



NATIONAL ENERGY TECHNOLOGY LABORATORY



NETL's Complementary Research Program

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Geological and Environmental Systems Focus Area

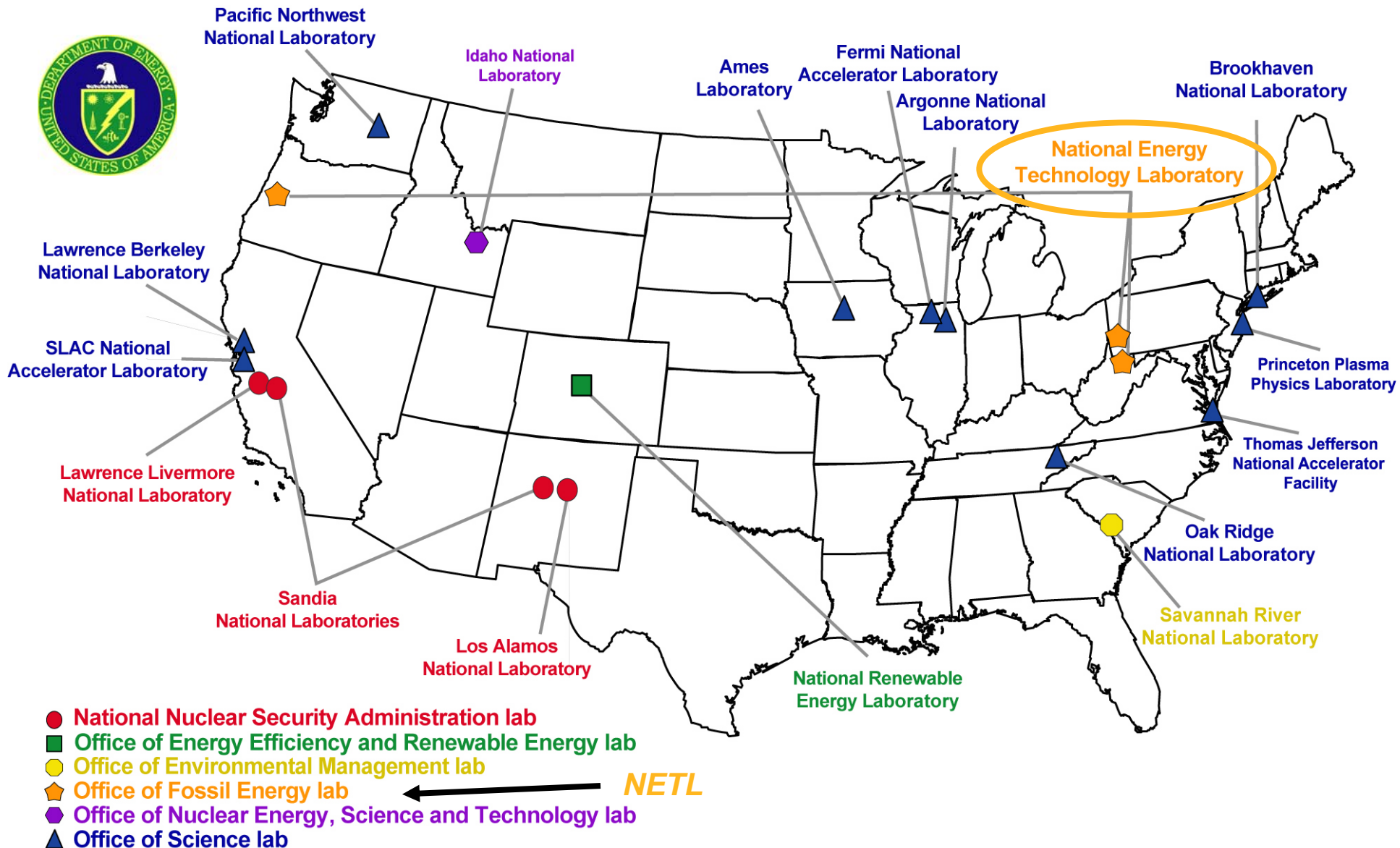
Office of Research & Development



Primary Research Areas for NETL's Complementary Program

- **Drilling under extreme conditions**
 - experimental facility; materials development/testing; computation
- **Environmental impacts of oil/gas productions**
 - produced water management: data collection, management, assessment
 - air quality: improved reliability and accuracy of predictions (data collection; model development)
 - ecological impacts: improved assessments through novel sensors
 - unconventional fossil production: identification and assessment of potential barriers
- **Unconventional oil and enhanced oil recovery**
 - CO₂ enhanced oil recovery: control of CO₂ viscosity
 - in-situ oil shale production: tunable microwaves with CO₂; environmental barriers
 - oil production from fractured media (e.g., shales): improved reliability and accuracy of predictions for multiphase flow in Bakken
- **Resource assessment; geospatial data management**
 - knowledge management database development
 - high resolution data on Marcellus shale for improved assessment

