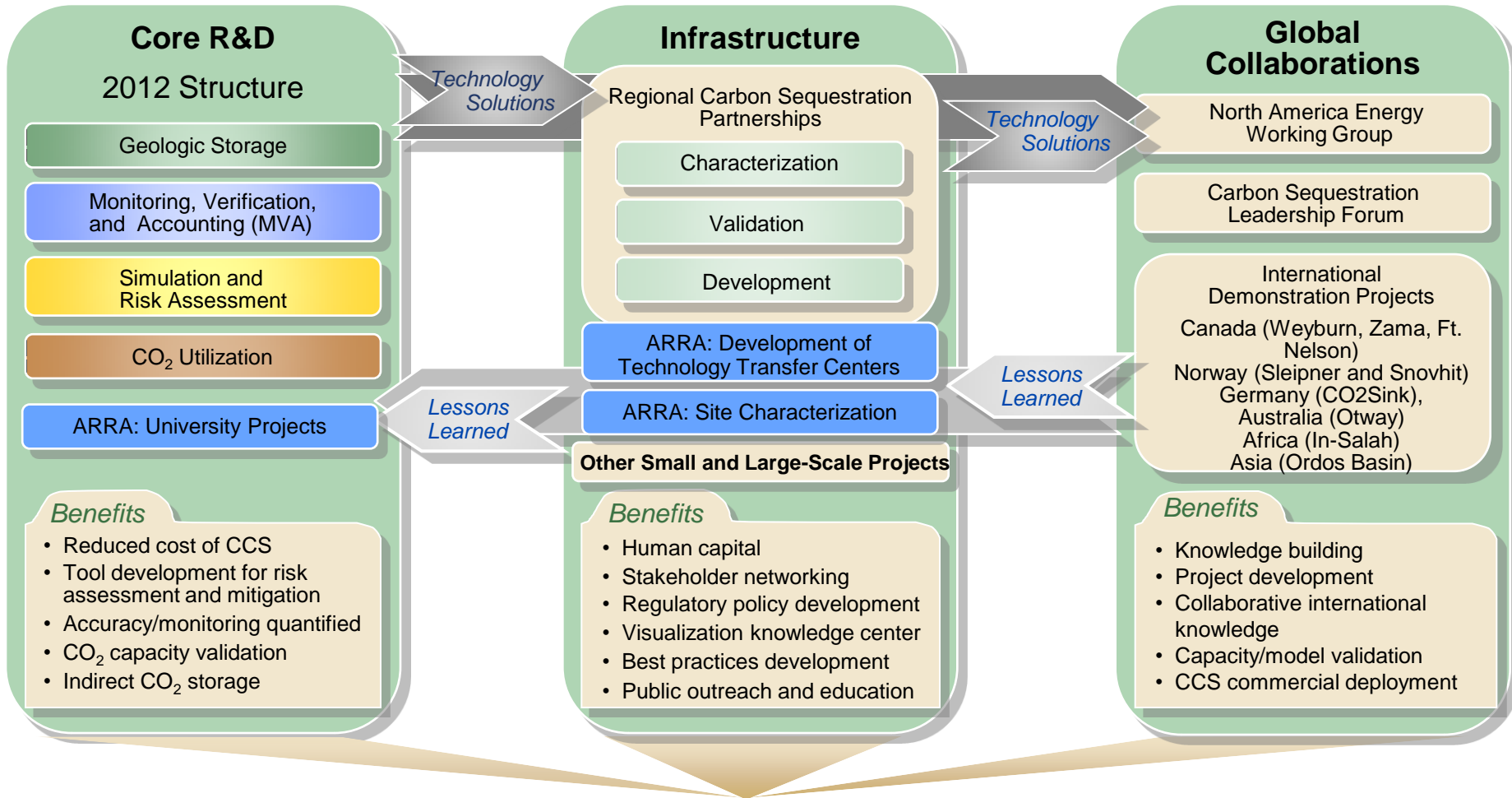


CCS Capacity Building Workshop

*U.S. Department of Energy's Carbon Storage Program,
Regional Carbon Sequestration Partnership Initiative
Traci D. Rodosta, P.G.*



