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DOE's/NETL's Carbon Sequestration Program Overview

Brian W. Dressel
Sequestration Division
October 25, 2011

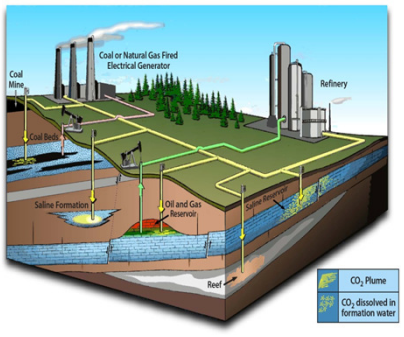
U.S. DEPARTMENT OF ENERGY

September 2011

Carbon Sequestration Program Goals

Develop Technology Options That...

- **Deliver technologies & best practices that provide Carbon Capture and Safe Storage (CCSS) with:**
  - 90% CO_2 capture at source
  - 99% storage permanence
  - < 10% increase in COE
    - Pre-combustion capture (IGCC)
  - < 30% increase in COE
    - Post-combustion capture
    - Oxy-combustion



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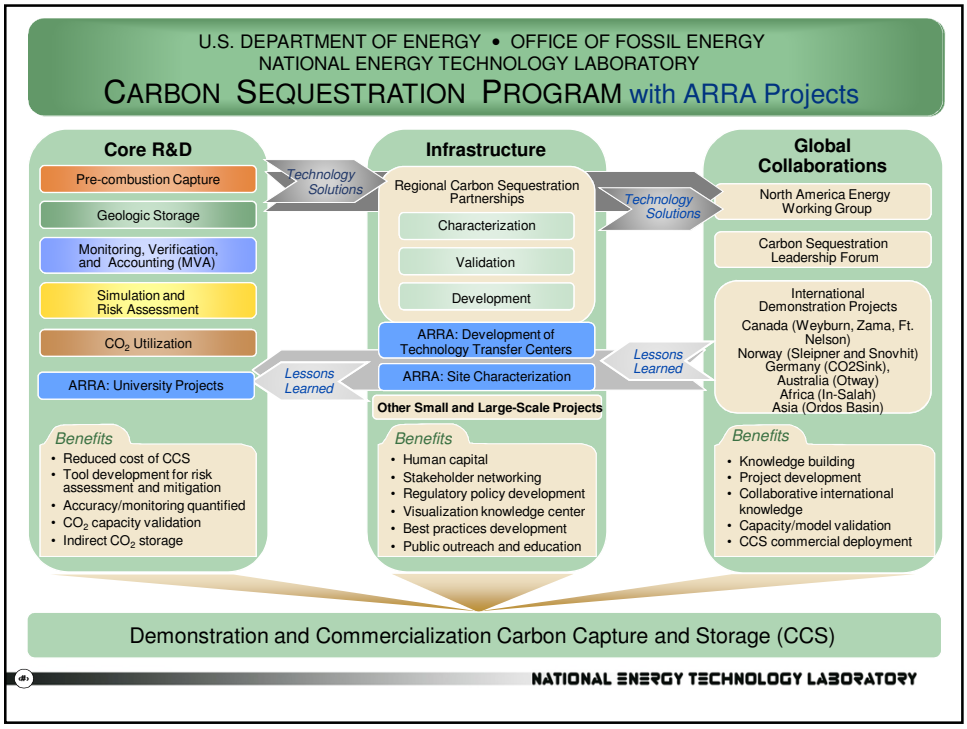
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CARBON SEQUESTRATION PROGRAM with ARRA Projects
Core R&D
Pre-combustion Capture
Geologic Storage
Monitoring, Verification, and Accounting (MVA)
Simulation and Risk Assessment
CO_2 Utilization
ARRA: University Projects
Technology Solutions
Lessons Learned
Infrastructure
Regional Carbon Sequestration Partnerships
Characterization
Validation
Development
ARRA: Development of Technology Transfer Centers
ARRA: Site Characterization
Other Small and Large-Scale Projects
Technology Solutions
Lessons Learned
Global Collaborations
North America Energy Working Group
Carbon Sequestration Leadership Forum
International Demonstration Projects
Canada (Weyburn, Zama, Ft. Nelson)
Norway (Sleipner and Snovhit)
Germany (CO2Sink),
Australia (Otway)
Africa (In-Salah)
Asia (Ordos Basin)
Benefits
• Reduced cost of CCS
• Tool development for risk assessment and mitigation