U.S. Department of Energy National Labs

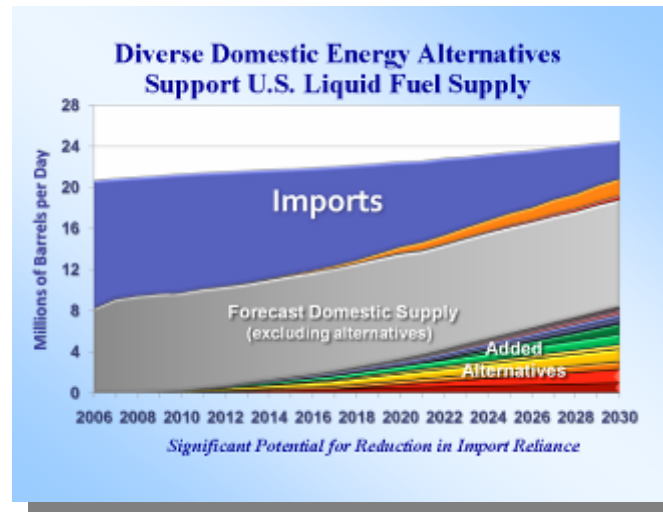


NETL applies basic science to technology development, demonstration, and transfer.

Onsite Research and Development



Systems, Analysis, and Planning



Extramural Research and Collaboration



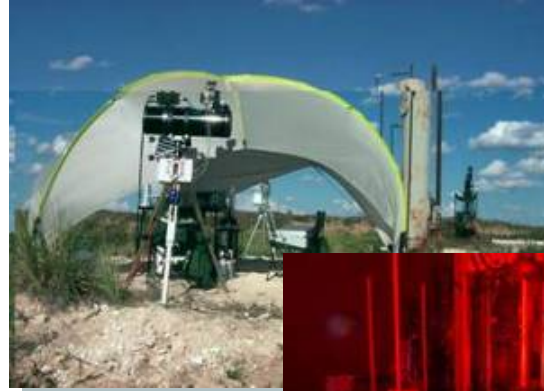
More Than 1,800 Activities in the United States and 40+ Other Countries

Geological/Environmental Systems Research Areas

Science and engineering research of natural systems to enable the clean production & utilization of fossil energy.

Complementary Program

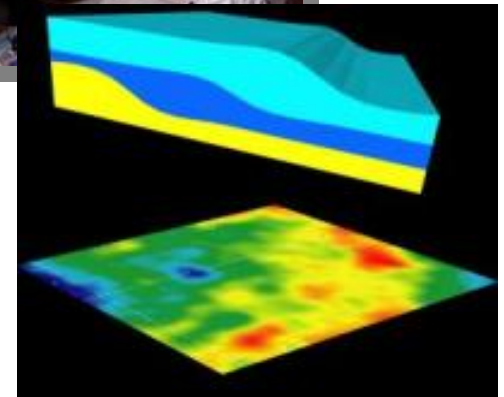
- Extreme drilling (deep & ultradeep)
- Environmental impacts
- Unconventional oil & gas
- CO₂-EOR



Methane hydrates

CO₂ Storage

- Capacity, injectivity, long-term fate
- Seal integrity (cement durability)
- Potential impacts (fluid-rock interactions)
- Monitoring and assessment (airborne, surface, subsurface; GIS; risk assessment)