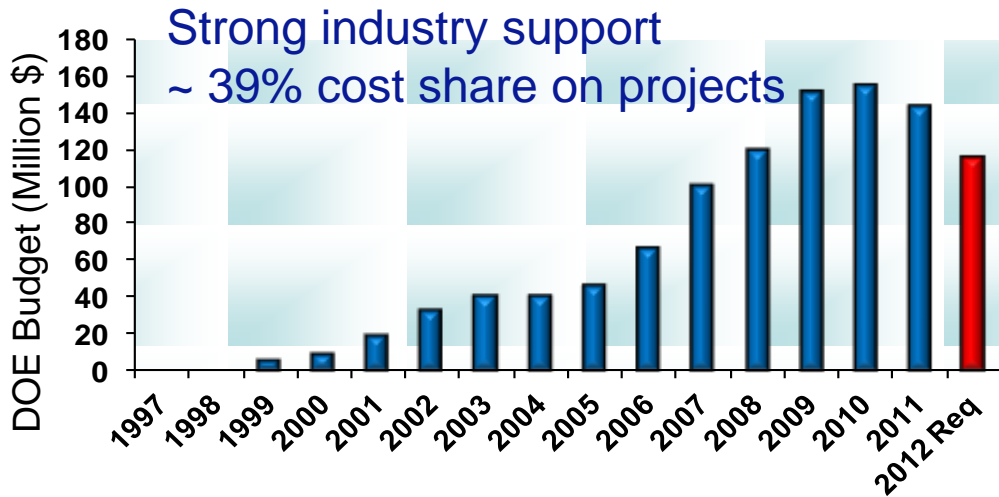
CARBON SEQUESTRATION PROGRAM with ARRA Projects



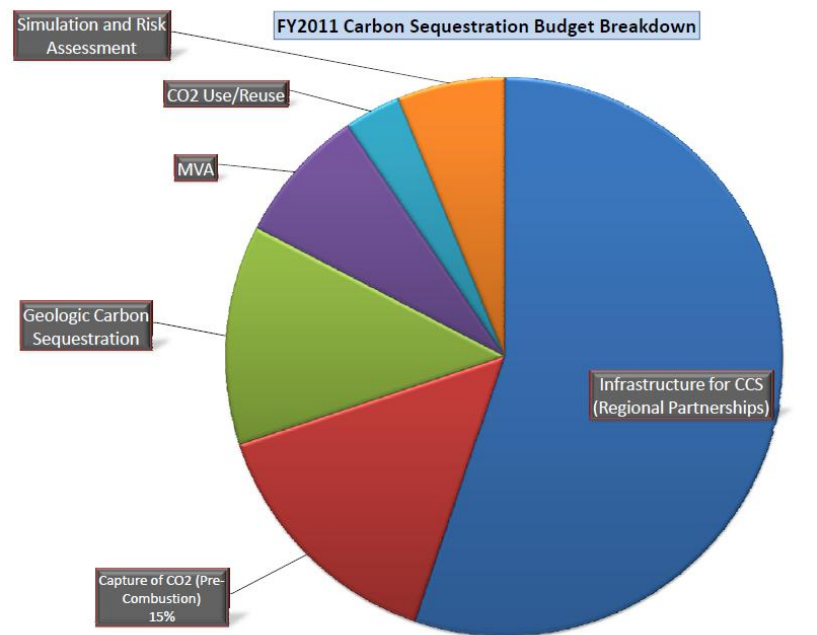
Demonstration and Commercialization Carbon Capture and Storage (CCS)