• Accuracy/monitoring quantified
• CO_2 capacity validation
• Indirect CO_2 storage
Benefits
• Human capital
• Stakeholder networking
• Regulatory policy development
• Visualization knowledge center
• Best practices development
• Public outreach and education
Benefits
• Knowledge building
• Project development
• Collaborative international knowledge
• Capacity/model validation
• CCS commercial deployment
Demonstration and Commercialization Carbon Capture and Storage (CCS)
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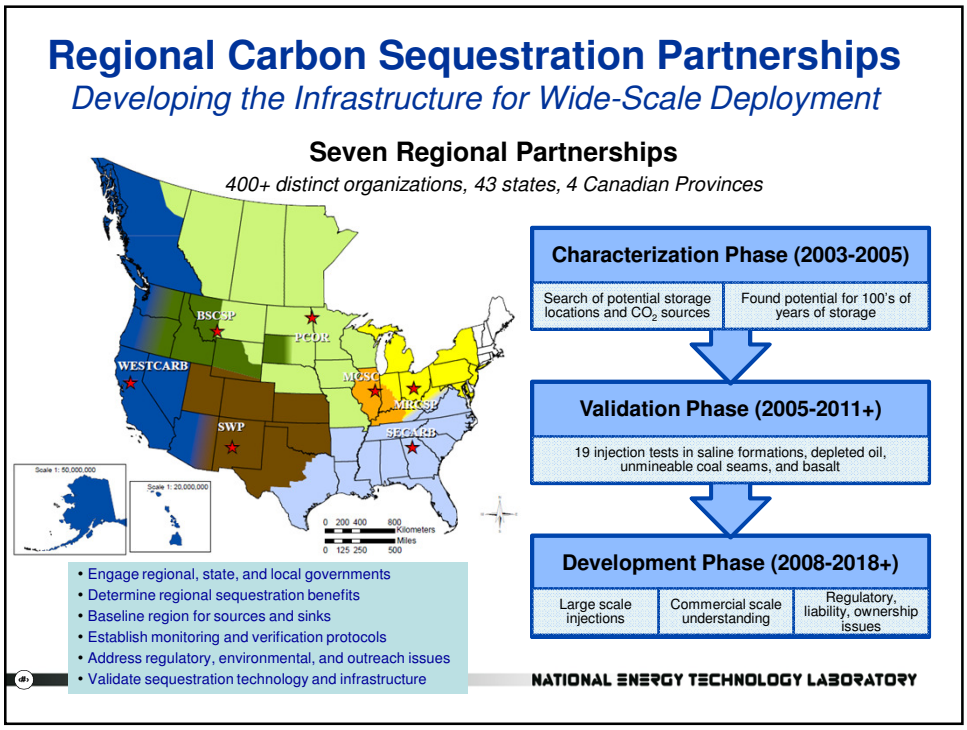
Regional Carbon Sequestration Partnerships
Developing the Infrastructure for Wide-Scale Deployment
Seven Regional Partnerships
400+ distinct organizations, 43 states, 4 Canadian Provinces
BSCSP
PCOR
WESTCARB
MGSC
MRCSP
SWP
SECARB
0 200 400 800 Kilometers
0 125 250 500 Miles
Characterization Phase (2003-2005)
Search of potential storage locations and CO_2 sources
Found potential for 100's of years of storage
Validation Phase (2005-2011+)
19 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt
Development Phase (2008-2018+)
Large scale injections
Commercial scale understanding
Regulatory, liability, ownership issues
• Engage regional, state, and local governments
• Determine regional sequestration benefits
• Baseline region for sources and sinks
• Establish monitoring and verification protocols
• Address regulatory, environmental, and outreach issues
• Validate sequestration technology and infrastructure
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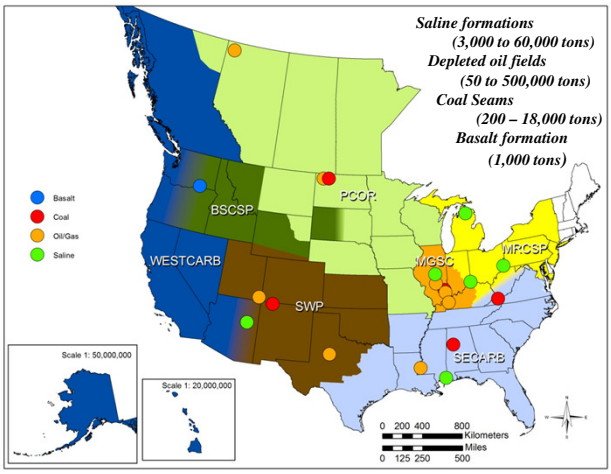
RCSP Validation Phase