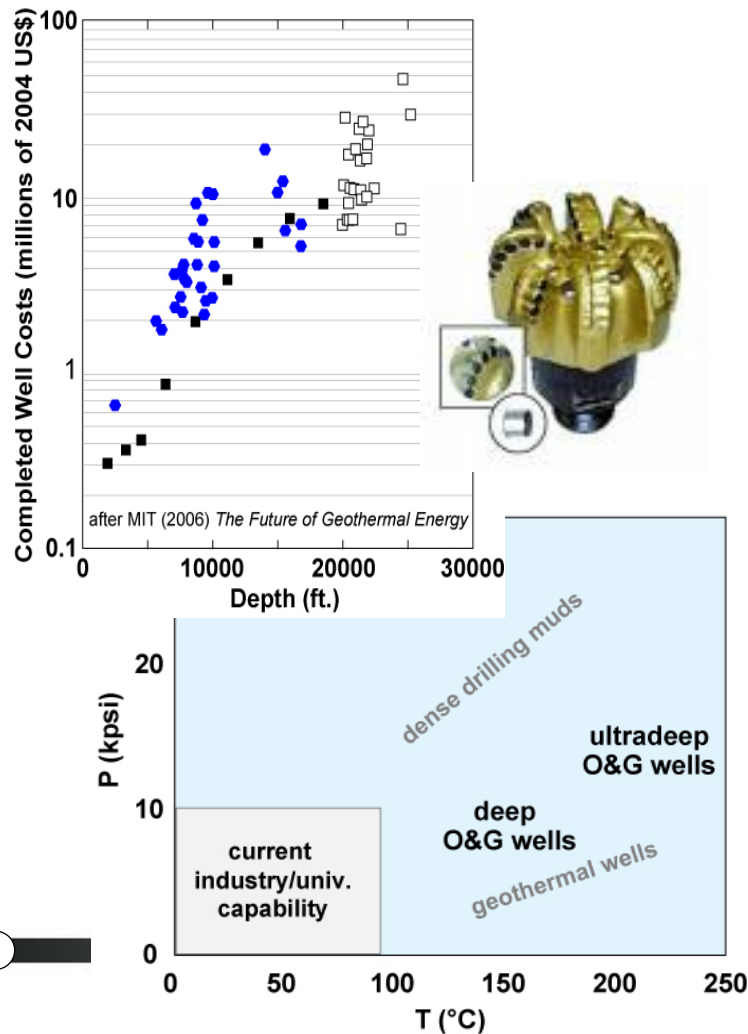


Primary Research Competencies for Geologic & Environmental Systems (GES)

- **Ultra-deep drilling**
 - experimental facility; materials development/testing; computation
- **Multiphase, multiscale flow**
 - particular strength in fracture flow (both computation and experiment; e.g., CT scanner)
 - coupled geomechanics and flow
- **Environmental field measurements and monitoring**
 - air, soils, tracers, water (including produced water)
- **Geomaterials characterization**
 - coal properties (structure; sorption behavior; swelling)
 - high pressure high temperature fluid-solid reactions (e.g., CO₂-brine-cement/rock); depth in experimental facilities
 - geophysical properties of materials at conditions (e.g., permeability; acoustic velocities)
- **Geospatial data and independent assessments (e.g., environmental; resource)**
 - Cyberinfrastructure database development (e.g., NATCARB)
 - Knowledge Management Database

Drilling under Extreme Conditions

Goal: To improve the economics of drilling deep and ultra-deep wells by increasing the rate of penetration and by developing better-performing materials for extreme drilling environments



Four Elements to Research Focus

- **Experimental investigation of drilling dynamics**
 - **Ultra-deep Drilling Simulator (UDS) and the Extreme Drilling Laboratory**
- **Development of predictive models for drilling dynamics**
- **Development of novel nanoparticle-based fluids for improved drilling**
- **Improvement of materials behavior/performance in extreme environments**

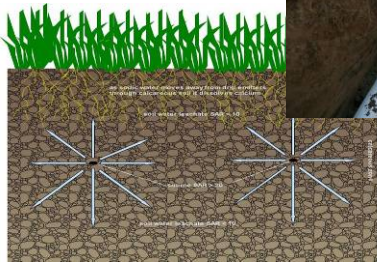
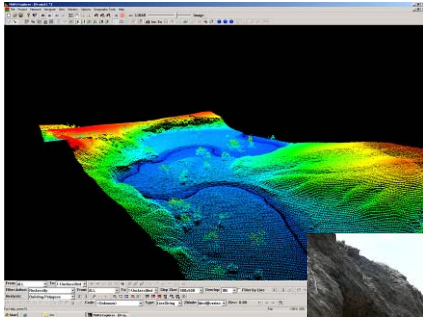
Drilling under Extreme Conditions

