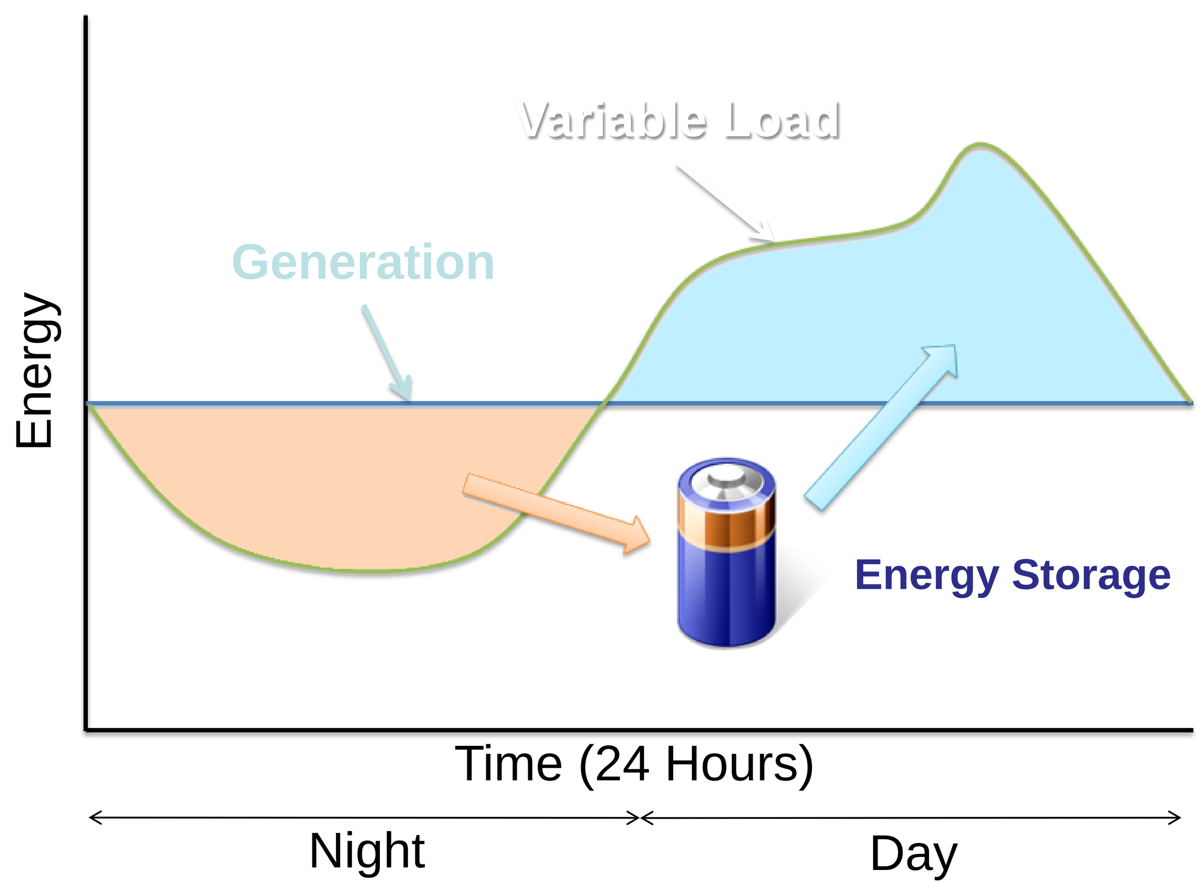
Challenge:

Lack of suitable large scale electrical energy storage devices is a major technological barrier to achieving the smart electrical grid – which integrates renewable and conventional generation sources and make electricity distribution more efficient and contributes to an overall decrease in CO_2 emissions.

Research:

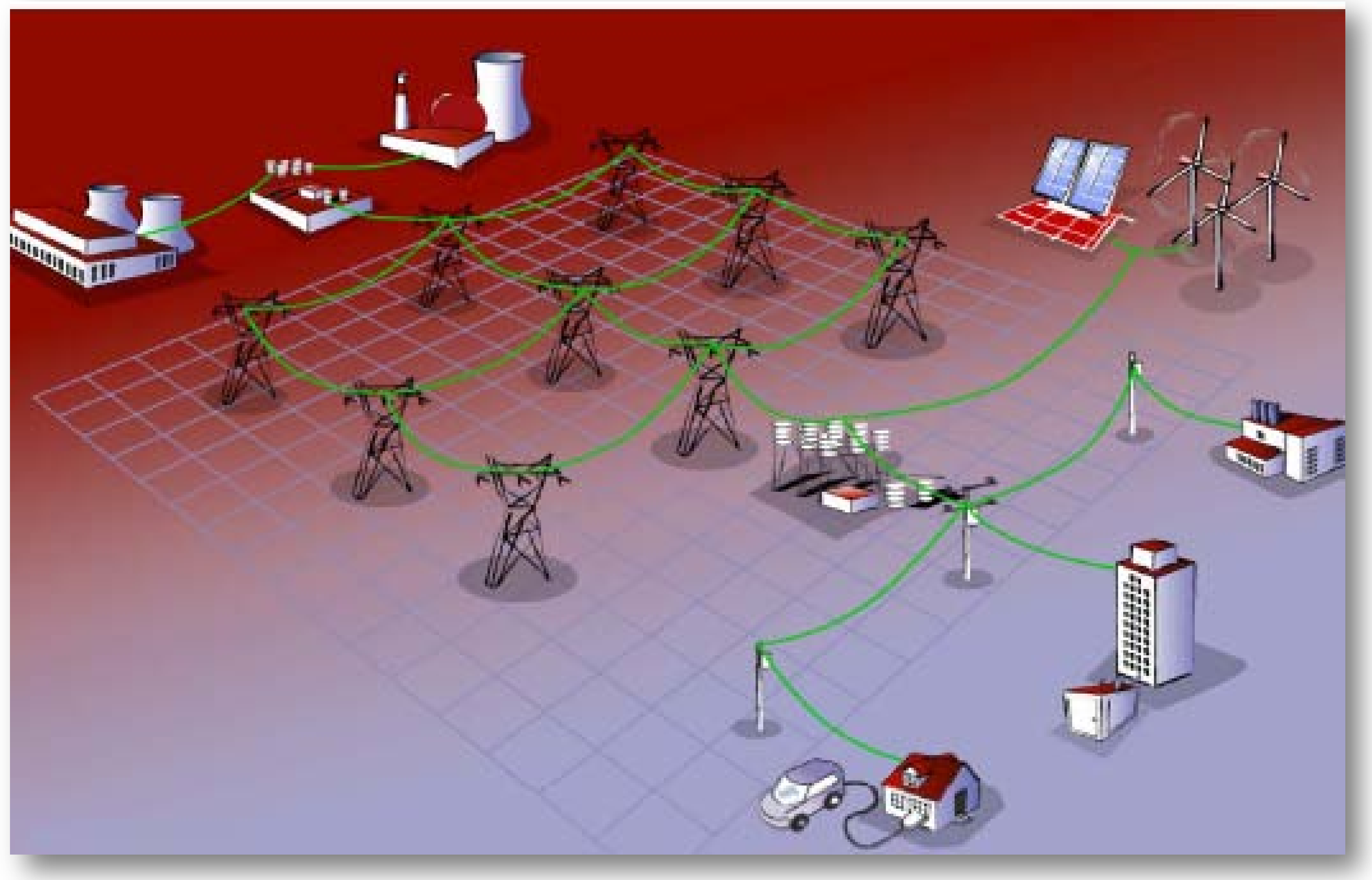
Focuses on solving the challenges associated with the design, synthesis, fabrication and characterization of advanced batteries with high energy storage capacities that can be recharged many times

Storage allows constant base load generation to meet variable demand



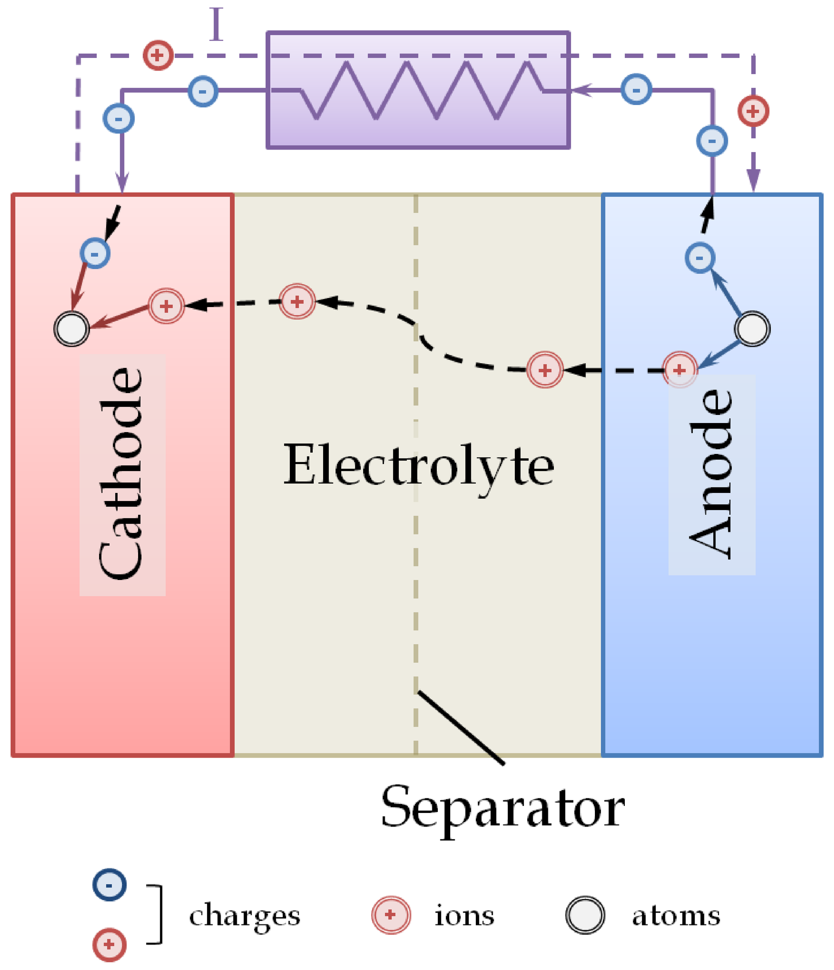
Make electricity distribution more reliable and more efficient

Storage allows shifting of power from intermittent sources



Storage of energy generated from solar, wind other renewable and distributed sources

Storage costs can be reduced with innovative fabrication methods



Nano-technology and nano-composite microstructures will reduce the cost of producing batteries with enhanced performance and durability

Collaborators: NETL, PENNSTATE 1855, University of Pittsburgh, URS

Fuels Conversion Team

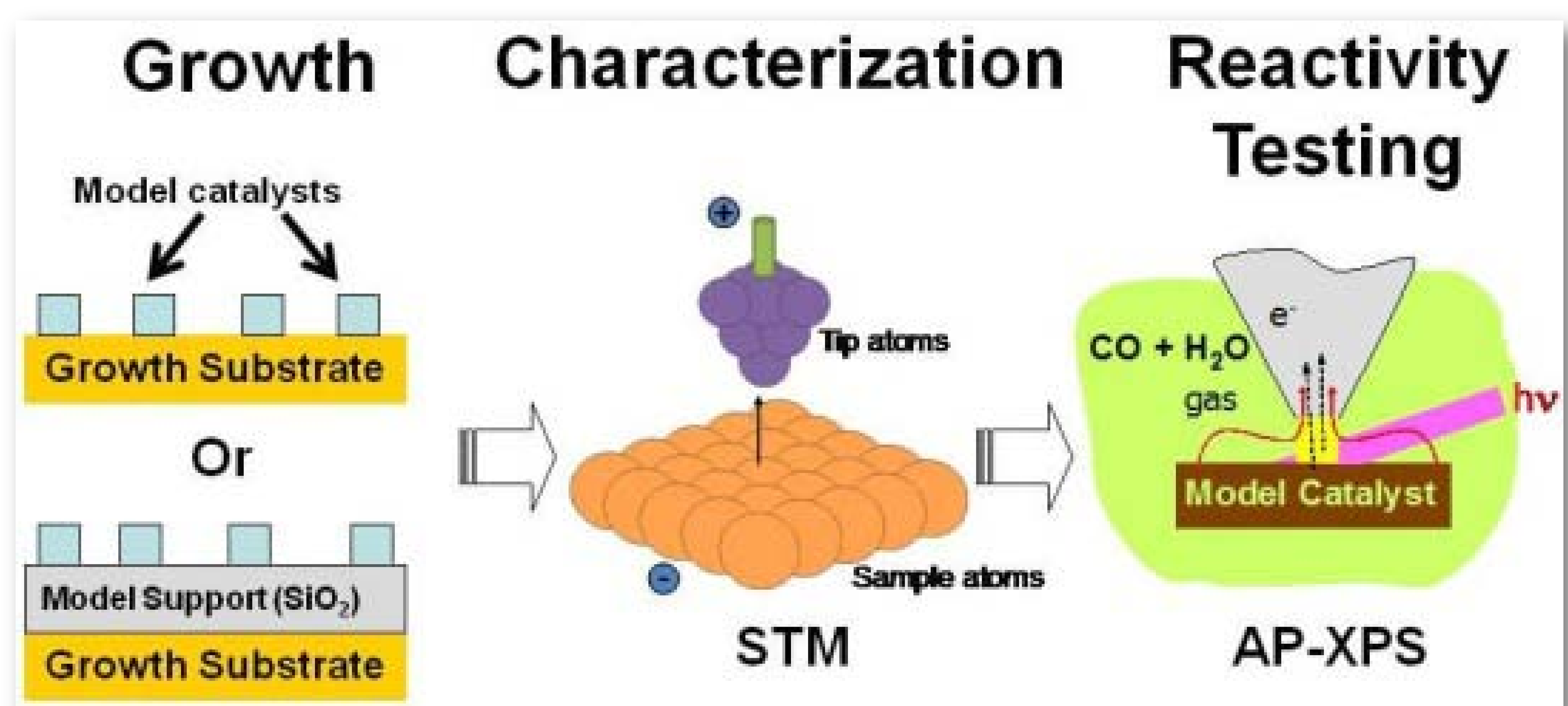
Challenge:

Effectively and efficiently produce hydrogen, clean fuels, and chemicals from domestic resources such as coal and biomass

Research:

Focuses on development of thermocatalytic processes for the production of transportation fuels and specialty chemicals

- Higher alcohols production from syngas
- Syngas conditioning using water-gas-shift reaction
- Fuel Processing
- Fischer-Tropsch syngas conversion catalysis



Collaborators: NETL, Carnegie Mellon, Penn State, University of Pittsburgh, URS, West Virginia University

CO_2 Utilization

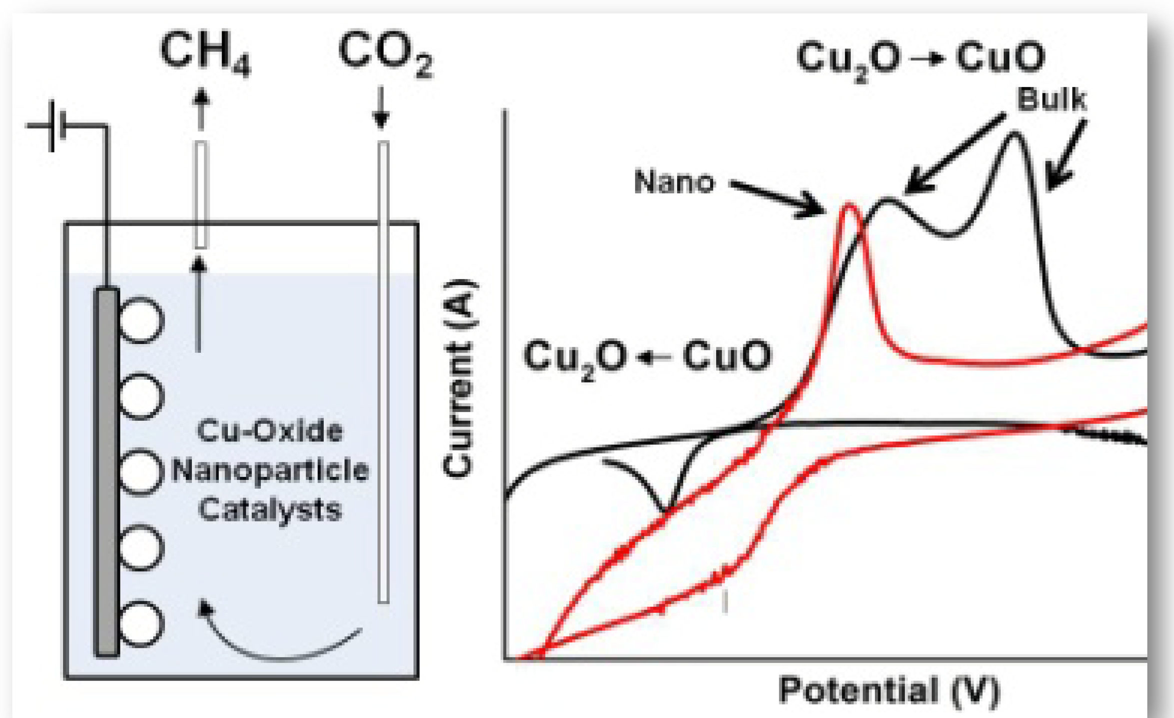
Challenge:

Develop alternative approaches to geologic sequestration in an effort manage large volumes of CO_2 being produced from power plants and industrial processes

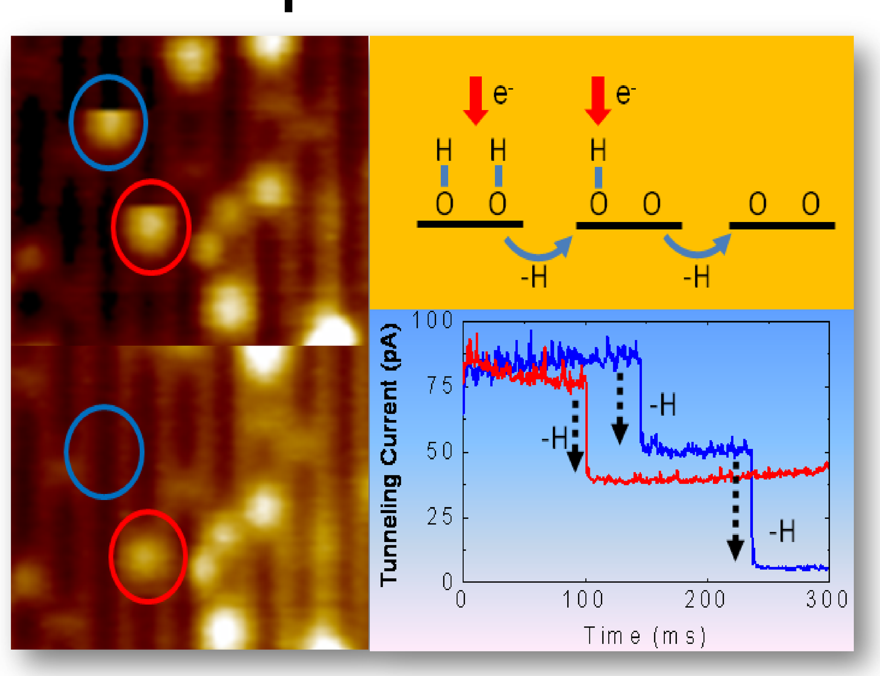
Research:

Focuses on developing economical and commercially viable processes to convert the carbon dioxide produced from power plants or industrial processes into useful fuels and/or chemicals

- Nanostructured Catalysts for the Electrochemical Reduction of CO_2



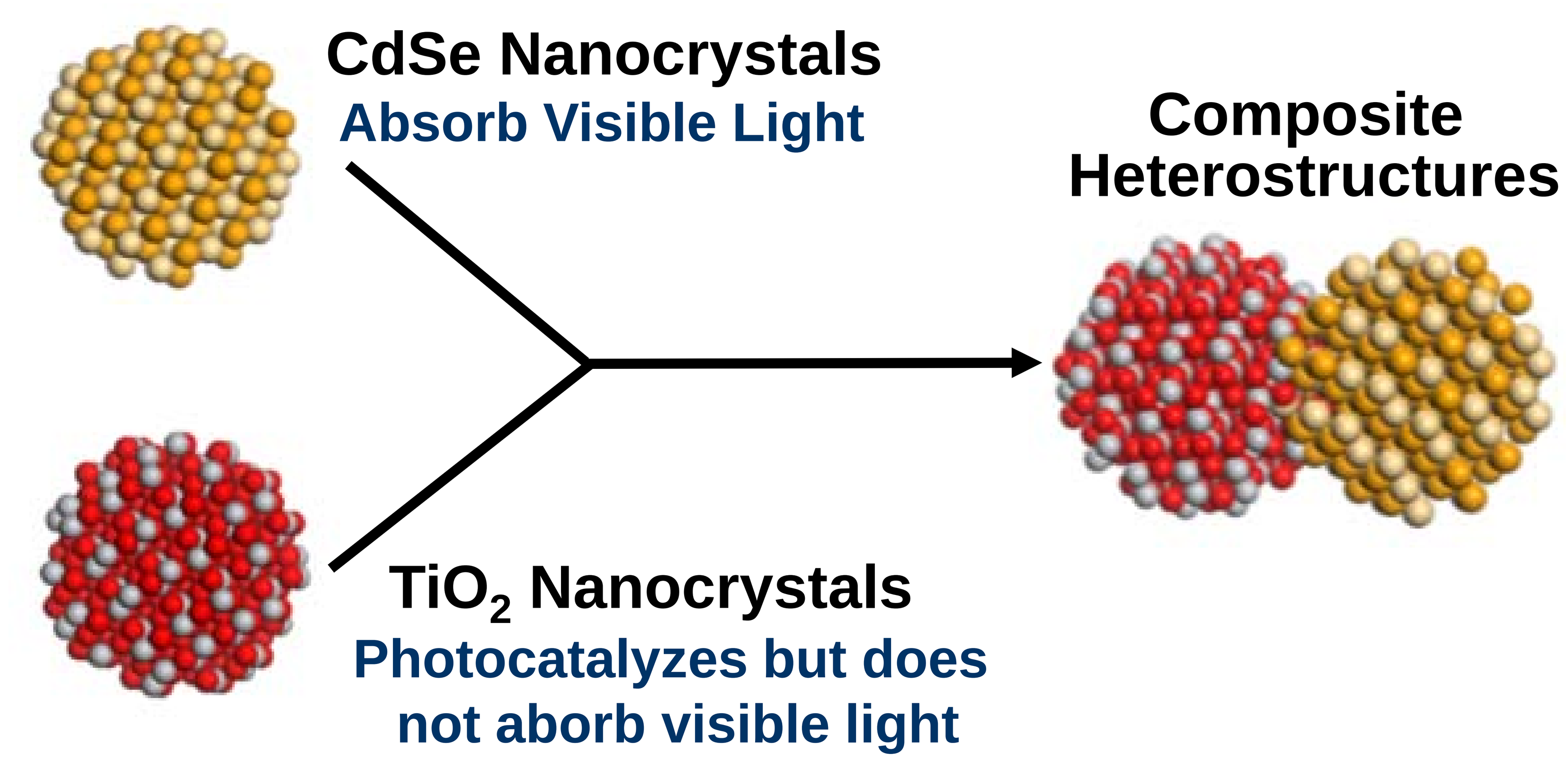
- Conversion of CO_2 to Value-Added Chemicals Using a Low-Temperature Plasma



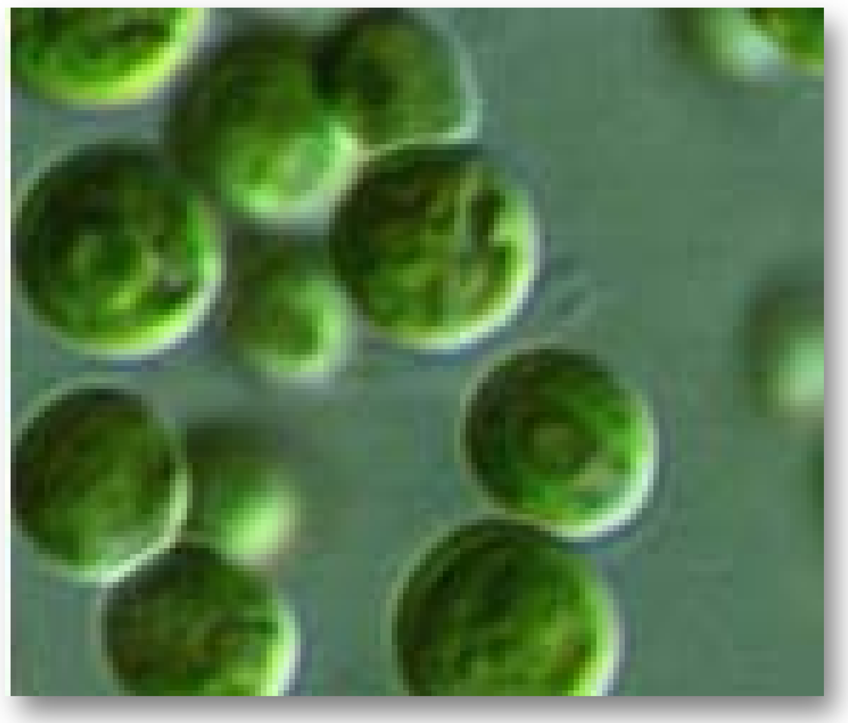
Electron Induced Chemistry

- Photoreduction of CO_2 on TiO_2 and Other Materials

Tailored Photo-catalysts



- Algal processes for capture and utilization of CO_2



Collaborators: NETL URS University of Pittsburgh

Advanced Simulation Team

NETL-RUA Regional University Alliance

U.S. DEPARTMENT OF ENERGY

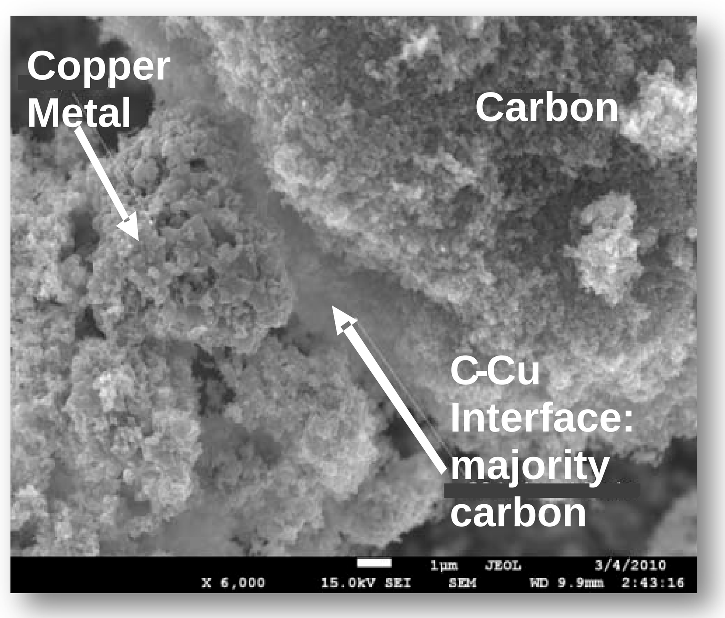
Challenge:

Accelerate development and deployment of novel process and equipment designs for fossil fuel utilization and carbon management

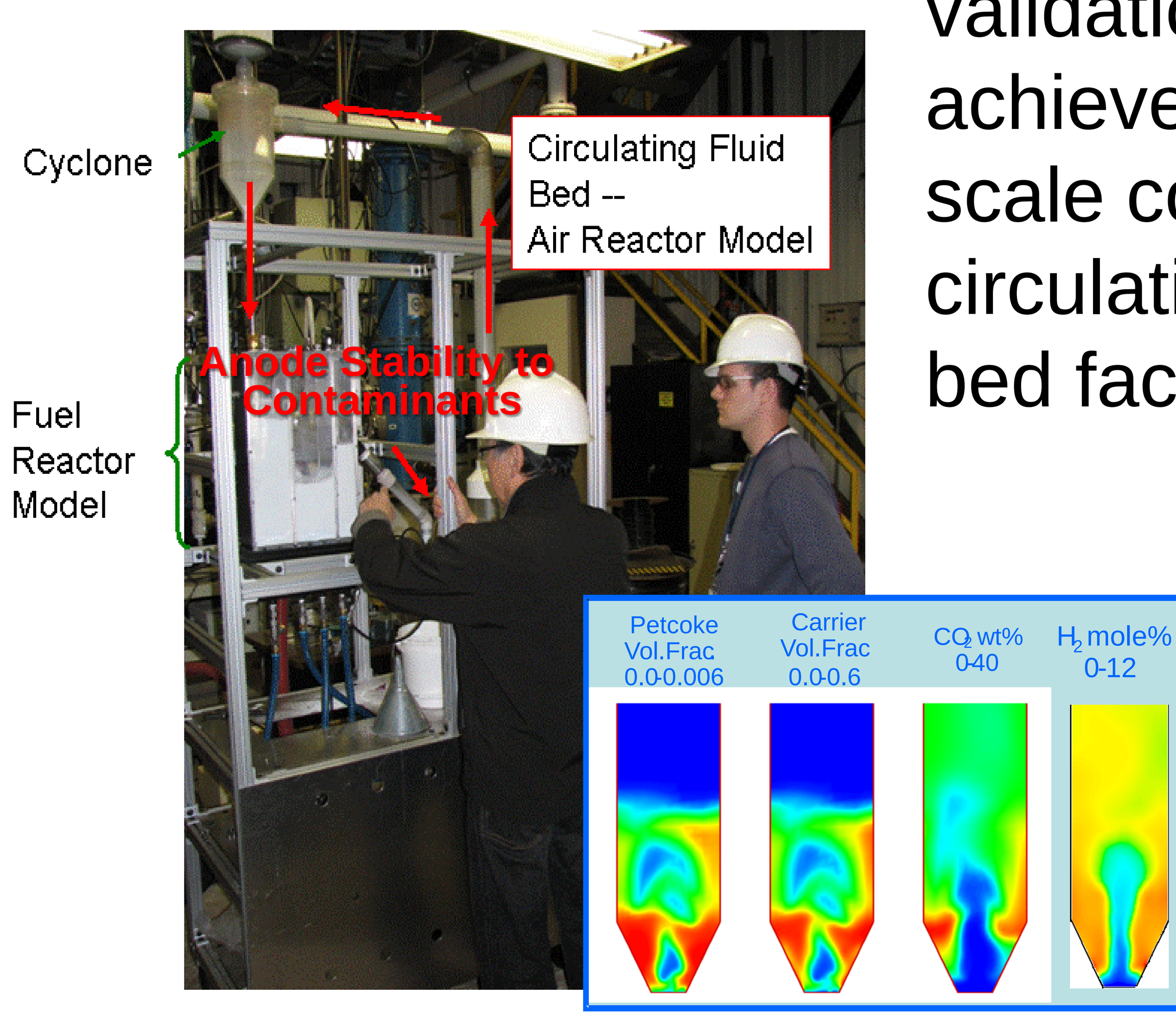
Research:

Focuses on developing comprehensive, integrated simulation and modeling tools that will reduce cost and increase efficiency for implementing carbon capture and sequestration