Sequestration Program Total Funding

2011 Program Statistics



FY12 Request for Program Funding does not include Pre-Combustion Capture



Diverse research portfolio

93 Active R&D Projects

60 ARRA Projects (FY10 - \$120M)

Sequestration Program – Core R&D

64 Current Active Core R&D Projects

Monitoring, Verification, and Accounting

Columbia University, NY
Intelligent Optical Systems, Inc., CA
Lawrence Berkeley Lab, CA (2)
Lawrence Livermore National Lab, CA
Los Alamos National Lab, NM (2)
Montana State University, MT (2)
Multi-Phase Technologies, NV
Pacific Northwest National Lab, WA (2)
Physical Sciences, Inc., MA
PEM, Inc., MA
PTRC, SK Canada
RMOTC, WY
Schlumberger, OH
Stanford University, CA
University of Miami, FL
University of Texas, TX
University of Wyoming, WY
West Virginia University, WV

Geologic Storage

ARI, VA
Clemson University, SC
City Utilities of Springfield, MO
Colorado School of Mines, CO (2)
Columbia University, NY
CONSOL Energy, PA
Fusion Technologies, TX
Indiana University, IN
Lawrence Berkeley Lab, CA
Montana State University, MT
NMIMT, NM
Paulsson, Inc., CA
Sandia National Lab, NM
Stanford University, CA
University of Kansas, KS
University of North Dakota, ND
University of Texas, TX (2)
University of Wyoming, WY
USGS
Yale University, CT

Simulation and Risk Assessment

ARI, VA
Battelle Memorial Institute, OH
Brookhaven National Lab, NY
Colorado School of Mines, CO
GoldSim Technology, LLC., WA
Headwaters, LLC., UT
Lawrence Berkeley Lab, CA
Los Alamos National Lab, NM (3)
Missouri S&T, MO
NMIMT, NM
Princeton University, NJ
University of Texas at Austin, TX

CO₂ Utilization

Brown University, RI
CCS Materials, Inc., NJ
MIT, MA
McGill University, Canada
PhosphorTech, GA
RTI International, NC

Sequestration Program – Infrastructure

39 Current Active Infrastructure Projects

Regional Carbon Sequestration Partnership

Big Sky
MGSC
MRCSP
PCOR
SECARB
SWP
WESTCARB

Geologic Site Characterization



North American Power Group, CO
Sandia Technologies, TX
SC Research Foundation, SC
Terralog Technologies, TX
University of Alabama, AL
University of Illinois, IL
University of Kansas, KS
University of Texas, TX
University of Utah, UT
University of Wyoming, WY

Knowledge Sharing



EOS Alliance, WA
NMIMT, NM
PTTC, OK
SSEB, GA
University of Illinois, IL
University of Texas, UT
University of Wyoming, WY

Small-Scale Field Tests

Blackhorse Energy, LA
University of Kansas, KS
Virginia Tech University, VT

Other Efforts

Carbon Sequestration Science

NETL Office of Research and Development

Consolidated Research

ANL LLNL
LANL ORNL
LBNL PNNL

Geologic Storage

Technology Development and Understanding

Research Pathways

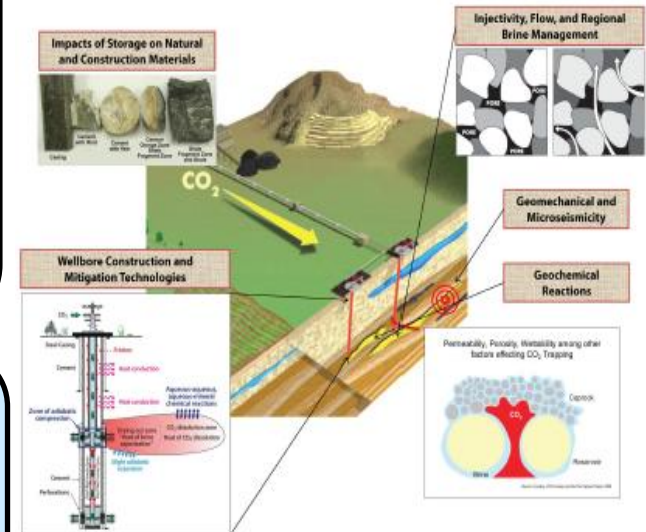
- Wellbore construction and materials technologies
- Mitigation technologies for wells and natural pathways
- Managing fluid flow, reservoir pressure, and brines
- Geochemical effects of CO₂ injection
- Geomechanical effects on reservoirs and seals