Small-Scale Geologic Tests



RCSP	Geologic Province
BSCSP	Columbia Basin
MGSC	Illinois Basin
MRCSP	Cincinnati Arch, Michigan Basin, Appalachian Basin
PCOR	Keg River, Duperow, Williston Basin
SECARB	Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin
SWP	Paradox Basin, Aneth Field, Permian Basin, San Juan Basin
WESTCARB	Colorado Plateau

Completed 18 Injections--Over 1.35 M Tons injected

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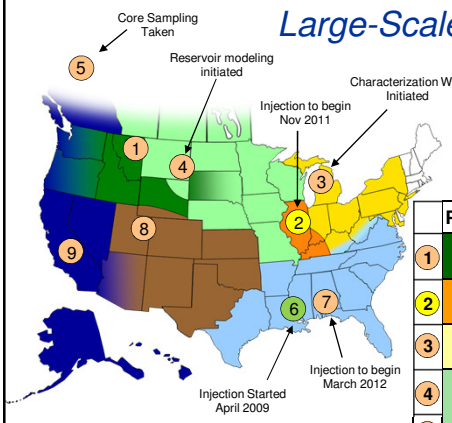
RCSP Phase III: Development Phase

Large-Scale Geologic Tests



- ✓ *Injection Targets -minimum planned volumes*
- ✓ *One injection commenced April 2009*
- ✓ *Remaining injections scheduled 2011-2015*

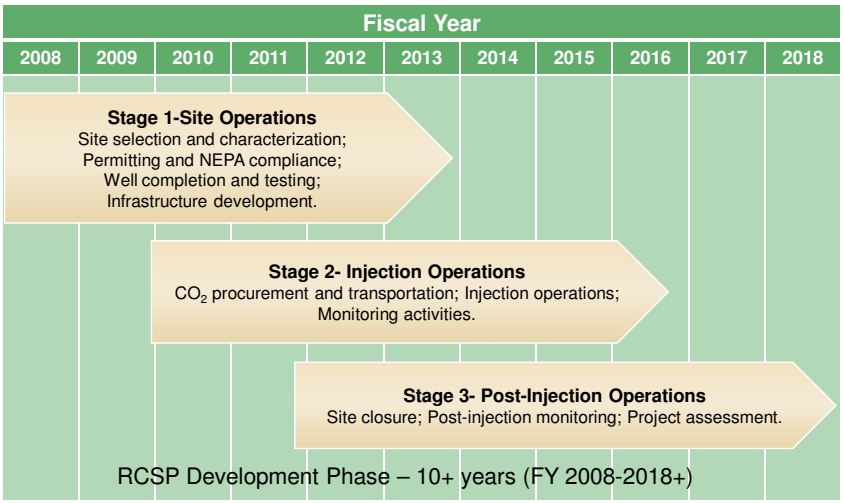
Injection Ongoing
2011 Injection Scheduled
Injection Scheduled 2012-2015

Note: Some locations presented on map may differ from final injection location

	Partnership	Geologic Province	Storage Type
1	Big Sky	Sweetgrass Arch-Duperow Formation	Saline
2	MGSC	Illinois Basin-Mt. Simon Sandstone	Saline
3	MRCSP	Michigan Basin-St Peter SS or Niagaran Reef	Saline/Oil
4	PCOR	Powder River Basin-Muddy Formation	Oil Bearing
5	PCOR	Alberta Basin-Sulphur Point Formation	Saline
6	SECARB	Interior Salt Basin-Tuscaloosa Formation	Oil/Saline
7	SECARB	Interior Salt Basin-Paluxy Formation	Saline
8	SWP	Wasatch Plateau-Navajo Sandstone	Saline
9	WESTCARB	Regional Characterization	TBD

RCSP Development Phase

Scaling Up Towards Commercialization



RCSP Development Phase – 10+ years (FY 2008-2018+)