Design Optimization and Integration

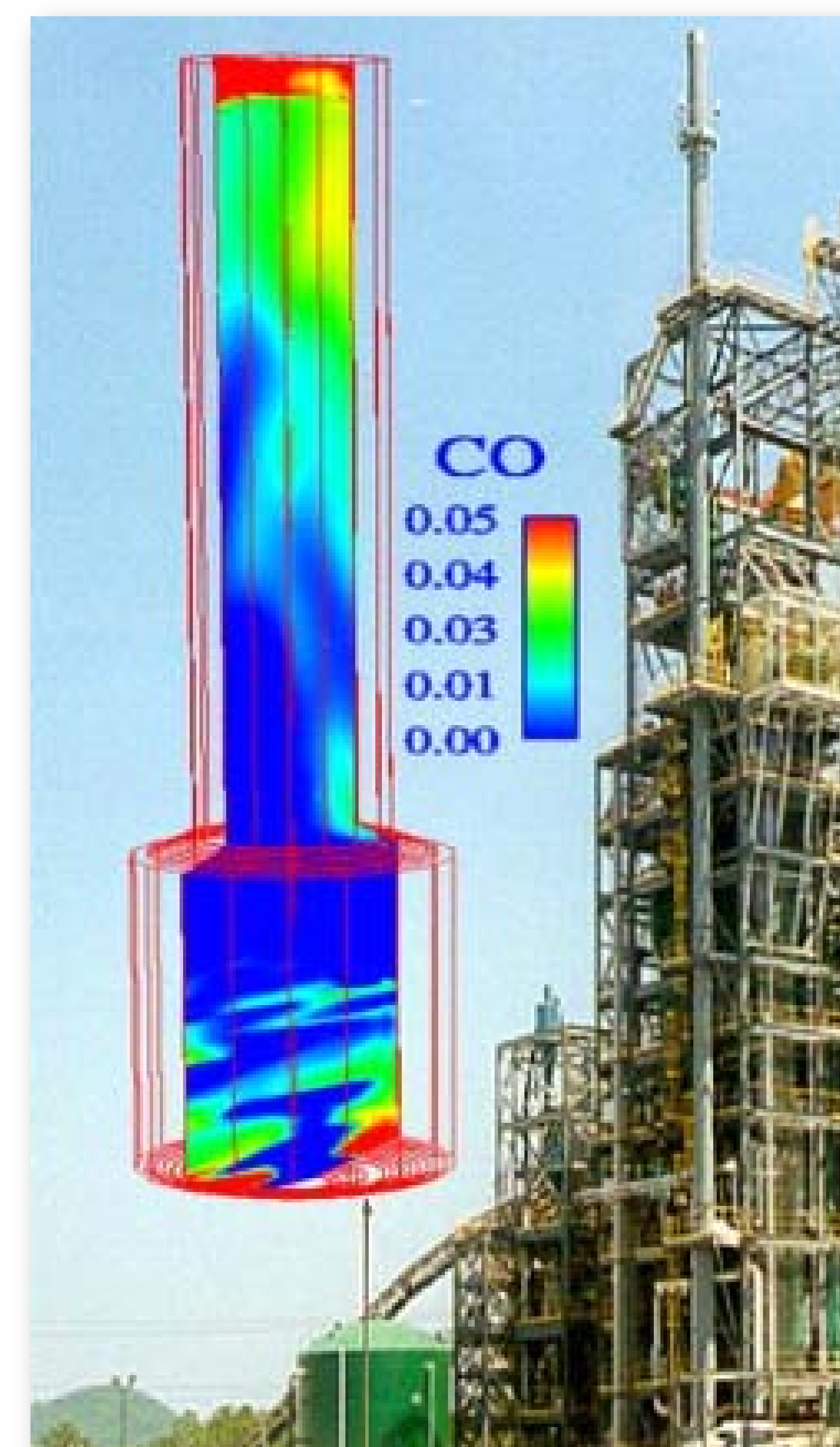


C/CuO Interface Regions



Advanced diagnostic tools are developed and used to capture data for model development, verification and validation. This is achieved in a large scale cold flow circulating fluidized bed facility at NETL.

Multi-scale Simulation and Model Development



Computer simulation tools are used to perform basic and applied research to further the understanding and modeling of the many types of dense and dilute, reacting multiphase flows.

Collaborators: NETL, Carnegie Mellon, Virginia Tech, West Virginia University

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Advanced Gasification Team

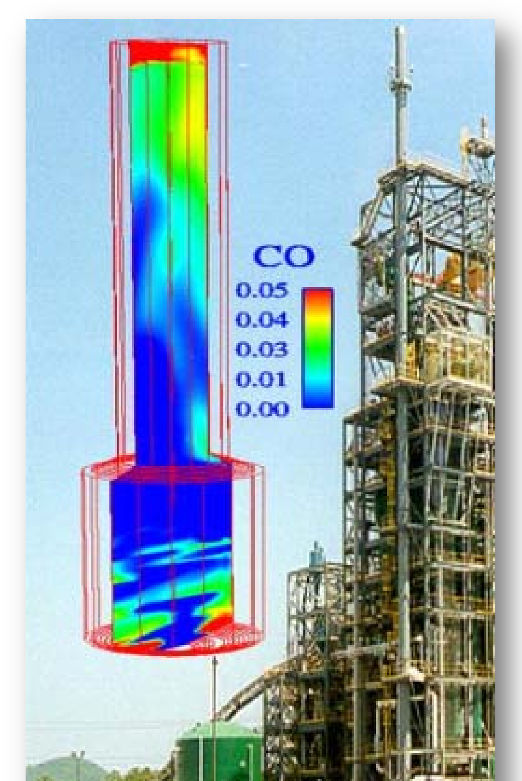
NETL-RUA Regional University Alliance

U.S. DEPARTMENT OF ENERGY

Challenge:
Generate clean power and fuels that use domestic resources and manage carbon dioxide

Research:
Focuses on gasification-based energy systems , which enables power production from coal with a reduced carbon footprint

Plant Optimization



Develop real-time simulators for research, plant optimization, and training of advanced energy plants

Fuel Flexibility

Coal+ biomass gasification with sequestration enables production of low-CO_2 fuels and power

Product Flexibility

Liquid fuels from gasification have potential to address national security, environmental and economic concerns

Collaborators: NETL, Carnegie Mellon, Penn State, University of Pittsburgh, Virginia Tech, West Virginia University

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0065 – CR – 10/10 – Guenther

Advanced Combustion Team

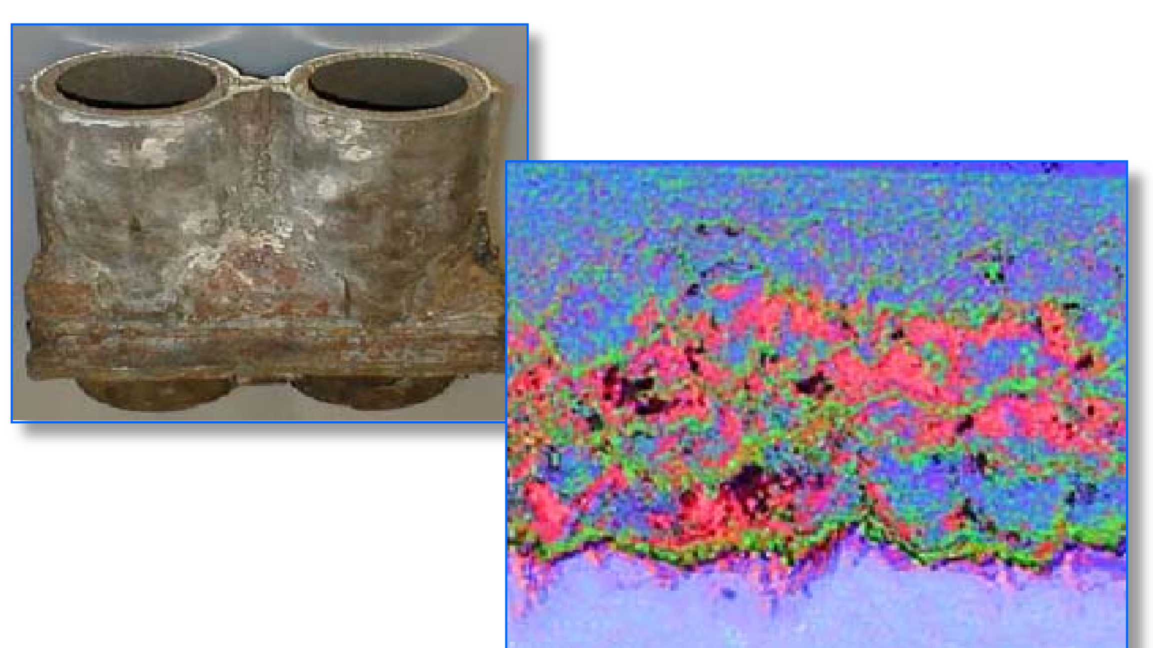
Challenge:

Address global climate change by reducing CO_2 emissions from coal-fired power plants with minimal increase in the cost of electricity

Research:

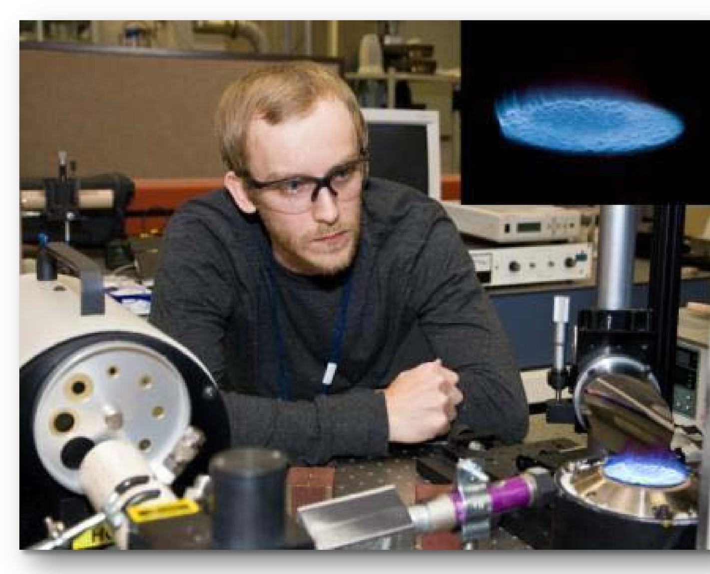
Focuses on low-cost CO_2 capture and improved efficiency to produce affordable, clean power from coal from new and existing power plants

Advanced Ultra-Supercritical Steam Cycles



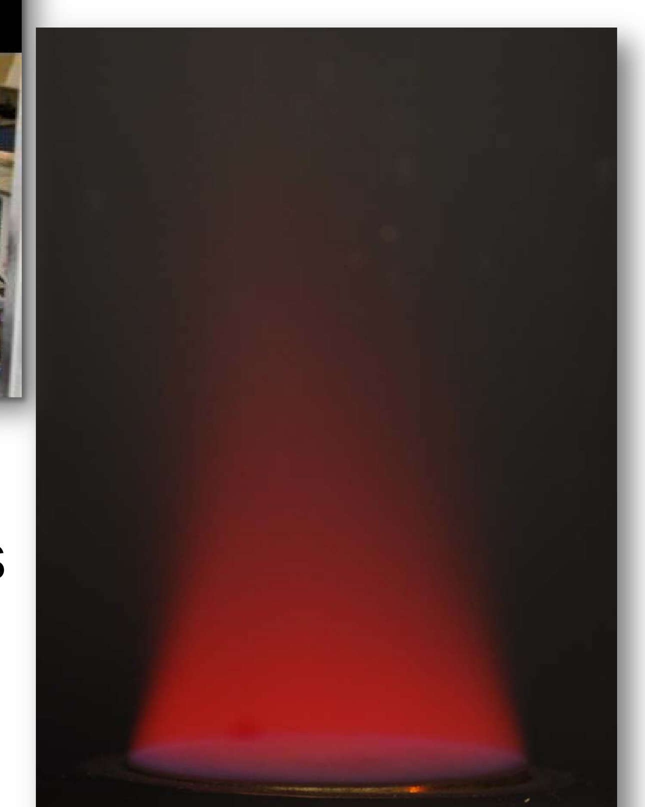
Develop materials than can meet extreme conditions for significantly improving plant efficiency

Oxy-fuel Combustion



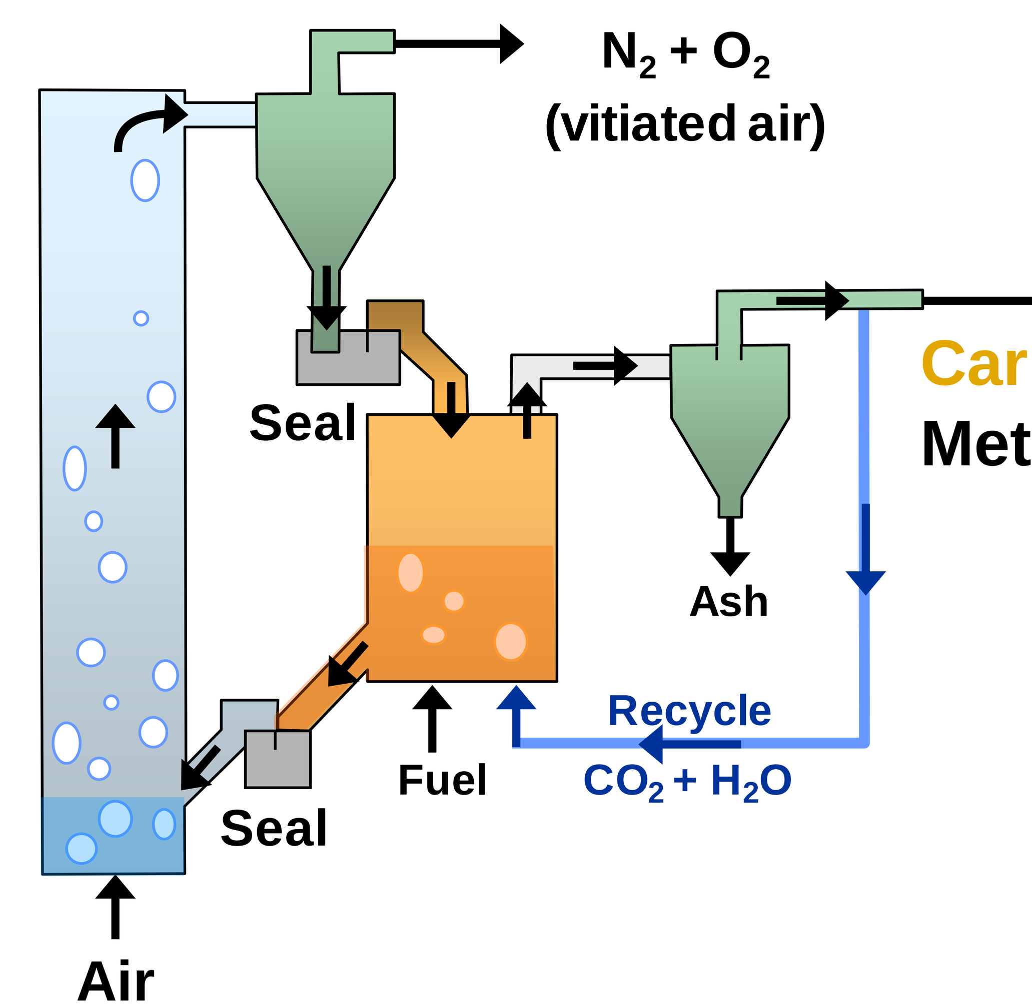
Measurement of oxy-fuel flame radiation properties

Hydrogen-Oxygen with steam



Burning coal with oxygen rather than air makes it easier to separate and remove CO_2 from the flue gas

Chemical Looping Combustion



Carbon + metal oxide = CO_2 + metal

Metal + air (oxygen) = metal oxide

Using carrier materials to provide the oxygen for combustion rather than using air

Next Generation Gas Turbines

Developing advanced materials for high-temperature, high-efficiency operation and researching combustion science

Collaborators:

NETL • OSU Oregon State University • PennState • University of Pittsburgh • URS • VirginiaTech

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0066– DJB – 10/2010 - CSummers