Summary of Focus Area

- 16 cooperative agreements awarded - FY10
- 14 Tasks with 6 National Labs
- China Energy Research Center \$1.25M per year
- Targeting 99% permanence and +/-30% capacity goals

Research Partners

University of Texas at Austin, Columbia University, Stanford University, Paullson Inc., University of Wyoming, Fusion Technologies, Consol, Montana State University – Bozeman, Indiana University, Clemson University, Yale University, New Mexico Inst of Mining and Tech, Advanced Resources International, Colorado School of Mines, West Virginia University, LBNL, LLNL, LANL, PNNL, ORNL



Challenges for Geologic Storage

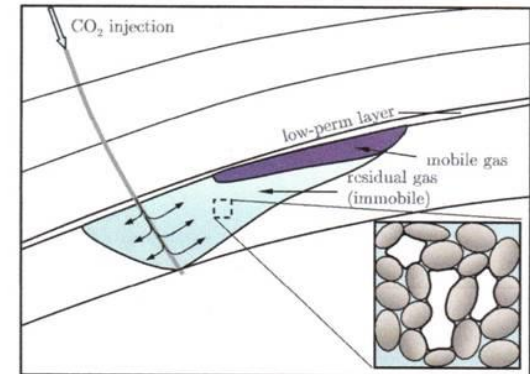
- **Ultimate plume size, and time for stabilization have many implications for project developers**

- Surface and subsurface access
- Regulatory requirements
 - Class VI 50 year post-injection monitoring
 - Area of review requirements for GHG reporting
- Liability; public acceptance
- Cost

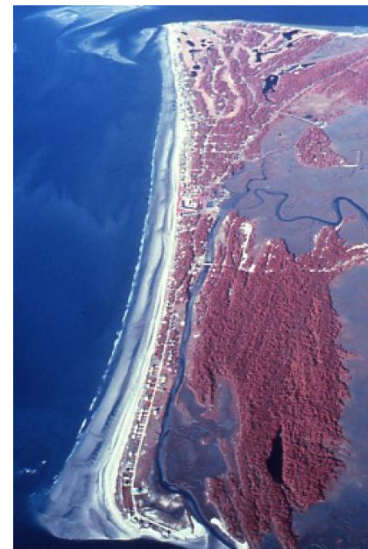
- **Multiple factors affect plume**

- Depositional environment
- Heterogeneity
- Open or closed structure
- Rock properties
eg., residual saturation

- **Very little post-injection field data**



Anatomy of a plume



Strandplain and fluvial depositional environments

Optimizing Storage through Fluids Management

- **Water may be extracted for reservoir management:**
 - Avoid impact to other mineral rights
 - Increased storage volume.
 - CO₂ distribution and pressure management
- **Significant engineering challenges for wide-scale beneficial use**
 - Quality; quantity; cost