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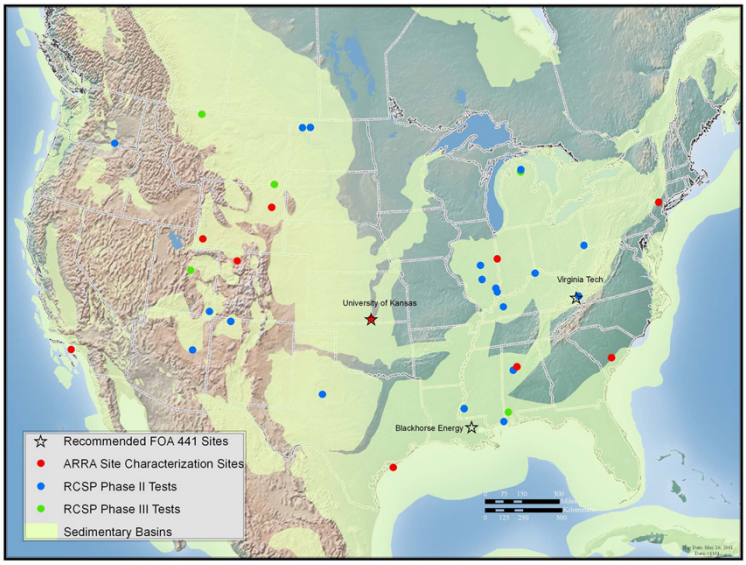
Project Locations



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Phase III Projects

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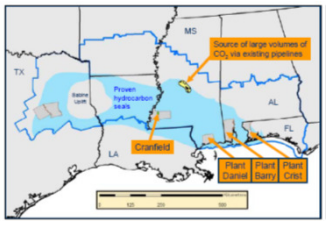
Southeast Regional CS Partnership

Cranfield Site Large-Scale Project

Target Formation

- Lower Tuscaloosa

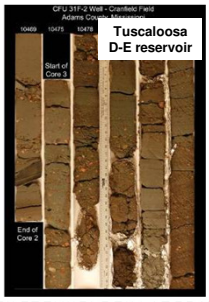


CO_2 Source

- Jackson Dome (natural source) delivered via Denbury Resources' Sonat CO_2 pipeline

CO_2 Injection Amount (Current)

- > 2.0 million metric tons (P3 only)
- > 2.7 million metric tons (combined P2 and P3)



Current Status

- Injection began on 04/01/2009
- Injection rate was ~ 432 metric tons/day, now < 100 metric tons/day
- Observation wells (F2 and F3) are between 220-370 feet from injection well
- Electrical Resistivity Tomography (ERT) receivers were installed in the two observation wells

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Southeast Regional CS Partnership

Plant Barry Site Large-Scale Project

Target Formation

- Upper Paluxy Formation

CO_2 Source

- Southern Company's Plant Barry Power Station

CO_2 Injection Amount

- ~ 300,000 metric tons over 3 years (March 2012)

Current Status

- Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) signed March 2011
- Characterization well drilled January 2011
- Capture Unit Shake-down at Southern Company's Plant Barry Coal-fired Power Plant started June 3rd
- UIC Class V Injection well permit (November 2011)
- Pipeline construction started (September 2011)
- Injection well drilling expected to start (December 2011)
- CO_2 injection expected to start (March 2012)

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SECARB Partnership

Anthropogenic Test Separator and Compression System

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Midwest Geological Sequestration Consortium

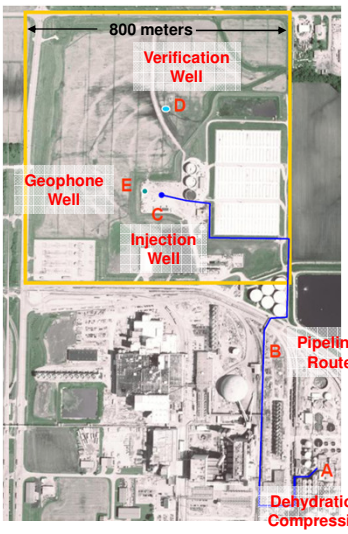
Decatur Site Large-Scale Project

Target Formation
- Mt. Simon Sandstone

CO_2 Source
- ADM's Ethanol Production Facility

CO_2 Injection Amount
- 1 million metric tons over 3 years (Nov 2011)

Current Status
- Completed 4 square mile 3D seismic survey
- Completed drilling injection well, groundwater monitoring wells, geophone well, and verification well.
- CO_2 Pipeline installed and connected to injection wellhead.
- Installed all subsurface monitoring equipment.
- Completed commission of compression/dehydration facility
- Completed baseline fluid samples from verification well.
- Completed satellite interferometry (InSAR) baseline imaging data collection.
- UIC Permit finalized in March, 2011. Approval from IEPA to begin injection expected in mid-October.
- Injection initiation expected in early November.