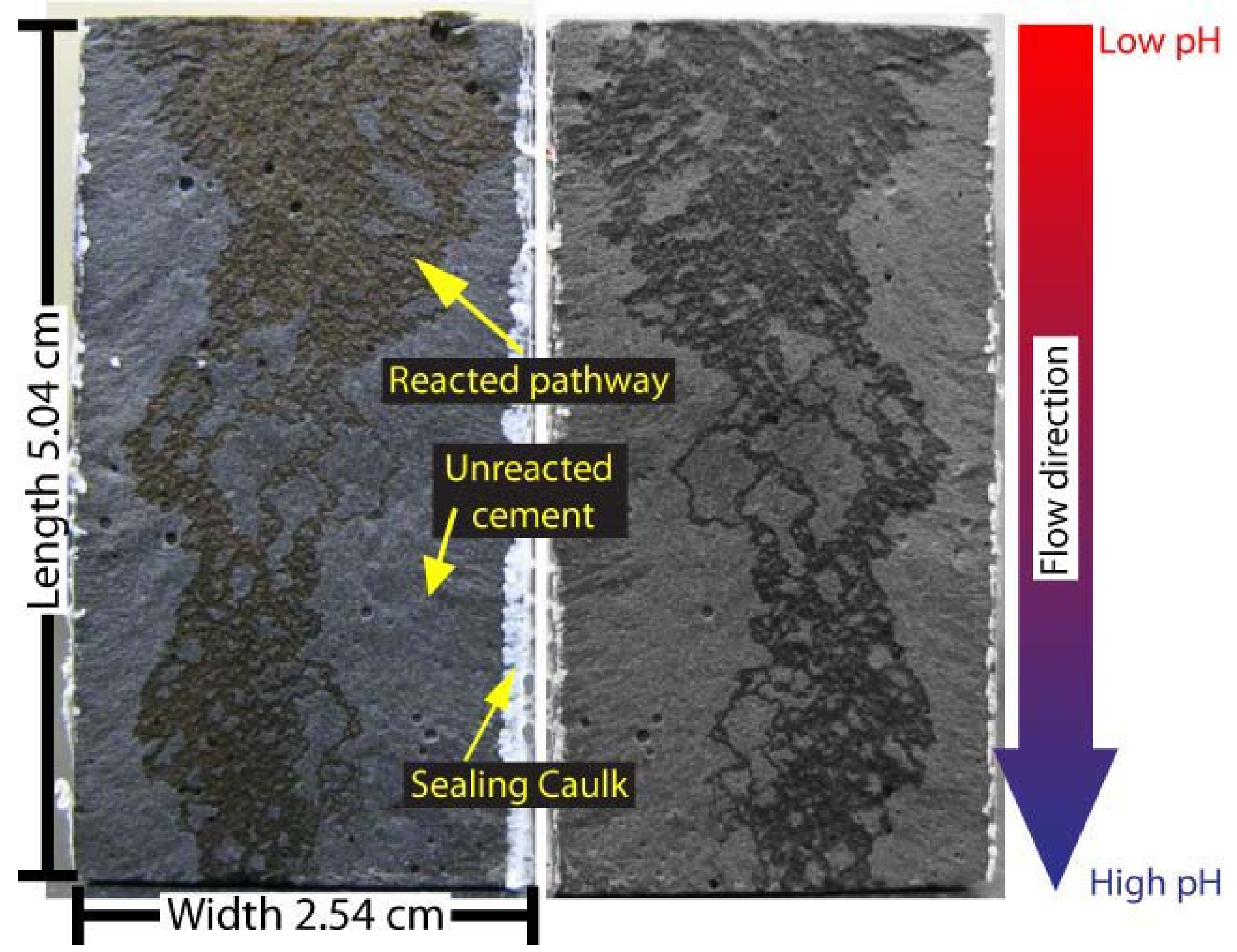
Seal Integrity for CO_2 Storage Team

Challenge:
Determine risk associated with storing CO_2 in a storage reservoir (assessing leakage risk)

Research:
Focuses on developing a science-based ability to account for the CO_2 contained in a storage reservoir

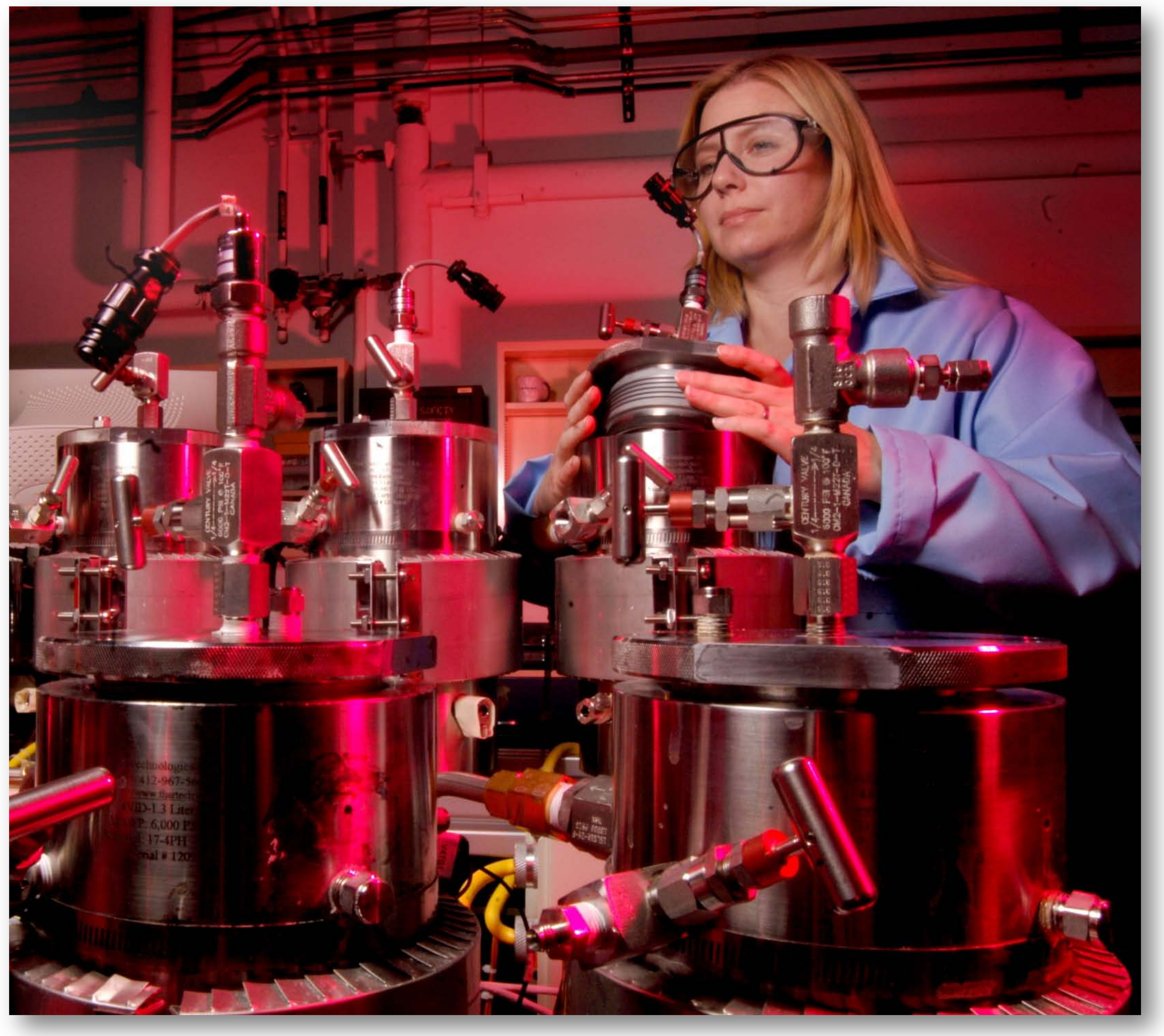
Geomechanics and Flow

Predicting leakage risk requires understanding the combined influences of chemical and mechanical properties of the well



The above image shows both faces of an induced fracture in wellbore cement that has been subjected to acidic fluid flow to simulate leakage

Geochemistry



Experiments re-create the conditions in the well to determine effect of temperature, brine composition, and other gas components on CO_2 chemical interaction with seal materials

Collaborators: NETL, Carnegie Mellon, Penn State, The University of Texas at Austin, URS, West Virginia University

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Carbon Dioxide Capture Team

U.S. DEPARTMENT OF ENERGY

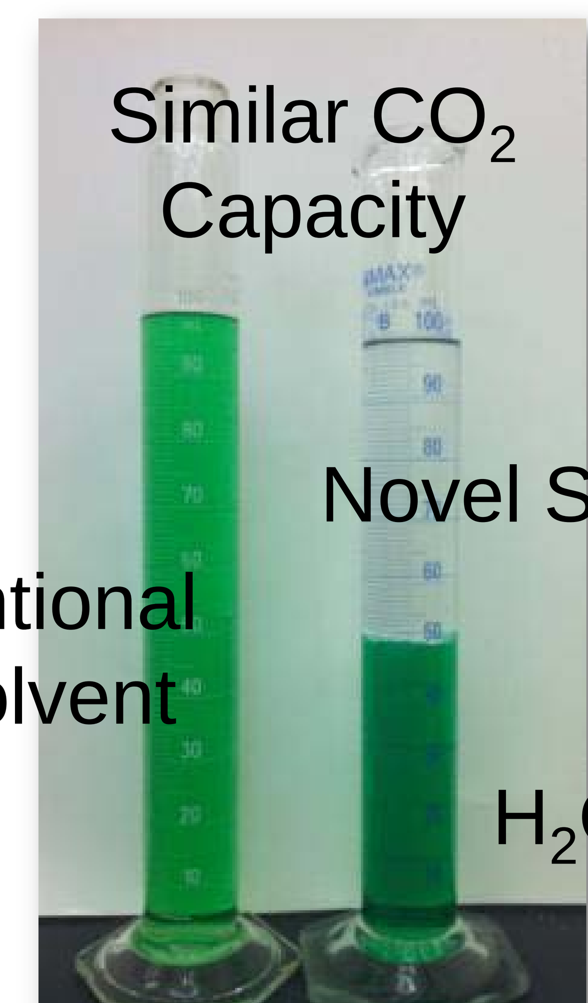
Challenge:

Develop low-cost CO_2 capture/separation technologies to reduce greenhouse gas emissions from existing and advanced power plants

Research:

Focuses on discovery, design, fabrication, testing, and analysis of new separation processes

New and Improved Solvents

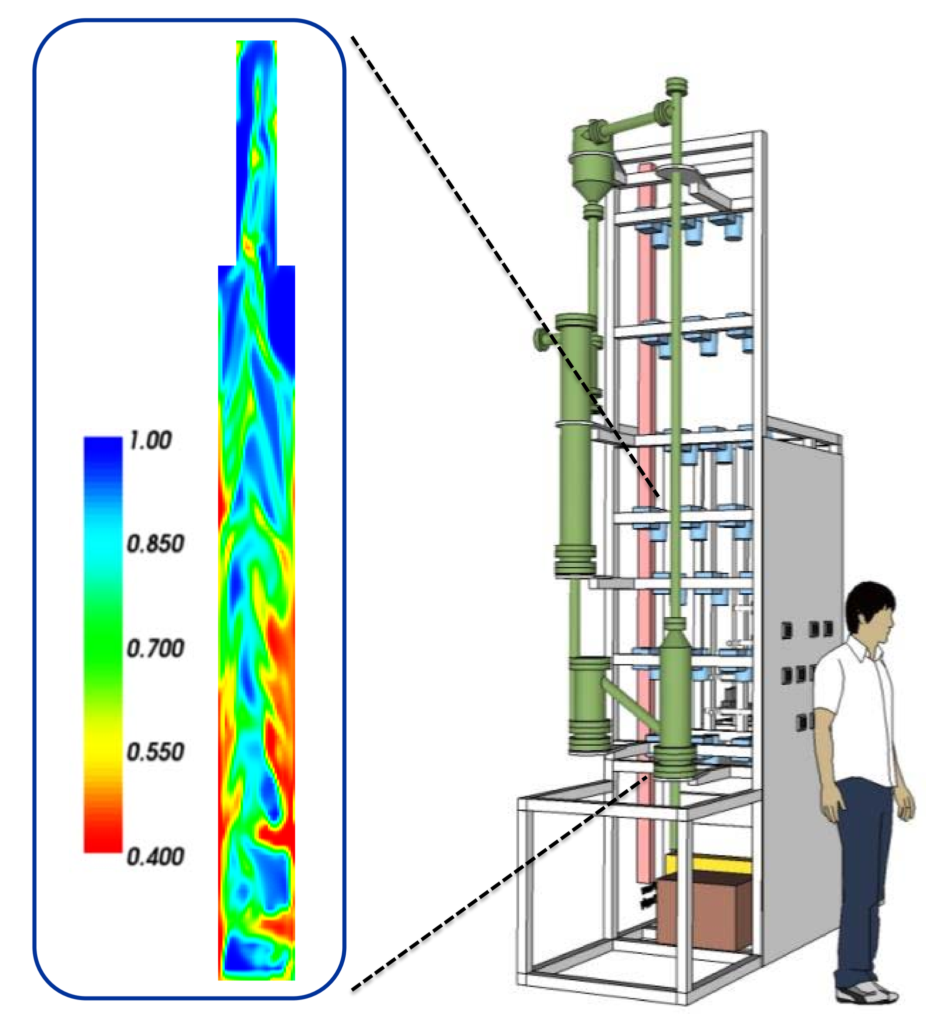


By simplifying reactor designs and increasing capacities for CO_2 , removal costs can be reduced

Sorbent Materials Development

Sorbents have potential to reduce regeneration energy compared to solvents, but they require new reactors and material handling

Sorbent Process Development



Using data from an experimental system to validate computer models enables rapid scale-up of the process

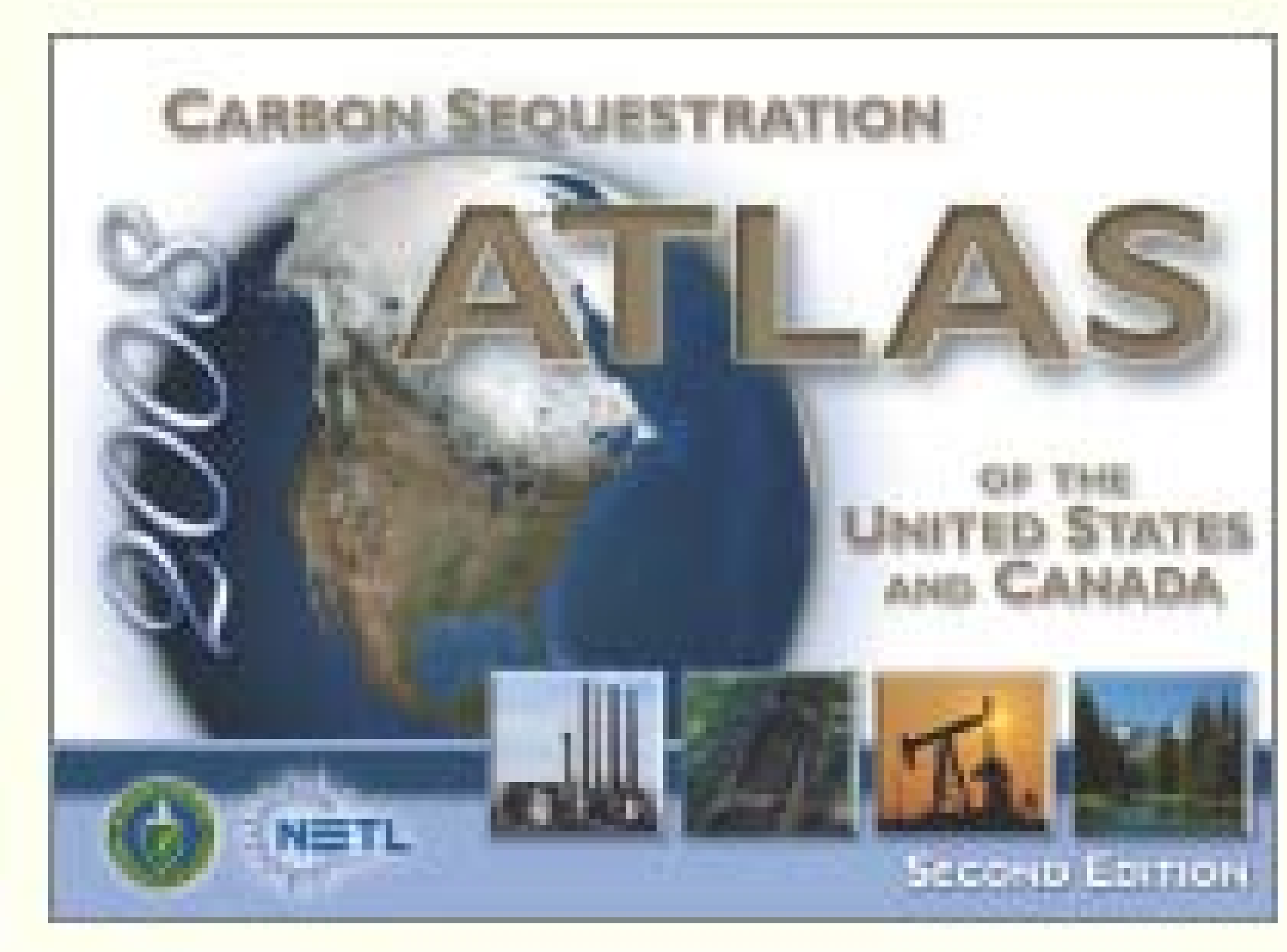
Gas Separation Membranes

Membranes have potential to purify CO_2 without process changes or energy input

Collaborators:

NETL • Carnegie Mellon • PENNSTATE 1855 • University of Pittsburgh • URS • VirginiaTech • WestVirginiaUniversity

CO_2 Storage Team



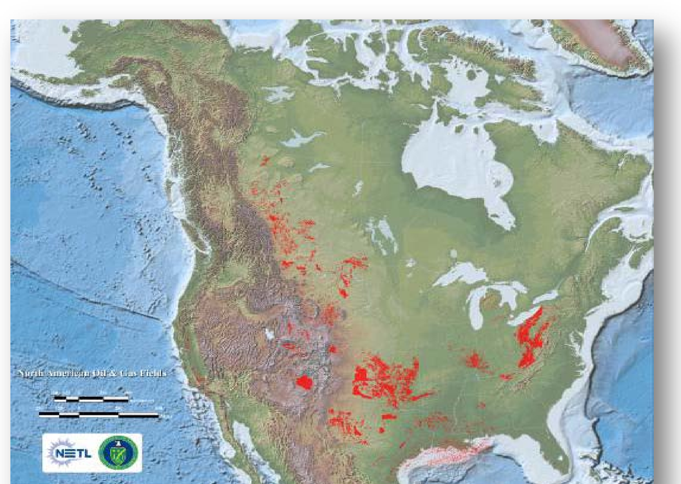
Challenge:

Quantifiable protocols for CO_2 storage are required for wide-scale deployment of carbon capture and sequestration

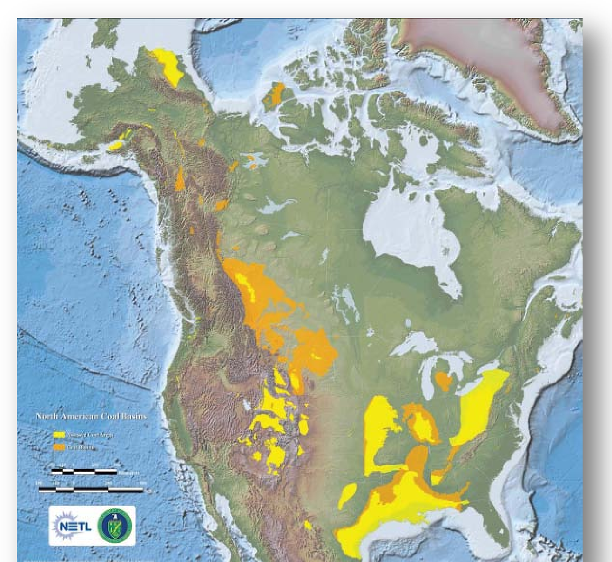
Research:

Focuses on improving CO_2 resource estimates of saline formations and unmineable coal seams for the Carbon Sequestration Atlas of the United States and Canada

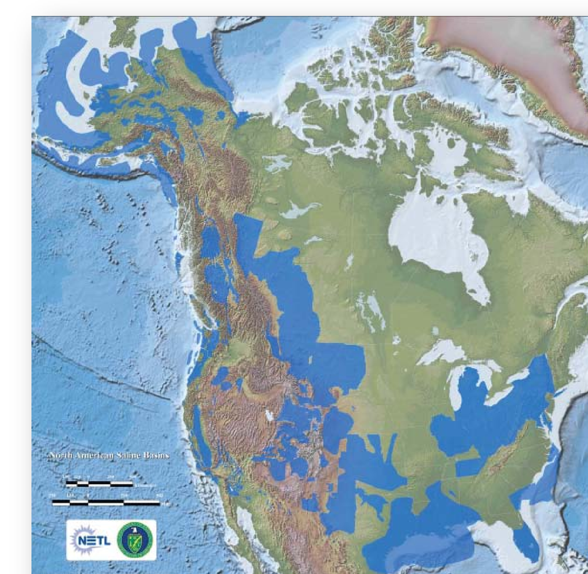
2008 Conservative Resource Assessment



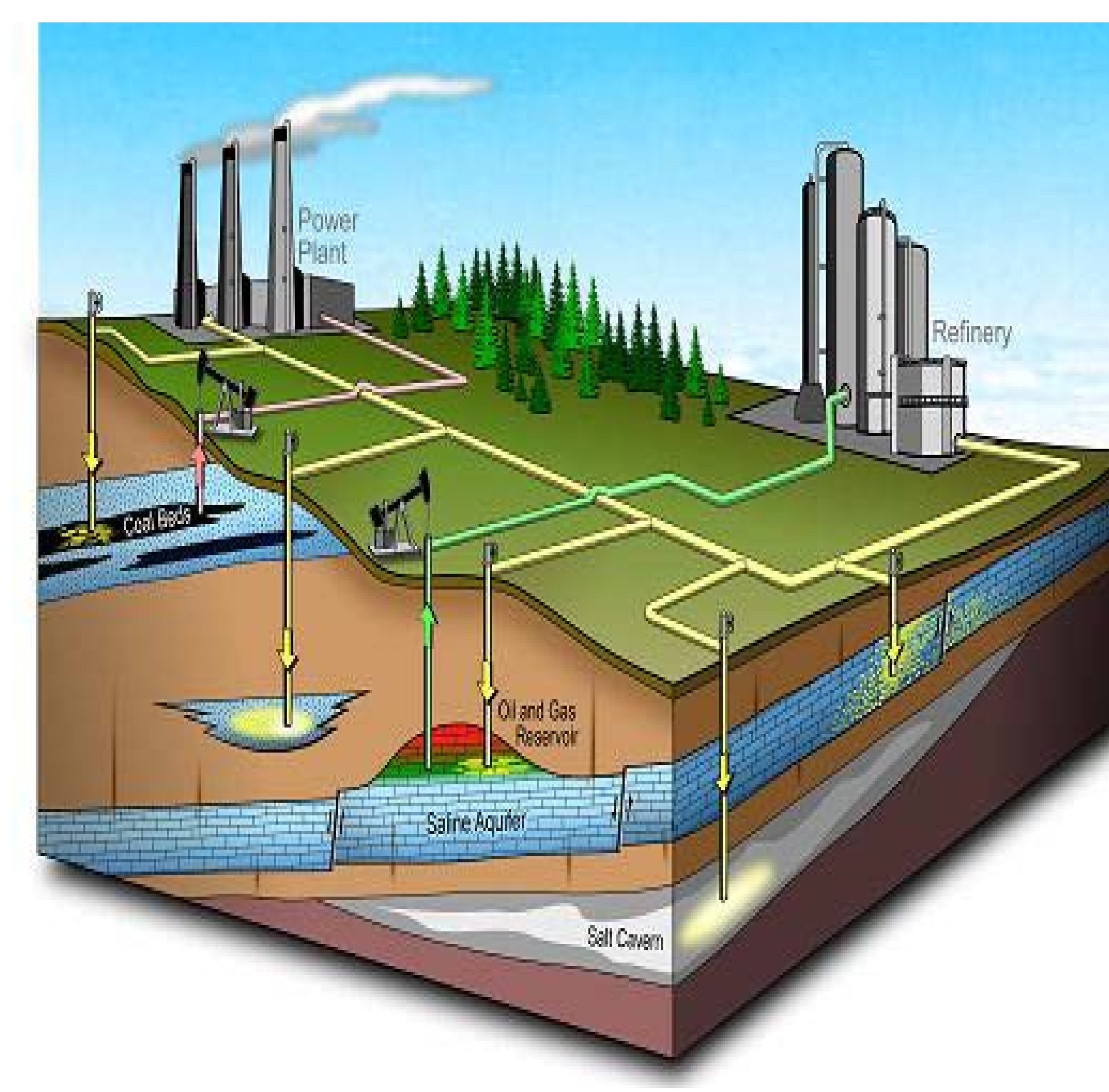
Oil and Gas Fields
138 GT CO_2 Storage Resource*



Unmineable Coal Seams
157-178 GT CO_2 Storage Resource*



Saline Formations
3,300–12,600 GT CO_2 Storage Resource*



- Refine CO_2 resource estimates accounting for physical properties of formations and regulatory, economic, and legal aspects of CO_2 storage
- Experimentally evaluate CO_2 solubility in saline formation brines at reservoir conditions
- Determine the uncertainties that affect resource estimates in coal

Collaborators:

NETL, Carnegie Mellon, PennState, University of Pittsburgh, URS, VirginiaTech, WestVirginiaUniversity

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CO_2-Water-Rock Geochemistry Team

NETL-RUA Regional University Alliance

U.S. DEPARTMENT OF ENERGY

Challenge:

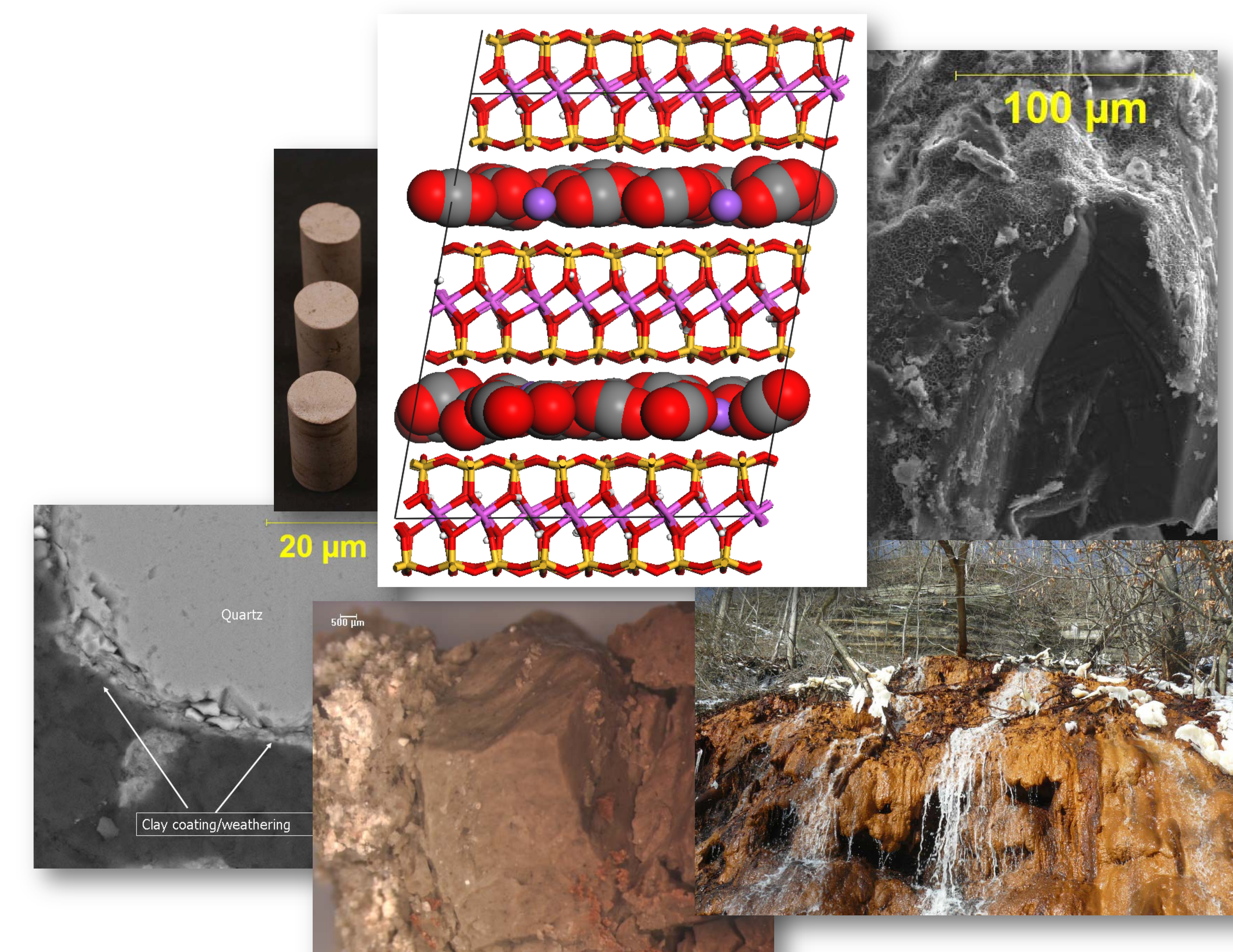
Minimize risk related to storage reservoirs for CO_2

Research:

Focuses on developing knowledge of CO_2-water-rock biogeochemical processes

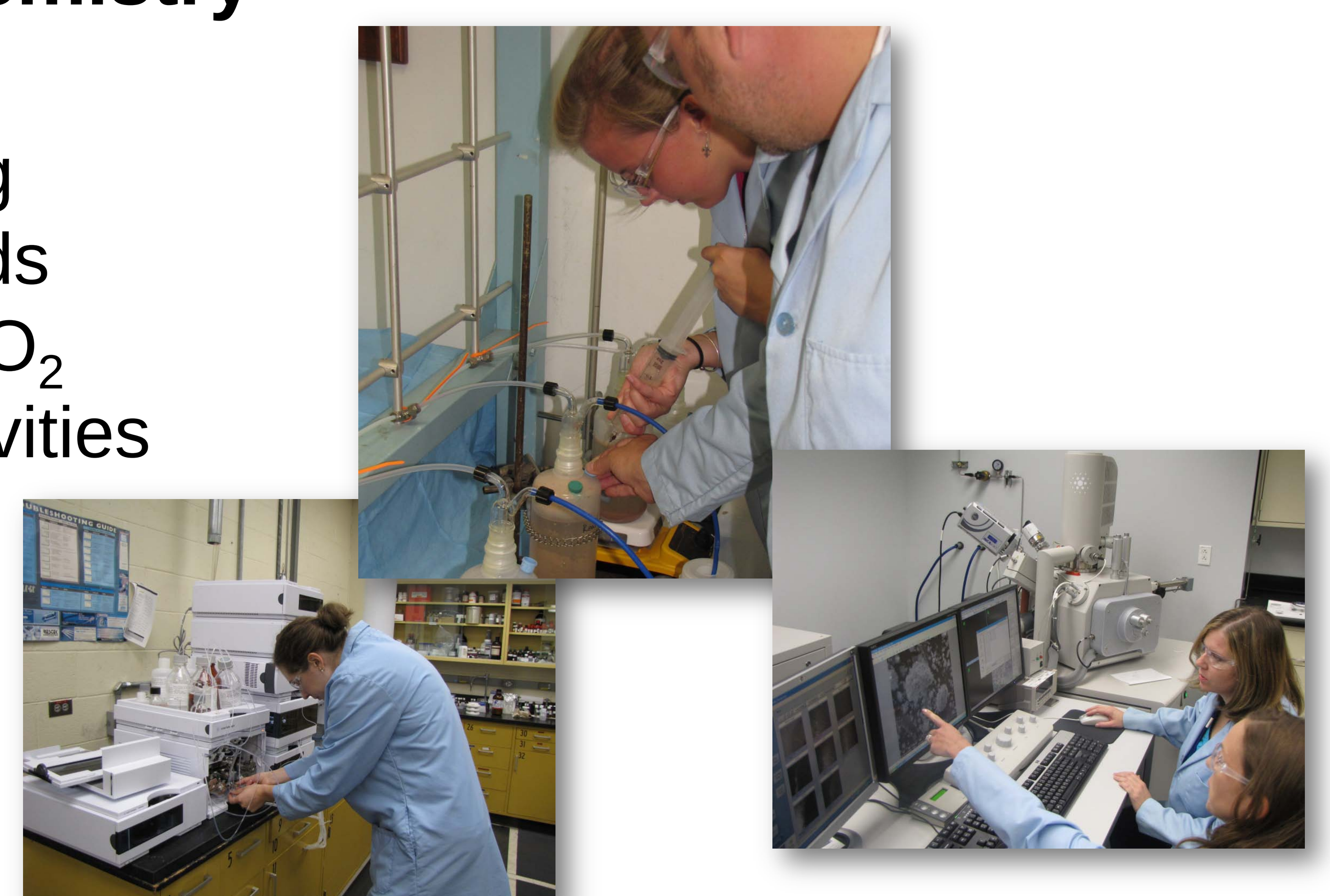
Hydrophobic/Hydrophilic Interactions

Understand the role of CO_2-mineral surface interactions



Organic Geochemistry

Assess the role of naturally-occurring organic compounds during geologic CO_2 sequestration activities