Artificial Recharge/
Subsidence Control

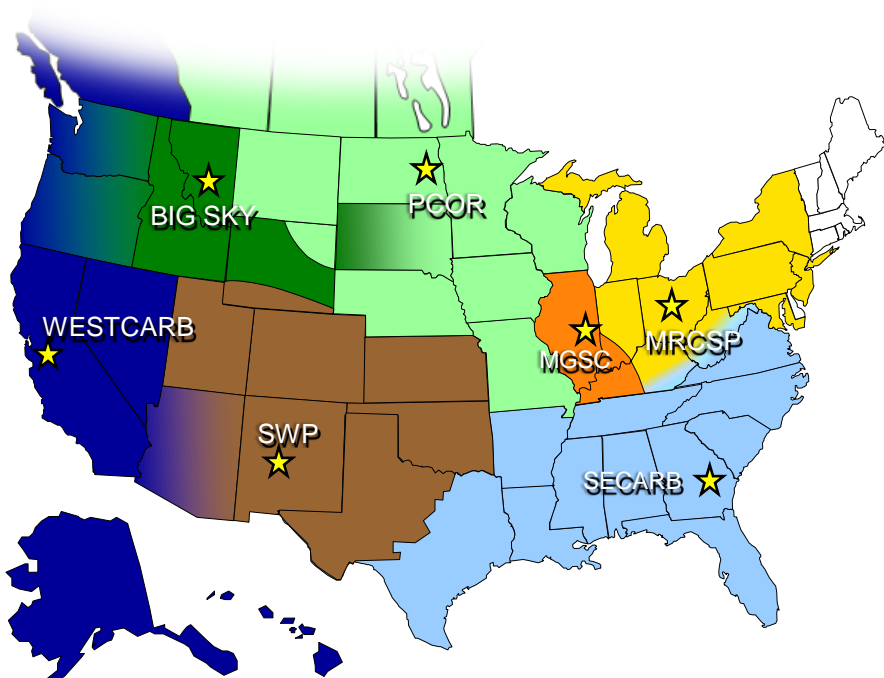


Regional Carbon Sequestration Partnerships

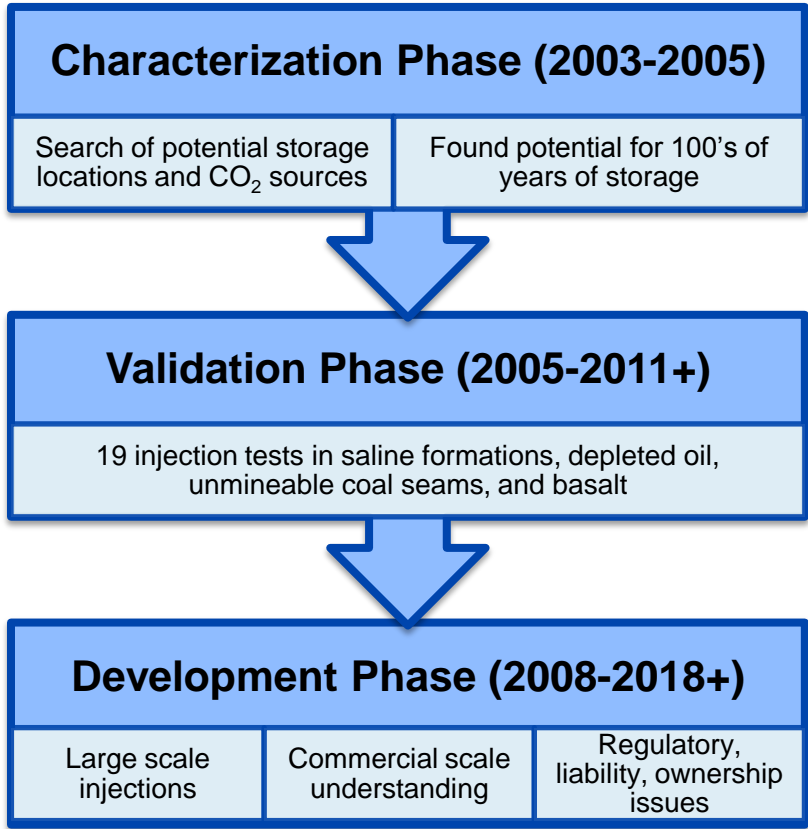
Developing the Infrastructure for Wide Scale Deployment