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Midwest Regional CS Partnership

Michigan Site Large-Scale Project

Target Formation
- St. Peter Sandstone or Niagaran Reef

CO_2 Source
- Core Energy provider per Natural Gas Processing Facility

CO_2 Injection Amount
- 1 million metric tons over 4 years
- Injection anticipated to begin 2012

Current Status
- Completed preliminary geologic assessment of Otsego County area
- Completed "Communications Plan" and met with various stakeholders including government and regulatory agencies
- Initiated Environmental Assessment (EA) Process
- Completed 3D Seismic Survey


MRCSP Well Drilling


CO_2 Compression Facility

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Plains CO_2 Reduction Partnership

Fort Nelson Site Large-Scale Project

Target Formation

- Elk Point Group/Sulphur Point Formation

CO_2 Source

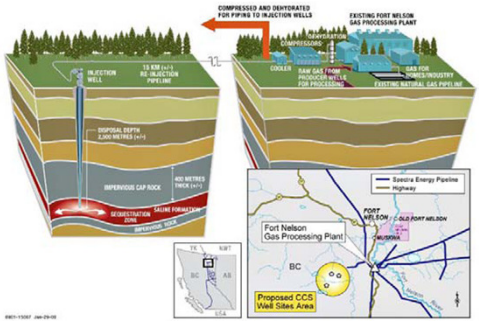
- Spectra Energy's Fort Nelson Natural Gas Processing Plant

CO_2 Injection Amount

- Up to 2 million tons/year
- Injection anticipated early 2014

Current Status

- Drilling of exploration well completed
- Conducted "side-track" to acquire additional reservoir data
- Developing integrated Risk Management Plan (RMP), Modeling and MVA Program



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Plains CO_2 Reduction Partnership

Bell Creek Site Large-Scale Project

Target Formation

- Colorado Group/Muddy Sandstone Formation

CO_2 Source

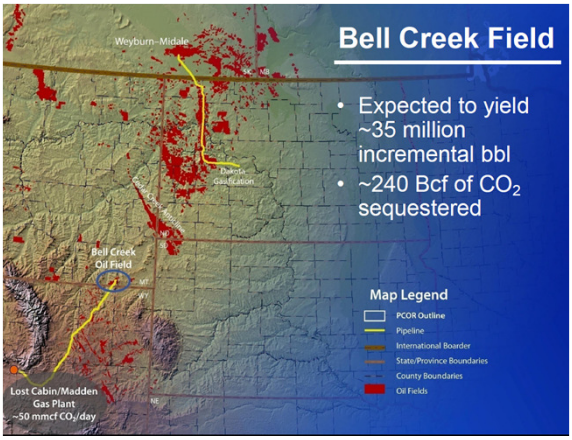
- Lost Cabin/Madden Gas Plant operated by Conoco Phillips

CO_2 Injection Amount

- As much as 1 million tons/year
- Injection anticipated late 2012 or early 2013

Current Status

- Working with commercial partner (Denbury Resources Inc.)
- Preparing monitoring well AFE
- Developing integrated modeling and MVA plan



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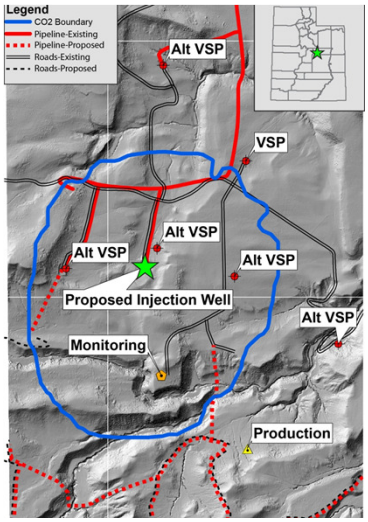
Southwest Regional Partnership on CS
Gordon Creek Site Large-Scale Project

Target Formation
- Navajo Sandstone

CO_2 Source
- Natural CO_2 Source (White Rim Frm.)

CO_2 Injection Amount
- > 1 million metric tons over 4 years
- Injection anticipated (2013)

Current Status
- Project Re-negotiation Complete
- Conducting NEPA Activities
- Preparing Permit Applications



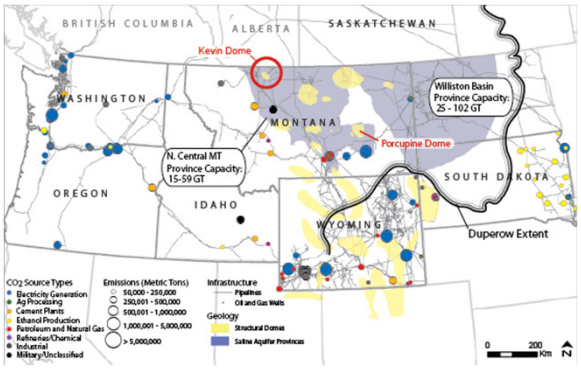
Big Sky Regional CS Partnership
Kevin Dome Site Large-Scale Project

Target Formation
- Duperow Formation

CO_2 Source
- Natural CO_2 Source (Kevin Dome)

CO_2 Injection Amount
- 1 million metric tons over 4 years
- Injection anticipated (2013/2014)

Current Status
- Project Re-negotiation Complete
- Conducting NEPA Activities
- Preparing Permit Applications



West Coast Regional CS Partnership

Regional Characterization Efforts
Colorado Plateau and Sacramento Basin

Some of the oil fields in southern California appear suitable for CO_2-EOR.