Ground Water Protection

Understand and predict potential influence of CO_2 on the fate and behavior of EPA-regulated compounds in ground water systems

Engineered CO_2 Mineralization

Assess the potential for permanent CO_2 storage in mineral phases

Reactive Flow

Understand coupled fluid flow and mineral reaction processes that can affect geologic CO_2 sequestration

Collaborators:

NETL, Carnegie Mellon, Penn State, University of Pittsburgh, URS, Virginia Tech, West Virginia University

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0070 – MH – 10/10 - Wildman

Multiscale and Multiphase Flow Team

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U.S. DEPARTMENT OF ENERGY

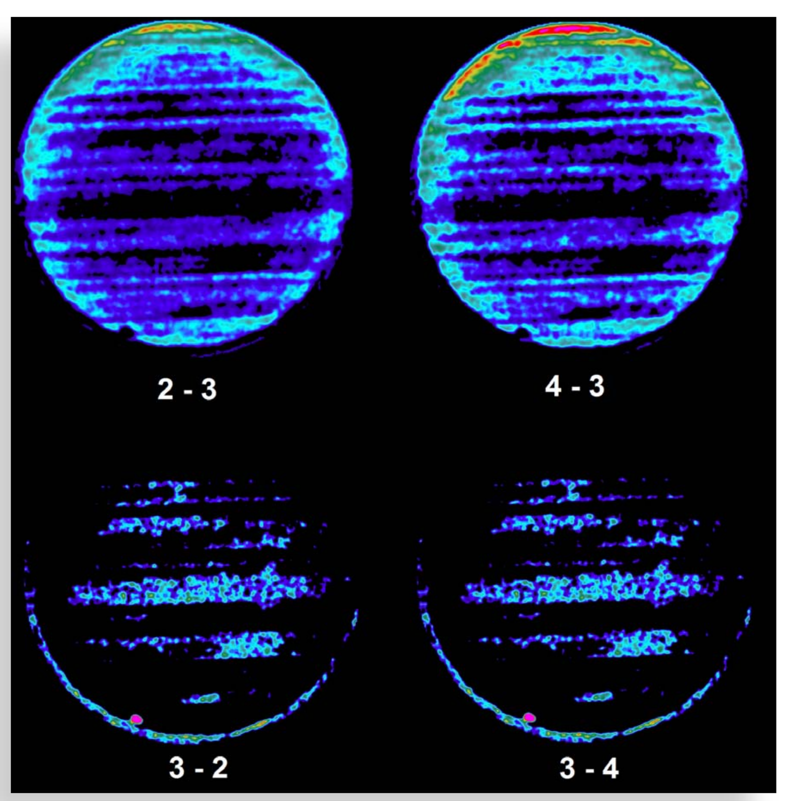
Challenge:

Safe and effective storage for CO_2 is required to achieve wide-scale deployment of carbon capture and sequestration to address global climate change

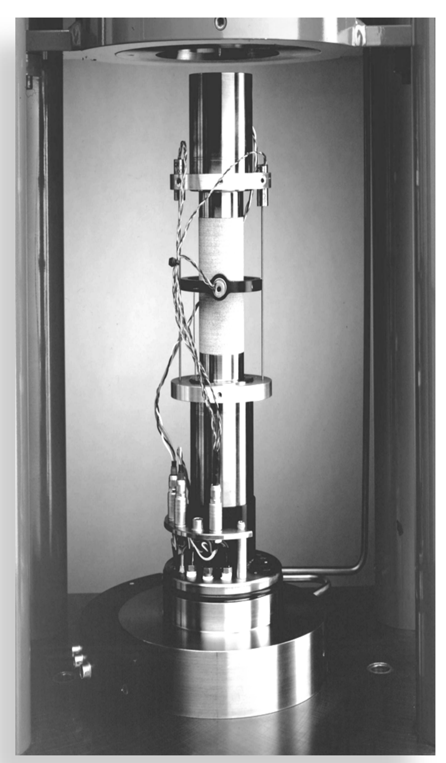
Research:

Focuses on developing tools and techniques for predicting the behavior of underground storage sites for CO_2 over a variety of scales and timeframes

Pore Scale Flow



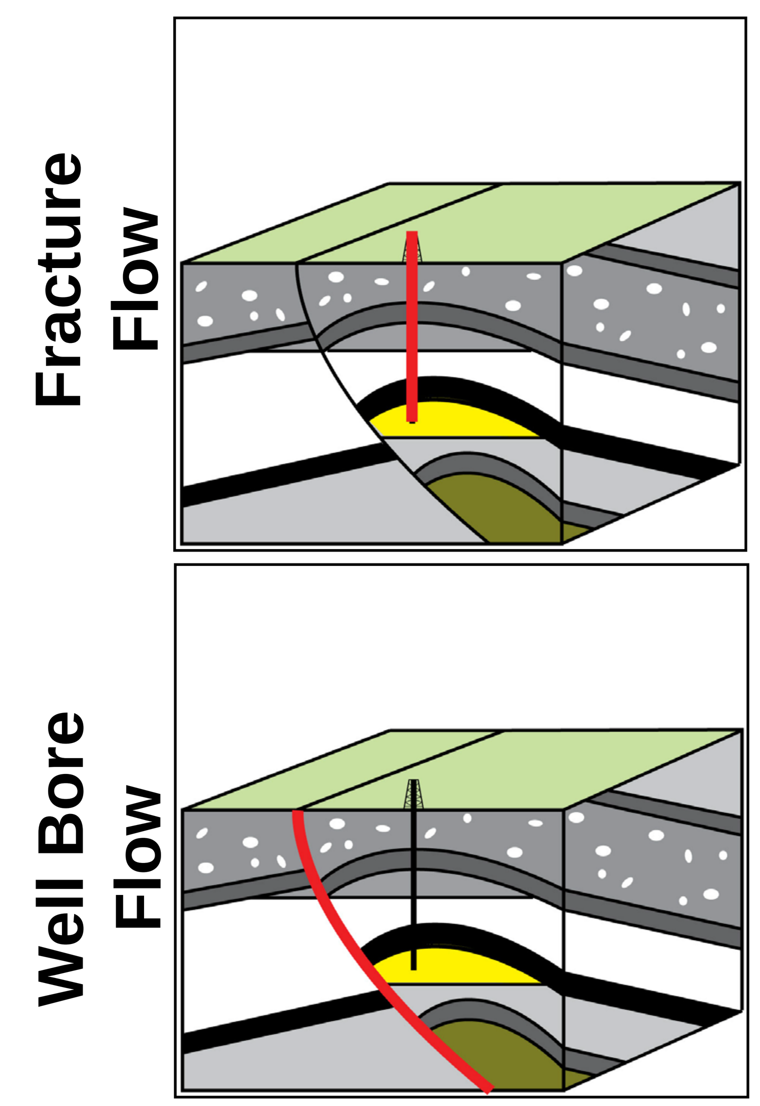
CT imaging to characterize fractures and track fluid flow



Core Flow Unit

Computational models at the pore size level characterize CO_2 storage formation injectivity and capacity and to understand interactions at the CO_2-brine interface

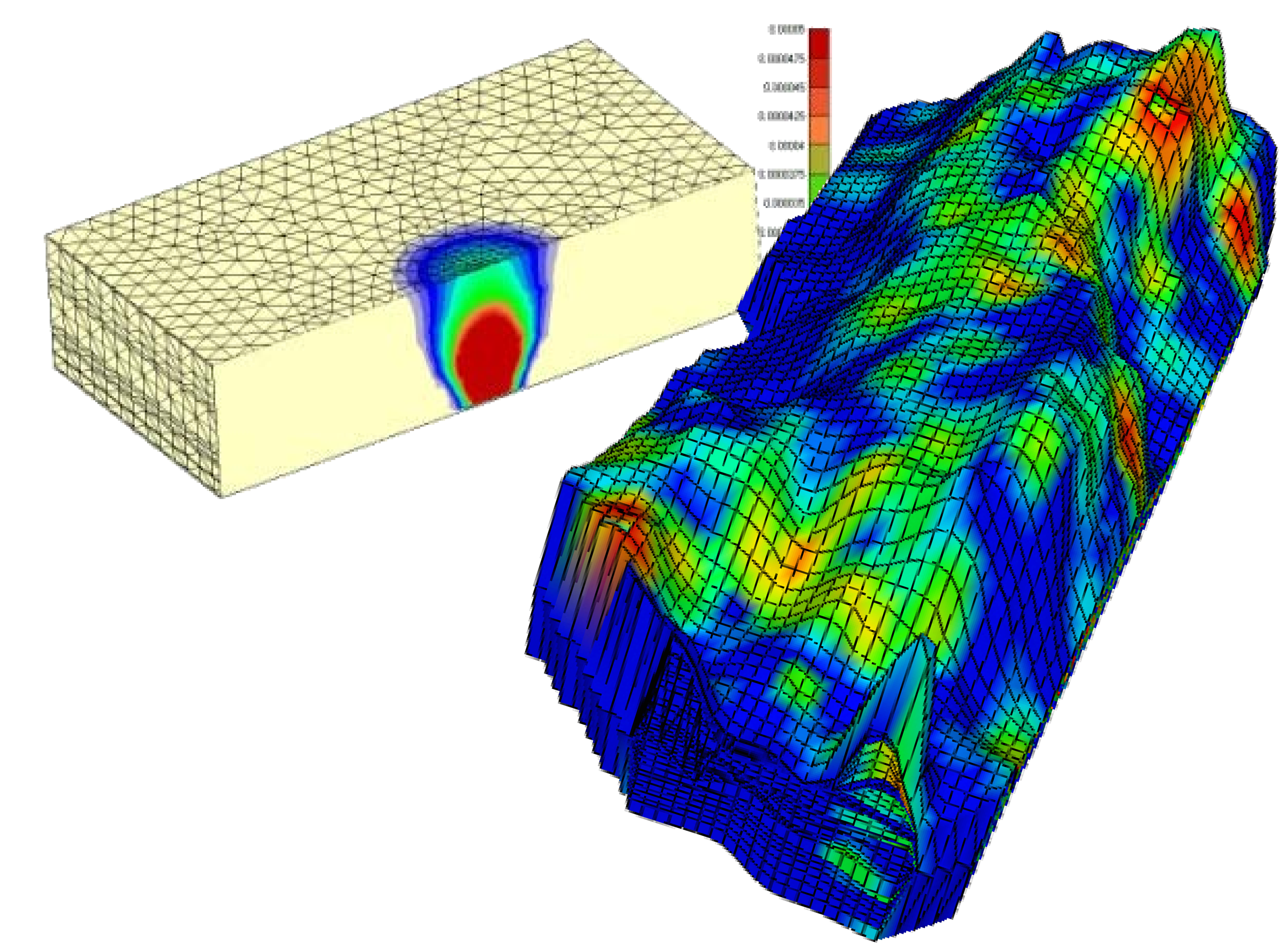
Geomechanics and Fracture Flow



CO_2 Transport

Flow and transport of CO_2 are measured experimentally. Models based on this data predict potential pathways for brine and CO_2 leakage from underground CO_2 storage sites

Reservoir Scale Modeling



Models are upscaled from molecular processes to system scale to predict reservoir behavior

Collaborators: NETL, Carnegie Mellon, Penn State, University of Pittsburgh, URS, Virginia Tech, West Virginia University

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0071 – DJB – 10/2010 – DWildman/DMcIntyre

National Risk Assessment Partnership Team

NETL-RUA Regional University Alliance

U.S. DEPARTMENT OF ENERGY

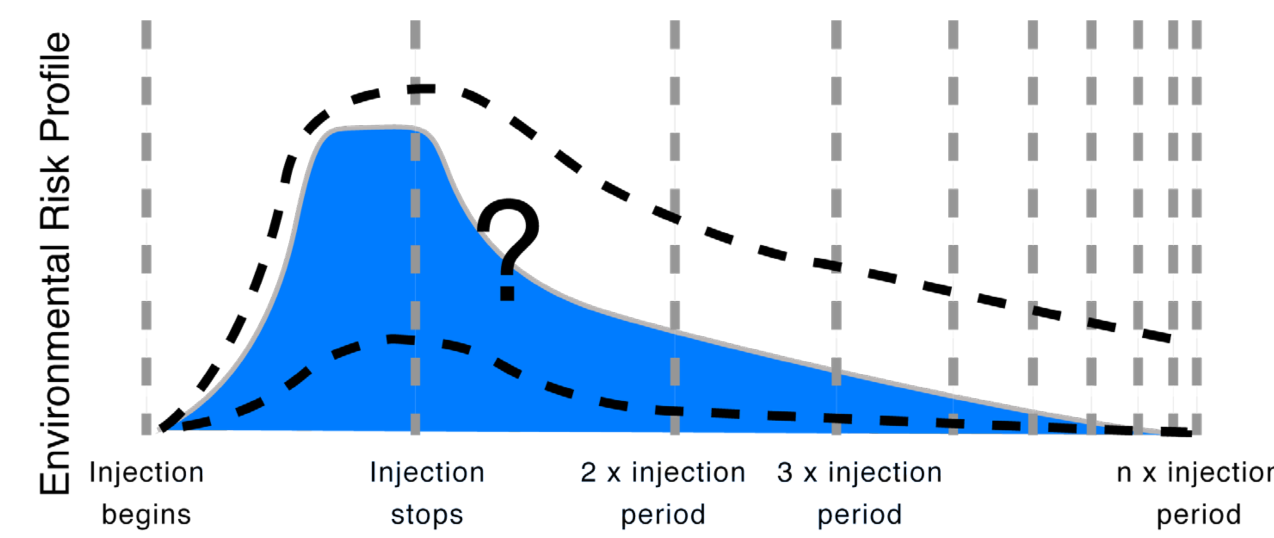
Challenge:

Develop validated, quantifiable risk protocols for the effective geologic storage of CO_2

Research:

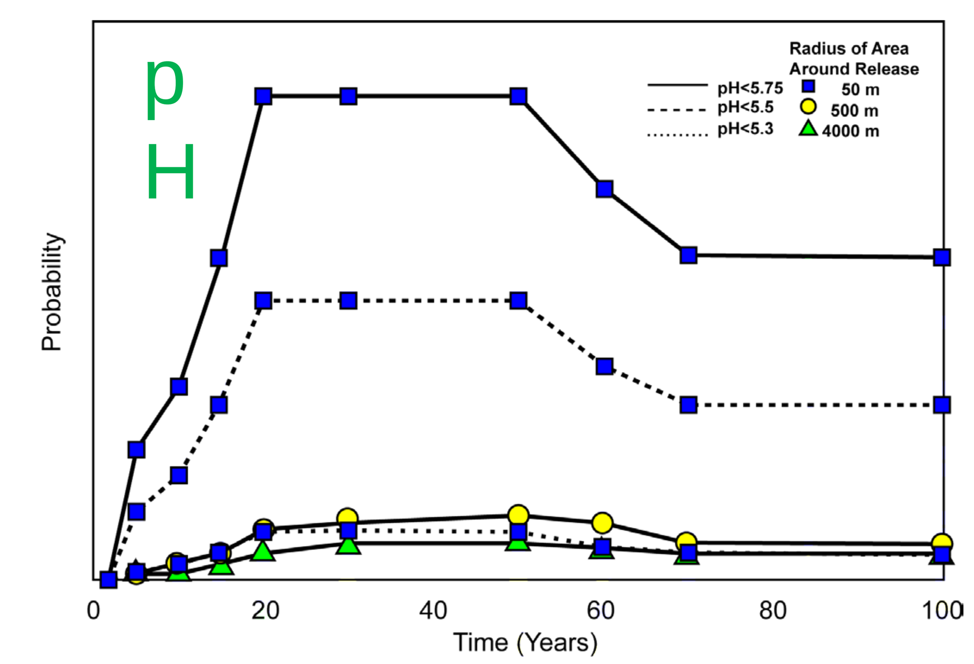
Perfom lab and field work to establish hypothetical and experimental data for well and seal leakage to establish first generation risk profiles