Seven Regional Partnerships

400+ distinct organizations, 43 states, 4 Canadian Provinces

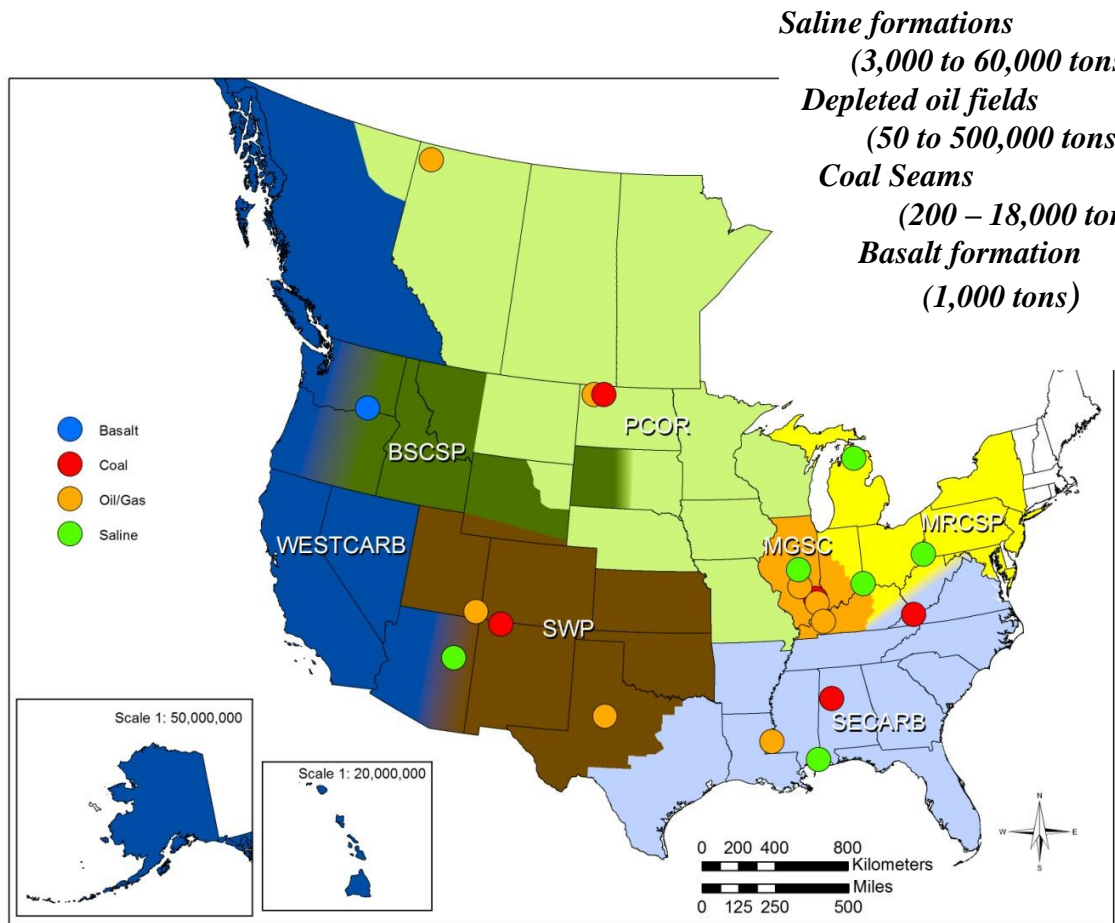


- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Address regulatory, environmental, and outreach issues
- Validate sequestration technology and infrastructure