Geologic characterization well near the ash pond at the Cholla Power Plant in Arizona.

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FOA 441 Small Scale Injection Projects

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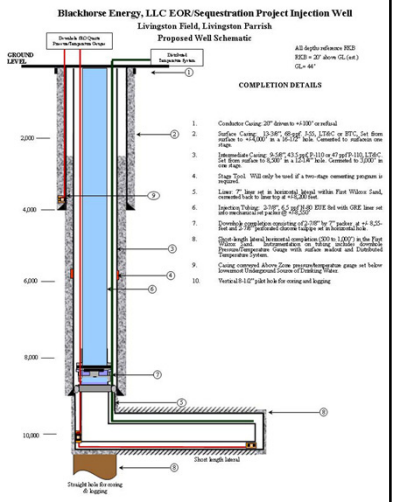
FOA 441 Small Scale Injection Tests
Blackhorse Energy

Project Synopsis

- Evaluate the early Eocene-aged Wilcox oil reservoir located in Livingston Parish, Louisiana.
- In-zone and remote time-lapse monitoring will be deployed in the project wells to measure, track, and assess effectiveness of the overlying zones to contain the injected CO_2, assess the physical and geochemical fate of CO_2 in the reservoir, and refine the storage resource estimate.
- The project will use an innovative injection well design to test the efficacy of increased sequestration using short-radius horizontal well technology to inject approximately 54,000 tonnes of supercritical CO_2 and CO_2 foam into the reservoir.
- Data results from the project wells will be compared with data collected from the two existing vertical injection wells.
- Existing field production wells will be leveraged for data gathering, effectively increasing the number of observation points beyond what a single injection well/observation well pair can provide.

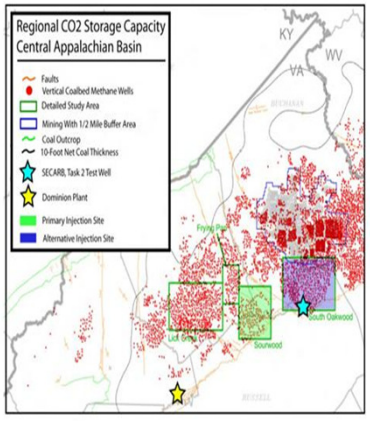


FOA 441 Small Scale Injection Tests

Virginia Polytechnic Institute and State University

Project Synopsis

- The proposed research will inject approximately 20,000 tonnes of CO_2 into unmineable coal seams and evaluate the potential for enhanced coalbed methane recovery (ECBM) by stressing the coals under continuous injection for a one-year period.
- The results of the injection and monitoring will help to better understand the effect of matrix swelling, due to the adsorption of CO_2 on the coal surface, on injectivity and ECBM.
- The benefit to this research is to prove the sequestration potential of coal seams with ECBM and other stacked unconventional formations in Central Appalachia.
- Many of the CBM operations in the Central Appalachian Basin are approaching maturity, providing large reservoirs suitable for the sequestration of CO_2.
- Injection of CO_2 into coal seams could increase CBM reserves by 20 to 40 percent while concurrently increasing the storage capacity for sequestration of large volumes of CO_2.

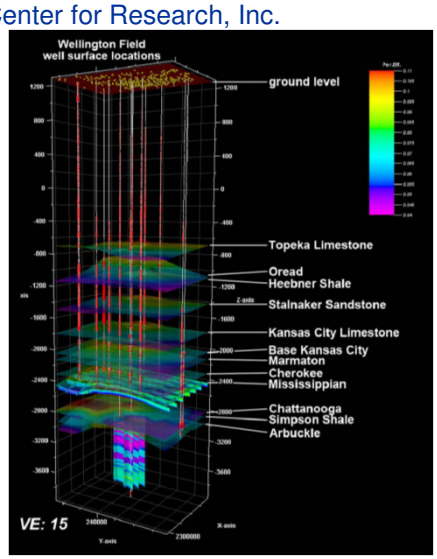


FOA 441 Small Scale Injection Tests

University of Kansas Center for Research, Inc.