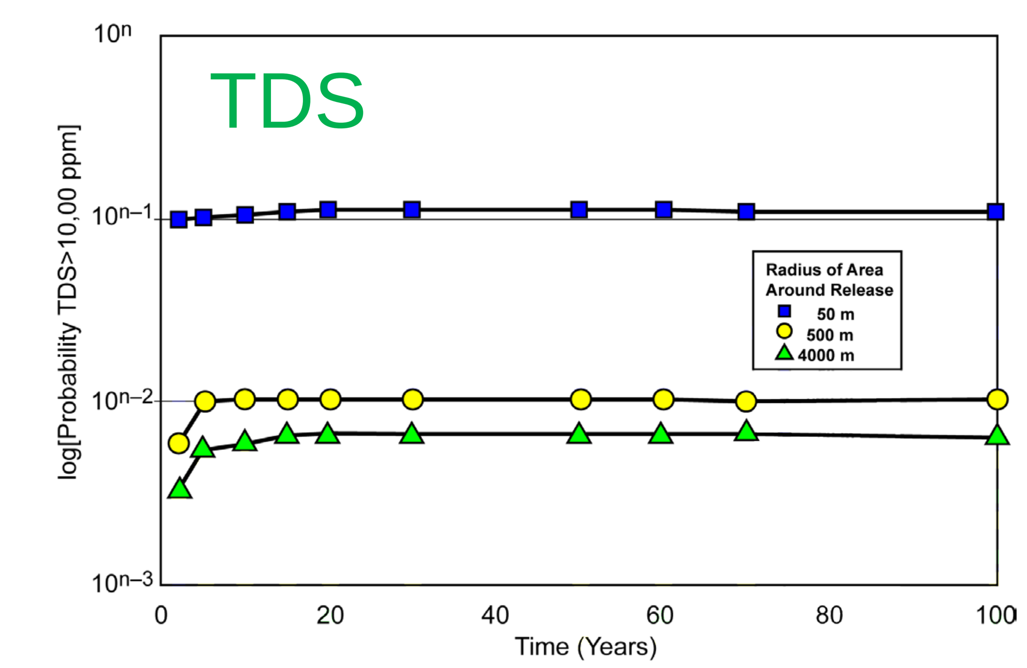
First Generation Risk Profiles



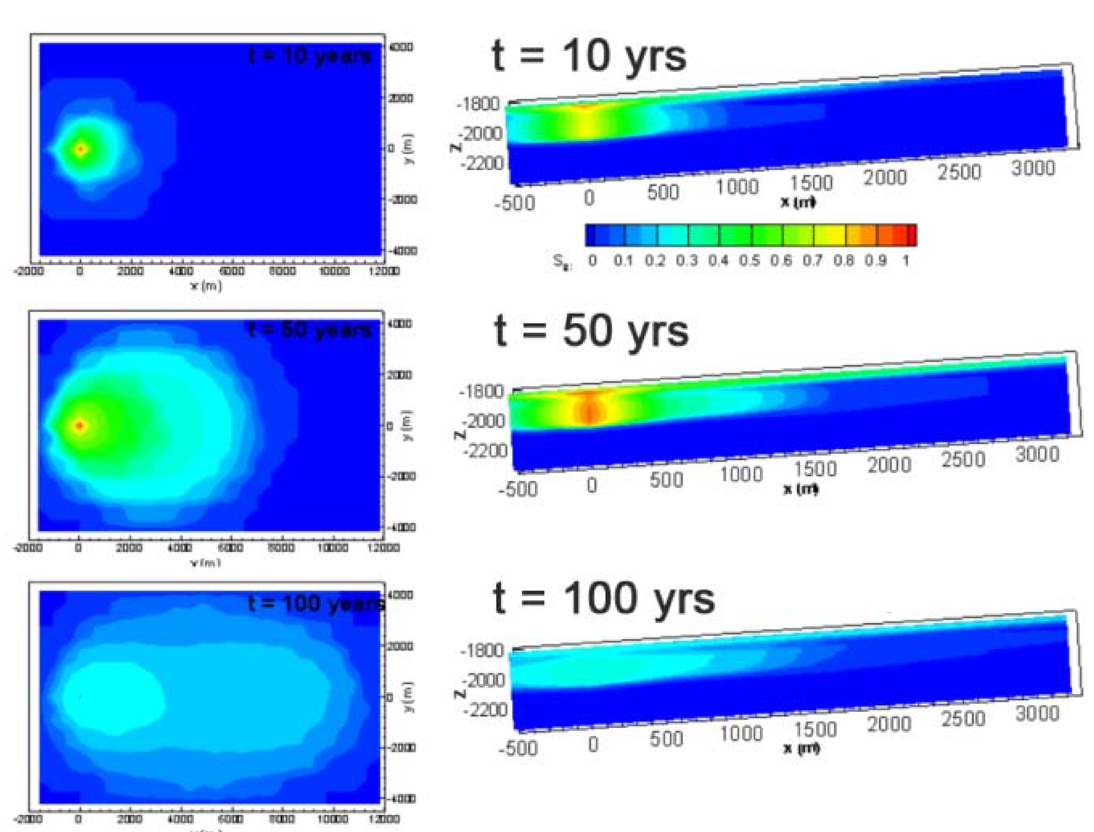
Initial Risk Data

① pH (function of CO_2 only)
② TDS (function of both brine & CO_2)
③ return of CO_2 to the atmosphere
④ reservoir stress

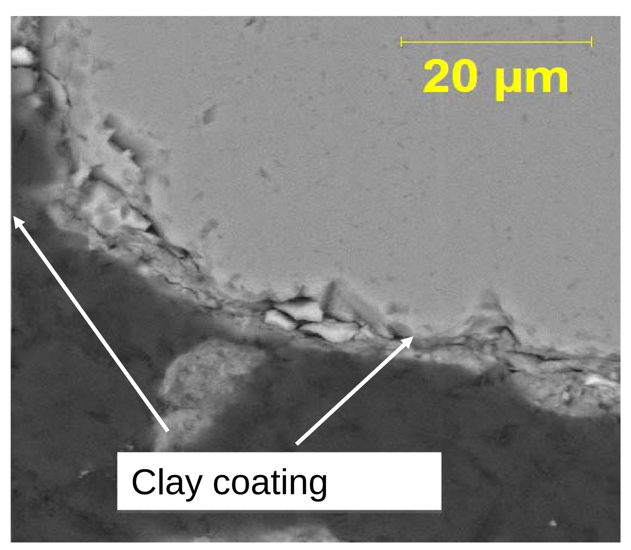




CO_2 Flow Rate in Aquifers

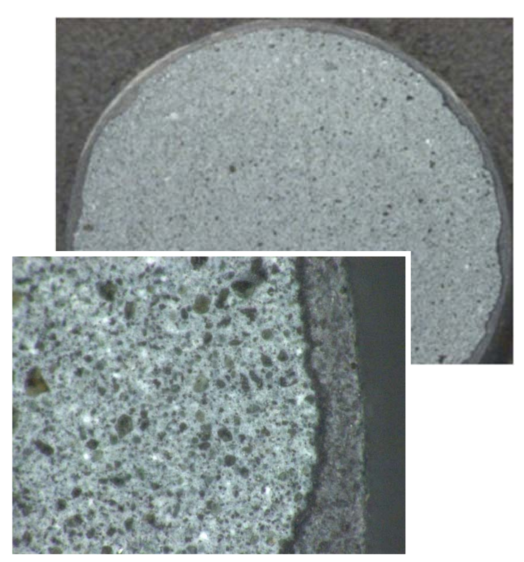


CO_2 Mineral Alteration



Characterization of mineral alteration on groundwater aquifer grains

Wellbore Cement Studies



Experimental determination of rates and mechanisms of leakage pathway alteration through wellbore cement due to CO_2

Collaborators:

NETL • Los Alamos National Laboratory • LLNL • Berkeley Lab • Pacific Northwest National Laboratory • URS

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Unconventional Fossil Energy Team

Challenge:

Effective development of unconventional oil and gas resources such as gas shale and tar sands requires an improved scientific understanding of complex underground reservoir environments and recovery operations

Research:

Addresses the oil and gas industry's need for better reservoir data in extreme environments and unconventional sources through computational and experimental methods and field observations

Experimental and Computational Methods

Lead to improved understanding, increased recovery efficiency and better predictability of unconventional gas resources

Recovery of Unconventional Fossil Energy Sources

Increase efficiency for tar sand, oil shale, shale oil, and enhanced oil recovery

Operationally Complex Settings Such as Deepwater Off-shore

Requires a greater knowledge of pressure-volume-temperature relationships in the reservoirs

Collaborators:

NETL · Penn State · University of Pittsburgh · URS · VCU Virginia Commonwealth University · Virginia Tech · West Virginia University

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Solid Oxide Fuel Cells (SOFC) Team

NETL-RUA Regional University Alliance

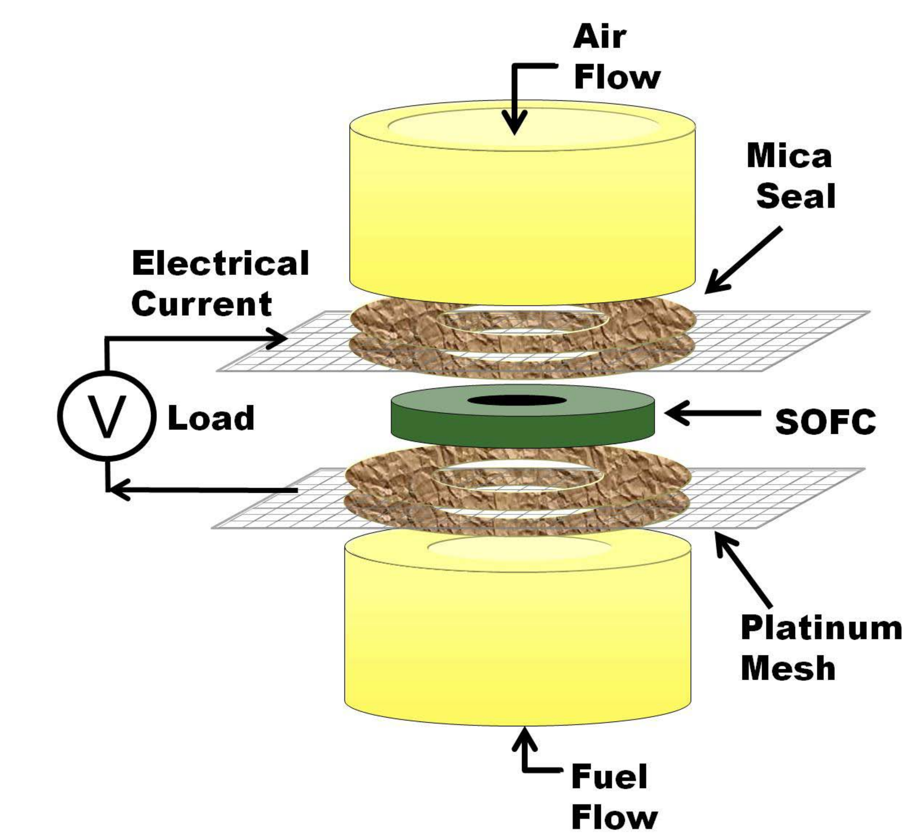
U.S. DEPARTMENT OF ENERGY

Challenge:

Develop highly efficient and environmentally clean power generation from coal using *Solid Oxide Fuel Cell* technology

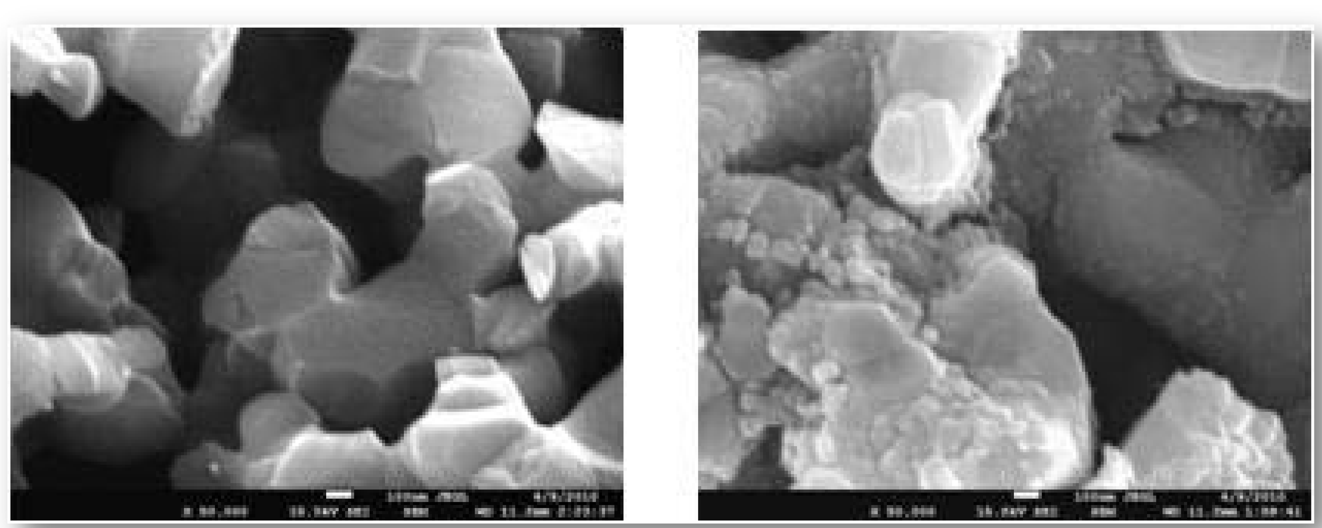
Research:

Focuses on development of affordable, robust and active anode and cathode materials for improving the efficiency and life-time of SOFC materials used to directly convert chemical energy stored in fuel to electrical energy



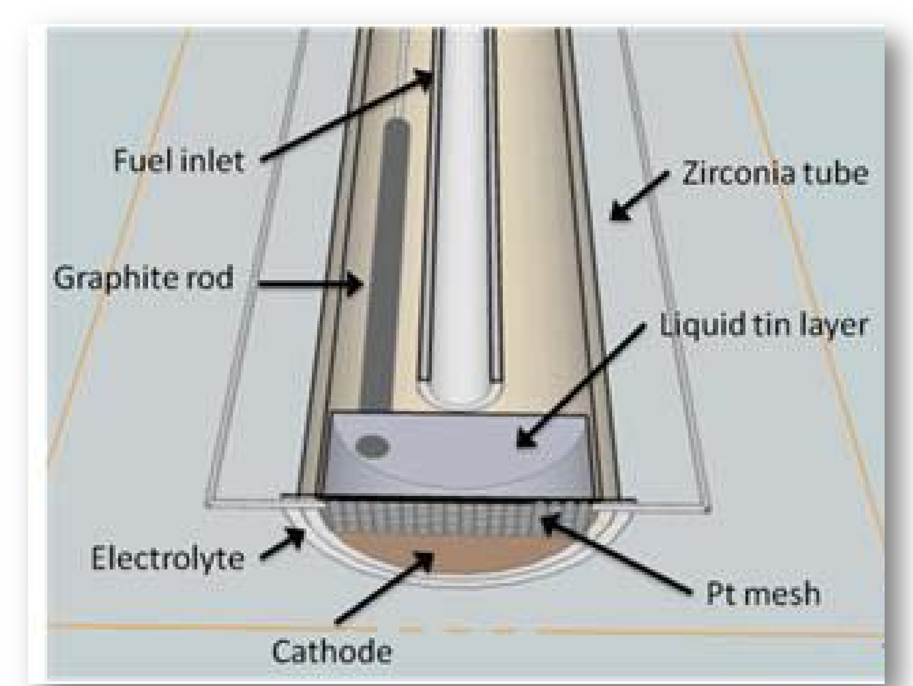
Simplified SOFC Test Specimen

Stable, High Performance Cathodes (where oxygen reactions occur)



More stable cathodes reduce amount of degradation at high temperatures as shown in this high magnification image

Improved Anode Technology (where fuel reactions occur)