Status

- **Experimental investigation of drilling dynamics**
 - Completed facility mods and equipment procurement for extreme drilling lab
 - Installation of UDS at NETL completed; pressure vessel proof tested
 - Initiated shakedown of UDS
 - Baseline testing to begin in early fall 2009
 - Validate single cutter relative to multi-cutter
 - Extend full bit simulation to elevated PT
 - Initiate testing matrix of drilling fluids with model rock system
- **Development of predictive models for drilling dynamics**
 - Discrete-element & continuum-scale models under development to predict reaction forces on bits & rock fragmentation; validation with future UDS data
 - CFD model of filter cake formation under development; validation with future UDS results; baseline comparison with commercial code (ANSYS Fluent)
- **Development of novel nanoparticle-based fluids for improved drilling**
 - Demonstrated nanoparticle haloing to stabilize colloidal barite suspensions
 - Demonstrated hydrophobic nanoparticles stabilize inverted emulsions
- **Improvement of materials behavior/performance in extreme environments**
 - Key failure mechanisms in Cl⁻ and H₂S-environments identified via industry
 - Ambient-pressure fatigue testing initiated for corrosion fatigue (H₂S)
 - Completed design of HPHT fatigue test unit; procurement/installation initiated

Environmental Impacts of Oil/Gas

Goal: To develop an improved, science-base understanding that leads to solutions for potential environmental challenges to oil/gas production



Major Elements to Research Focus

- **Evaluation of strategies for effective and environmentally sound disposition of produced waters**
 - **Produced water database (PWMIS)**
 - **Evaluation of potential options (subsurface drip irrigation; ephemeral streams)**
 - **Quantitative models via a portfolio of monitoring options (airborne, UAV, hyperspectral, electromagnetic, LIDAR, etc.)**

- **More accurate assessment of air-quality impacts by detailed measurement and improved computational representations**

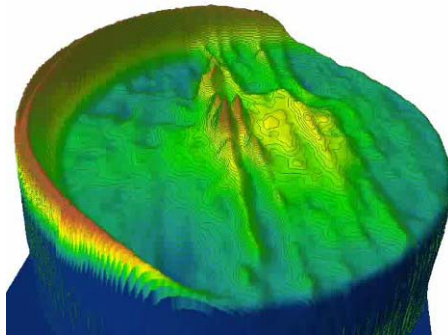
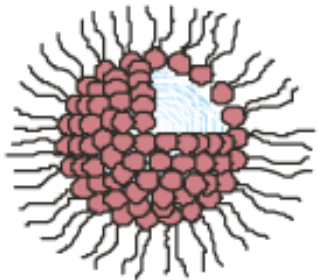
Environmental Impacts of Oil/Gas

Status

- **Produced Water**
 - Expanded the on-line Produced Water Management Information System (PWMIS); averaging ~6000 hits/month
 - Continued monitoring & independent evaluation of subsurface drip irrigation
 - Fall and mid-winter electromagnetic-conductivity surveys; meteorological station installed; groundwater wells sampled
 - Planned 5-yr study, unless site equilibrium is attained earlier
 - Sufficient divalent cations in groundwater and soil minerals to counteract impact of high-SAR produced water at least in the short term; too early to assess potential impact on groundwater flow
- **Air Quality**
 - Completing construction of mobile air monitoring station; to be deployed in Allegheny National Forest in Q3 FY09
 - Will provide site-specific data for improving accuracy and reliability of predictive atmospheric-dispersion and source-receptor models
 - Developing wireless monitoring network and unmanned aerial vehicle (UAV) platforms for efficient and effective site monitoring

Unconventional Oil & Enhanced Oil Recovery

Goal: To enable broader utilization of domestic fossil resources through improved efficiency and lowered environmental impact



Four Elements to Research Focus

- **CO₂-enhanced oil recovery: Improved flow control by increasing CO₂ viscosity (tailored surfactants)**
- **In-situ production of oil shale: Improved heating of kerogen by tuned microwave and CO₂; environmental impacts**
- **Oil production in fractured media: Improve accuracy/reliability of predicting primary–tertiary oil recovery in shale**
- **Catalog experience/knowledge from oil-shale and tar-sand activities**