Project Synopsis

- Inject at least 40,000 metric tons of CO_2 under super-critical conditions, into the Arbuckle saline aquifer and 30,000 metric tons into overlying Mississippian boreholes to evaluate sequestration of CO_2 and miscible CO_2-EOR potential;
- Demonstrate the application of state-of-the-art MVA (monitoring, verification, and accounting) tools and techniques to monitor and visualize the injected CO_2 plume;
- Develop a robust Arbuckle geomodel by integrating data collected from the proposed study area;
- Conduct reservoir simulation studies to map CO_2 plume dispersal and estimate tonnage of CO_2 sequestered in solution, as residual gas and by mineralization;
- Integrate MVA data and analysis with reservoir modeling studies to detect CO_2 leakage and to validate the simulation model;
- Establish proof-of-feasibility of a novel concept that uses multiple in-situ and ex-situ monitoring systems in tandem to track the location of the injected CO_2.



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ARRA Site Characterization Projects

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ARRA Site Characterization Projects

Receipent	Title	Formation(s) Being Investigated
Univ. of Wyoming	Site Characterization of the highest-priority geologic formations for CO_2 storage in Wyoming	Rock Springs Uplift & Moxa Arch
Univ. of Illinois	An Evaluation of the Carbon Sequestration Potential of the Cambro-Ordovician Strata of the Illinois and Michigan Basins	Illinois and Michigan Basins
Terralog Technologies USA Inc.	Characterization of Pliocene and Miocene Formations in the Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2	Pliocene and Miocene Formations
University of Utah	Characterization of Most Promising Sequestration Formations in the Rocky Mountain Region	Dakota, Entrada, and Weber
University of Alabama	Site Characterization for CO2 Storage from Coal-fired Power Facilities in the Black Warrior Basin of Alabama	Black Warrior Basin
South Carolina Research Foundation	Geologic Characterization of the South Georgia Rift Basin for Source Proximal CO_2 Storage	Jurassic/Triassic Saline Formations
University of Texas at Austin	Gulf of Mexico Miocene CO_2 Site Characterization Mega Transect	Miocene Off-Shore Formations
Sandia Technologies, LLC	Site Characterization - Triassic Newark Basin-New York & New Jersey	Newark Rift Basin
University of Kansas Center for Research	Modeling CO_2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO_2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas	Arbuckle Formation and Mississippian Chat
North American Power Group, Ltd.	Two Elk Energy Park Carbon Site Characterization Project	Powder River Basin

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Best Practice Manuals (BPMs)

Important Program Outputs

- **BPMs demonstrate to the public, regulators and policymakers that geologic storage is a safe effective GHG control technology**
- **BPMs provide technical and nontechnical guidance on key components of a storage project**
- **BPMs build upon knowledge and experience gained from the RCSP efforts and industry**
- **BPMs provide Information to potential developers of commercial CCS projects**

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CCS Best Practice Manuals

Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned

Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting	2009 2012	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation and Risk Assessment	2010	2016	2020
**Well Construction, Operations and Completion	2011	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

***Regulatory Issues will be addressed within various Manuals*

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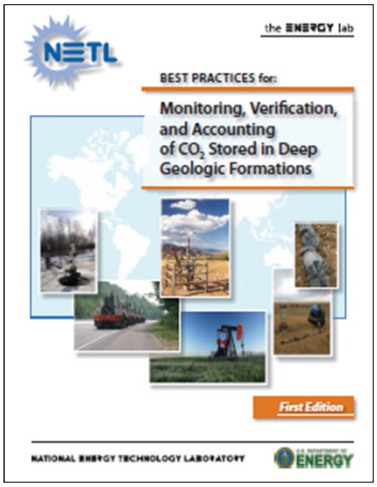
www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html

Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations

- **Based on DOE Supported and leveraged monitoring activities**
  - RCSP Program
  - Core R&D
  - International Projects
  - Industrial applications
- **Regulatory requirements and associated monitoring needs**
- **35 technologies divided into:**
  - Primary
  - Secondary
  - Additional
- **To be Updated 2012**



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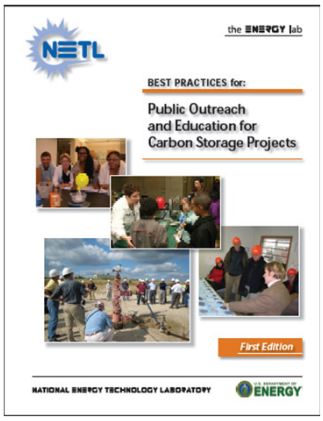
Public Outreach and Education for Carbon Storage Projects