More stable, active anodes, such as this liquid metal anode, can tolerate fuel contaminants improving overall fuel cell performance

Advanced Fuel Cell Systems

Gasification + fuel cell + turbine = ultra high efficiency with carbon capture controlling the combined plant is a new challenge

Collaborators: NETL, Carnegie Mellon, PennState, URS, West Virginia University

Turbines Team

Challenge:

Develop high efficiency, affordable advanced power systems with near-zero emissions and capable of producing multiple products (such as electricity and hydrogen)

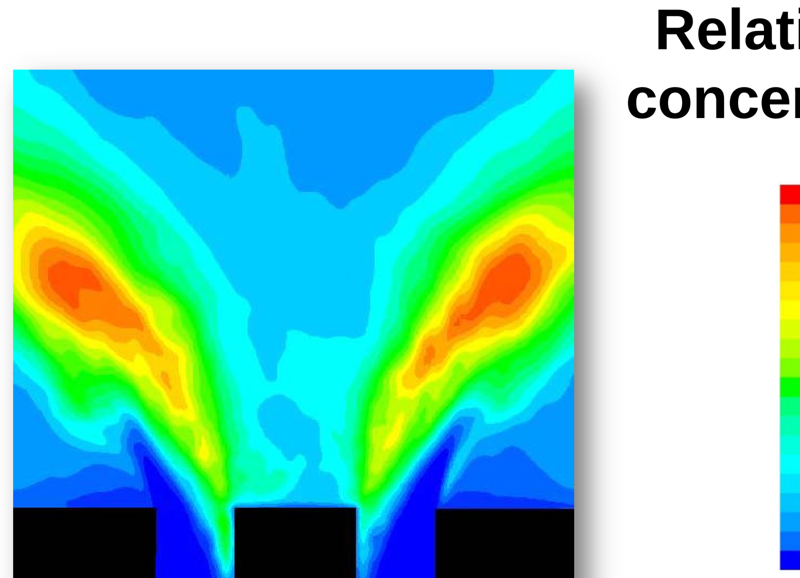
Research:

Focuses on development of advanced, fuel-flexible turbines to increase plant energy efficiency while eliminating emissions and reducing the cost to generate electricity

High-Temperature Materials

New high temperature alloys and coatings for blade protection offer operation at higher temperatures improving turbine performance

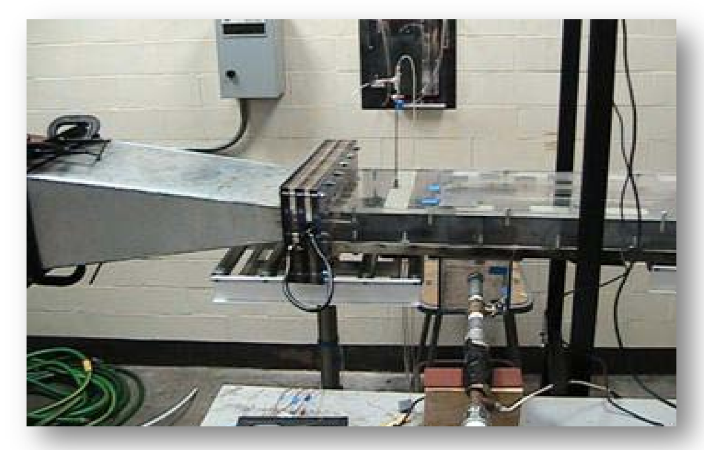
Advanced Computer Simulation



LES Simulation

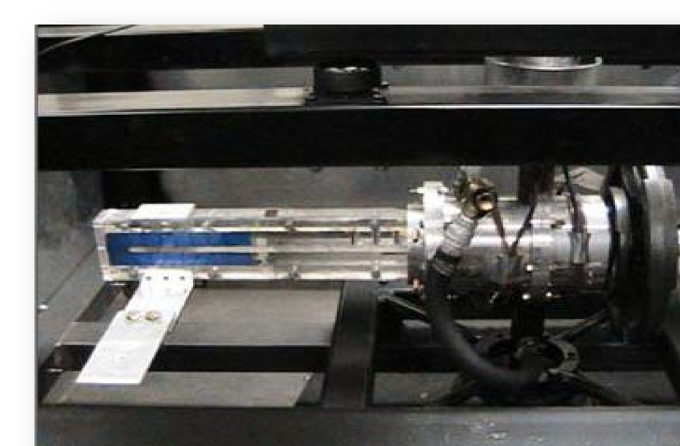
Models allow ability to enhance turbine efficiency with reduced development costs

Novel CO_2 Capture Systems



Recycling turbine exhaust gas makes it easier to capture and sequester CO_2 from the process

Turbine Blade Cooling



Improving turbine blade cooling is required for oxy- and hydrogen- combustion for land-based gas turbine airfoils

Test Facility

A world-class experimental test facilities allow study of novel combustion systems and effects of air leakage in land-based gas turbines

Collaborators:

NETL, Carnegie Mellon, Penn State, University of Pittsburgh, URS, Virginia Tech, West Virginia University

Power Generation Sensors Team

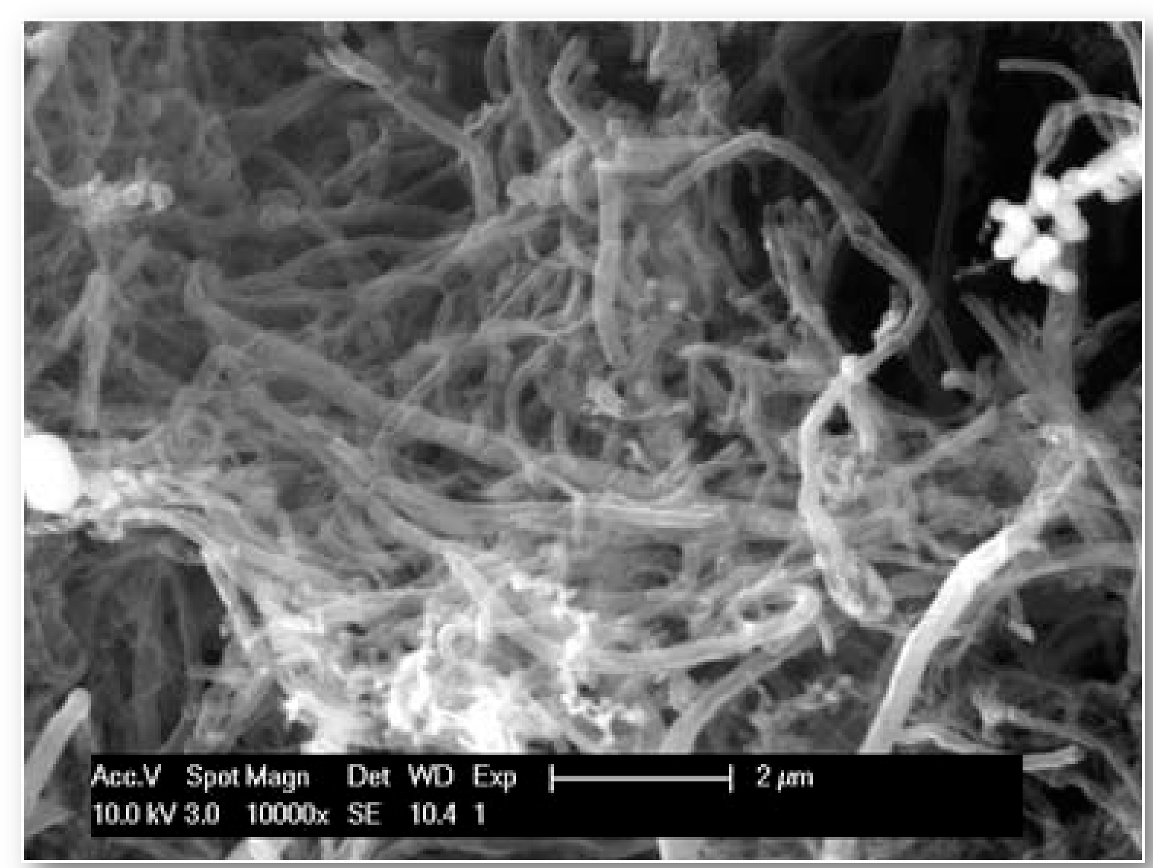
Challenge:
Improve power plant efficiency and performance to reduce CO_2 emissions and reduce cost of carbon capture and storage, while minimizing increases in system costs

Research:
Focuses on sensor technologies for improved measurement of plant gas composition and temperature to achieve better monitoring and smarter system operation

Gas Composition Sensing

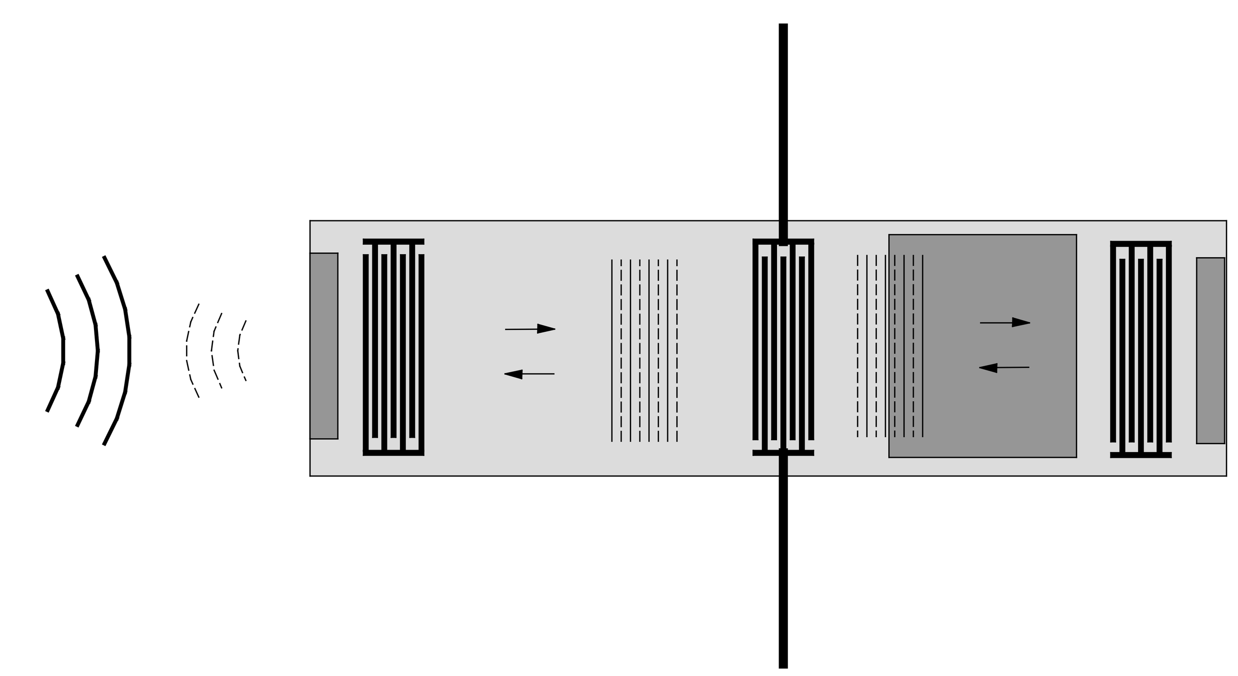
Green laser sensing technology enables fuel flexibility in power plants

Sensor Nanomaterial Development



New materials enable low-cost, reliable, miniaturized gas sensors for the harsh environments of advanced power generation systems

Wireless Surface Acoustic Wave Sensor



Detect very low levels of CO_2 emissions at geological sequestration sites

Collaborators: NETL, Carnegie Mellon, University of Pittsburgh, URS

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NETL-RUA Regional University Alliance

Natural Gas Hydrates Research Team

U.S. DEPARTMENT OF ENERGY

Challenge:

Currently, estimates of the volume of organic carbon trapped within natural hydrate occurrences exceeds that of organic carbon in all other known resources such as coal, oil and gas combined. Research and technologies are needed to improve the current understanding of natural gas hydrate systems, which form primarily in permafrost regions and deep marine sediments.

Research:

Conducting research to advance our understanding of where, why, and what controls the occurrence of natural gas hydrate, a vast store of natural gas, in order to address key climate, stability, and energy/resource related issues

Gas Hydrate *In Situ* Predictions & Evaluation

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

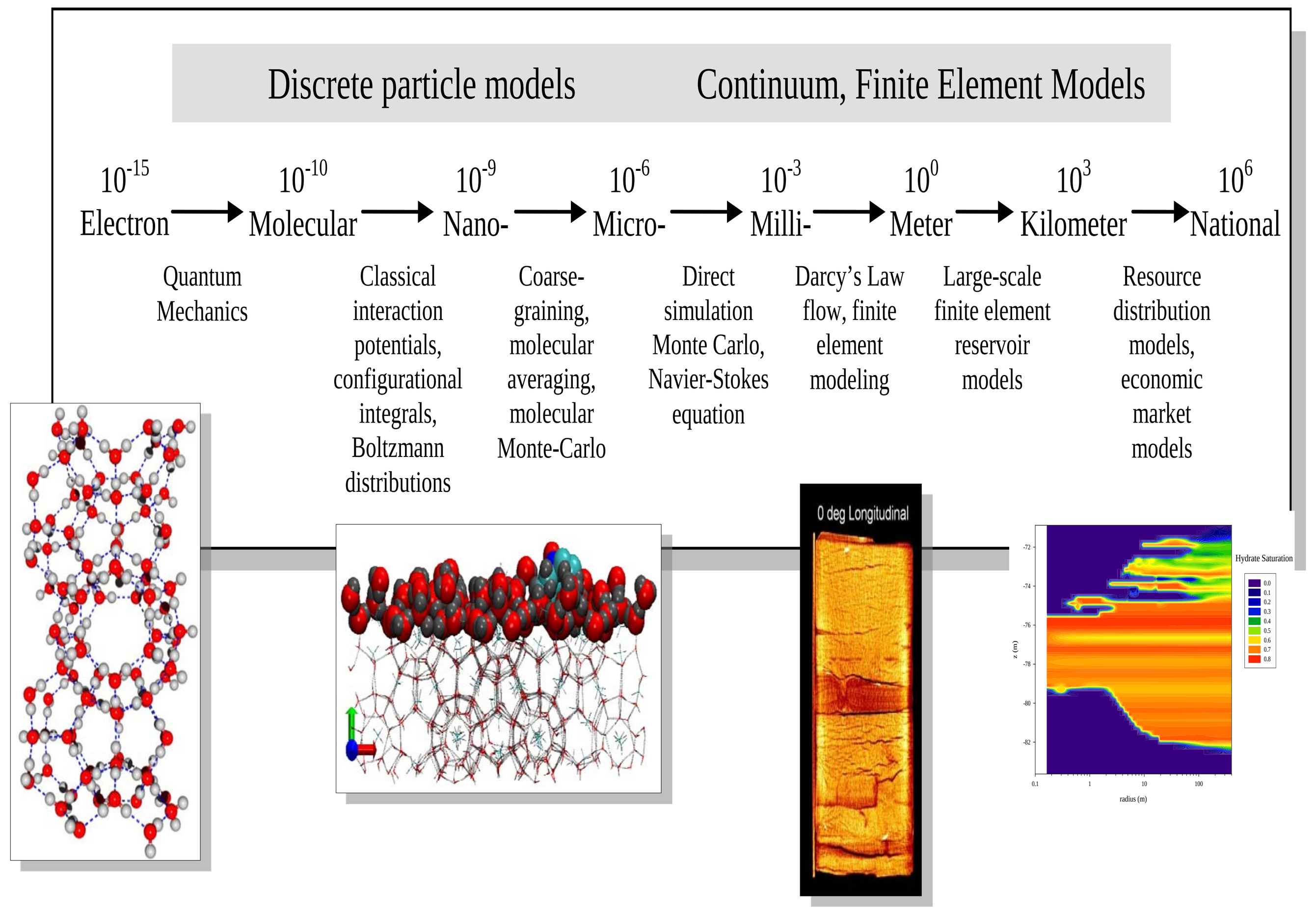
Field Studies in the Natural Environment

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

Laboratory Studies

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

Numerical Analysis



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

Collaborators:

NETL · Carnegie Mellon · OSU Oregon State University · University of Pittsburgh · URS · VirginiaTech · WestVirginiaUniversity

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