Unconventional Oil & Enhanced Oil Recovery

Status

- **CO₂ Enhanced Oil Recovery**
 - Designed and synthesized fluororous and non-fluororous CO₂-soluble surfactants that can form rodlike micelles, increasing CO₂ viscosity
 - Demonstrated that two commercially available nonionic surfactants can stabilize a CO₂-in-brine emulsion at MMP
 - Developing core-flow experiment to assess viscosity performance in porous media

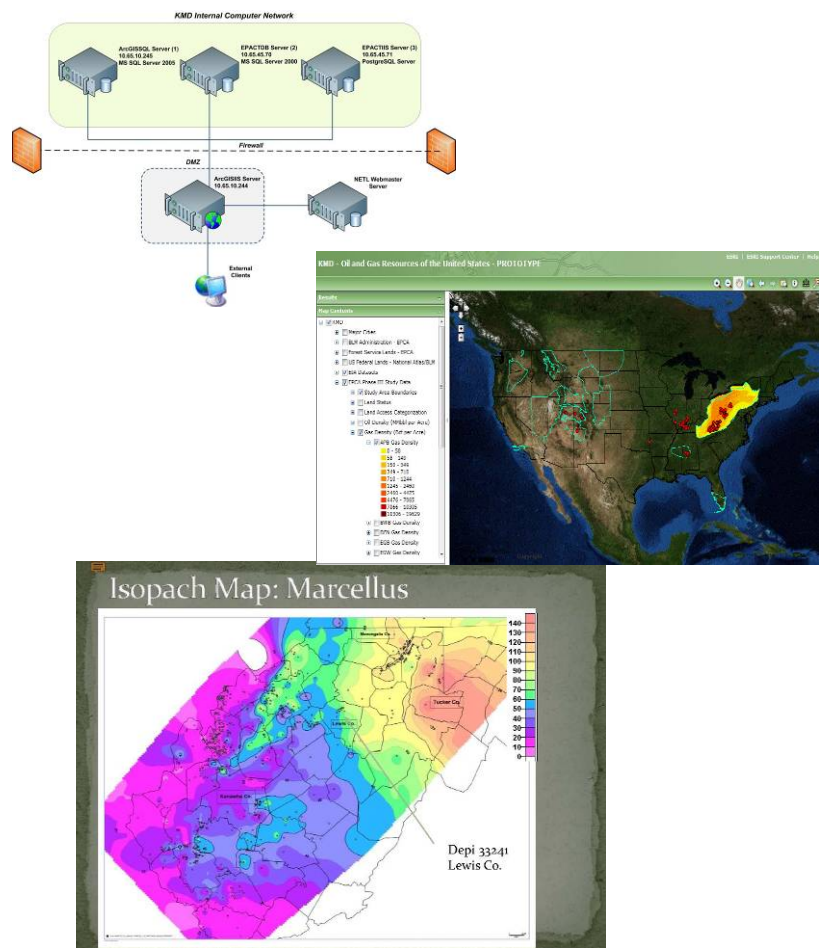
- **In-Situ Production of Oil Shale**
 - Initiated experiments to assess the dielectric and thermophysical properties of isolated kerogen; review of electromagnetic methods in oil shale production
 - Developing effort on science-based understanding of potential water issues for various in-situ production methods

- **Oil Production in Fractured Media**
 - Characterizing multiphase flow in Bakken shale cores
 - CT imaging of fractures; permeability/geomechanics under stress
 - Imaging of multiphase flow with CO₂ planned Q4 2009
 - Neural-network approach to predict location of highly productive wells

- **Catalog Experience/Knowledge from Oil-Shale and Tar-Sand Activities**
 - Archived historic oil-shale and tar-sand documents (18,000 reports) in a relational database management system

Resource Assessment

Goal: To enable better assessment of fossil resources by collection, management, and integration of high-resolution geospatial data



Elements to Research Focus

- Knowledge management database development
 - Repository for R&D results related to the Section 999 R&D program
 - Searchable database that also includes historical oil/gas research from NETL
 - ArcGIS to enable data visualization
 - Beta version anticipated Aug/Sept 2009
- Marcellus shale database: high resolution data for improved assessment
 - Quantitative assessment of commercial gas in place via laboratory/well-logs correlations for improved models

Questions