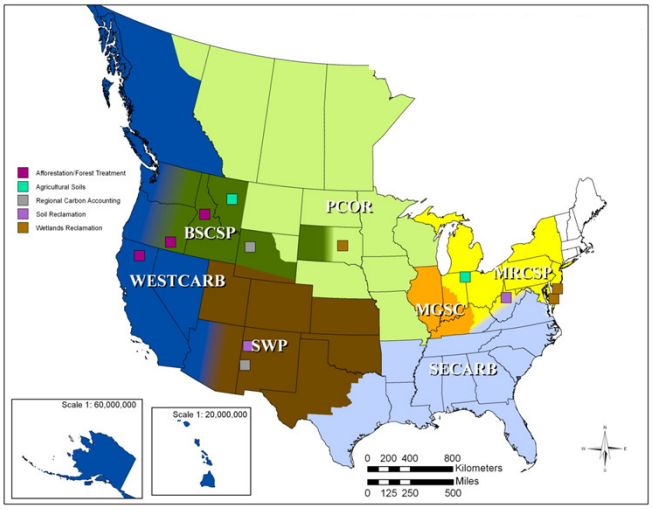
Focused on project developers providing 10 Best Practices based on practical RCSP experience

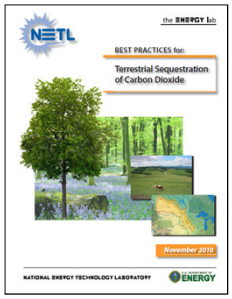
- **Do your homework**
  - Integrate outreach with project management
  - Establish an outreach team
  - Identify stakeholders
  - Conduct and apply social characterization
- **Develop plans and materials**
  - Develop plan tailored to community
  - Develop key messages
  - Tailor materials to audience
- **Implement, Assess and Refine**



RCSP Validation Phase:

Terrestrial Field Tests

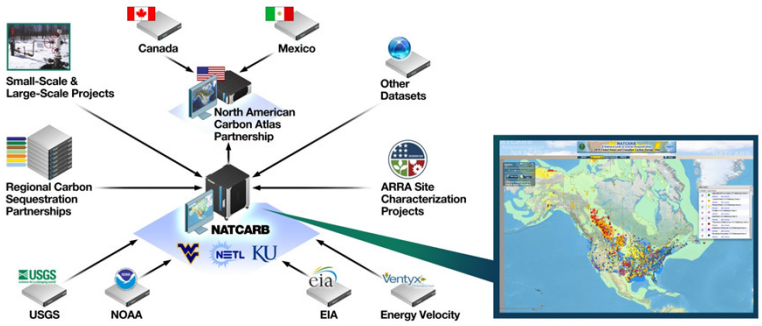




- **All field tests completed in FY2011**
- **Best Practices Manual Published FY2010**
- **Limited Development Phase monitoring activities**

Knowledge Sharing

National Carbon Sequestration Database and Geographic Information System (NATCARB)



Hundreds of Years of Storage Potential

U.S. Emissions ~ 6 GT CO_2/yr (all sources)

Oil and Gas Fields
143 GT CO_2
Storage Resource

Saline Formations
1,653 - 20,213 GT CO_2
Storage Resource

Unmineable Coal Seams
60-117 GT CO_2
Storage Resource

Knowledge Sharing

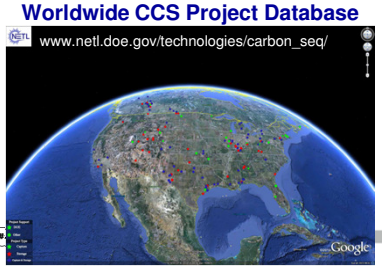
Integrating "Corporate Knowledge" from the RCSPs

ARRA Regional Technology Training

RCSPs Working Groups

- Geological and Infrastructure
- Monitoring, Verification, Accounting
- Simulation and Risk Assessment
- Capture and Transportation
- GIS and Database
- Water
- Public Outreach and Education

Worldwide CCS Project Database



Carbon Sequestration Reference Shelf

Knowledge Sharing

Disseminating Information through the RCSPs

- Annual RCSP Meeting
- RCSP Working Groups
- Domestic/International Collaborations
- Technical Workshops
- Domestic/International Conferences
- Training-IEAGHG CCS Summer School, RECS Summer Program

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For More Information…

- **NETL website:**
  - www.netl.doe.gov
- **Office of Fossil Energy website:**
  - www.fe.doe.gov

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