RCSP Phase II: Validation Phase

Small-Scale Geologic Tests

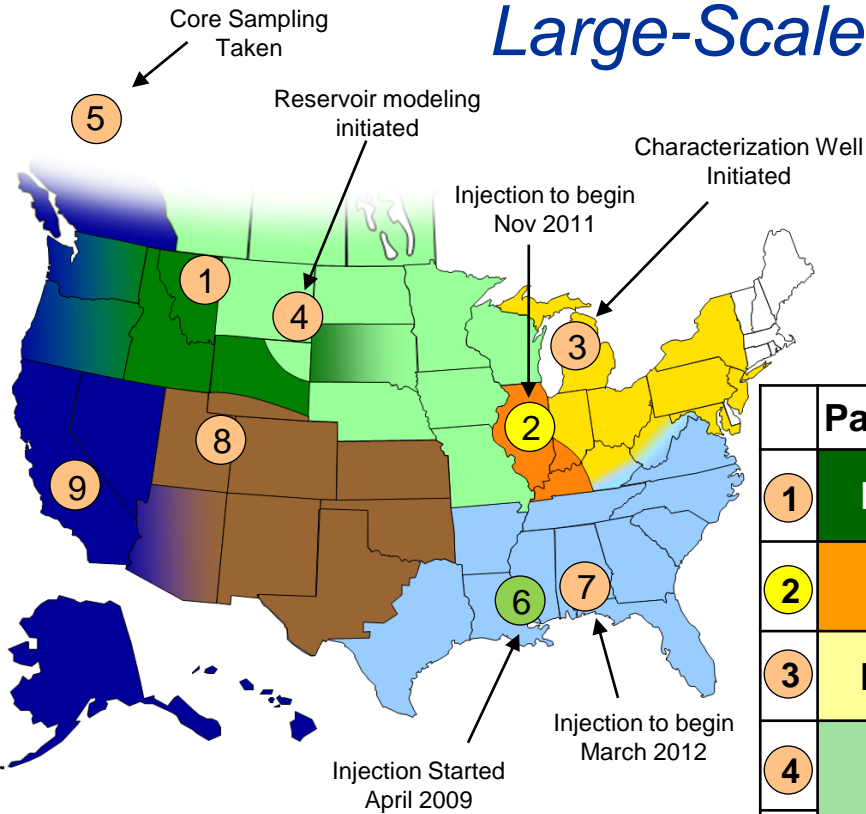


RCSP	Geologic Province
Big Sky	Columbia Basin
MGSC	Illinois Basin
MRCSP	Cincinnati Arch, Michigan Basin, Appalachian Basin
PCOR	Keg River, Duperow, Williston Basin
SECARB	Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin
SWP	Paradox Basin, Aneth Field, Permian Basin, San Juan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

Completed 18 Injections--Over 1.35 M Tons injected

RCSP Phase III: Development Phase

Large-Scale Geologic Tests



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

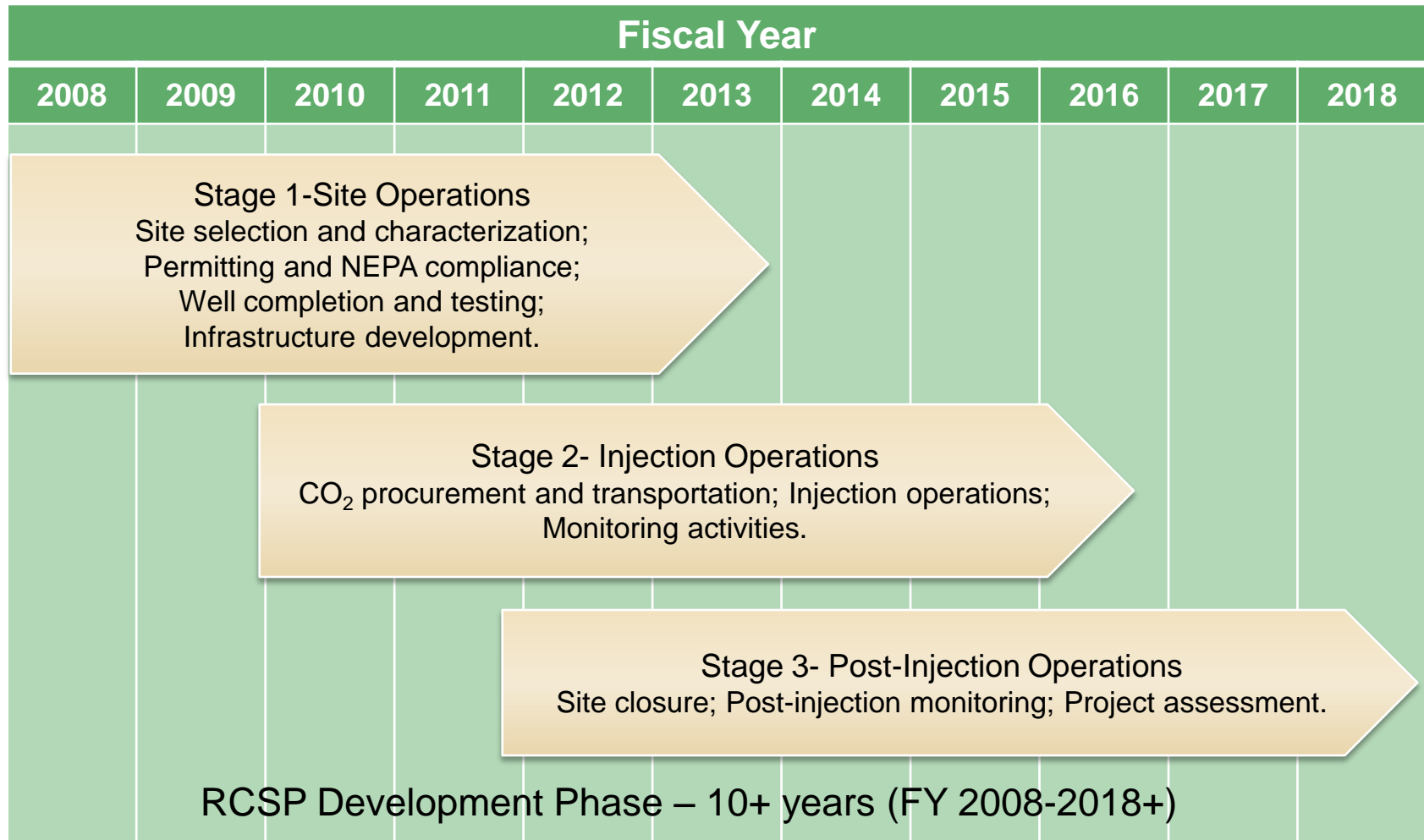
- Injection Ongoing
- 2011 Injection Scheduled
- Injection Scheduled 2012-2015

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		Alberta Basin-Sulphur Point Formation	Saline
● 6	SECARB	Interior Salt Basin-Tuscaloosa Formation	Oil/Saline
● 7		Interior Salt Basin-Paluxy Formation	Saline
● 8	SWP	Wasatch Plateau-Navajo Sandstone	Saline
● 9	WESTCARB	Regional Characterization	TBD

Development Phase

Scaling Up Towards Commercialization



Southeast Regional CS Partnership

Cranfield Site Large-Scale Project

Target Formation

- Lower Tuscaloosa

CO₂ Source

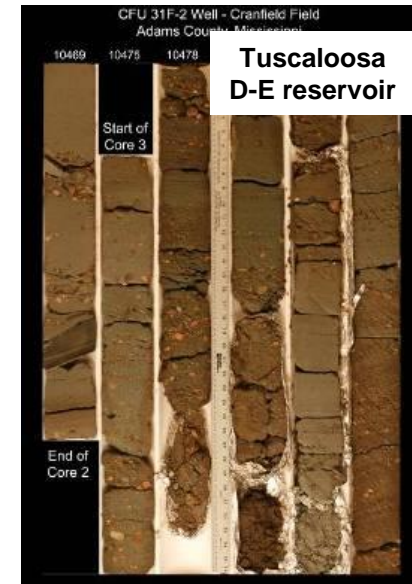
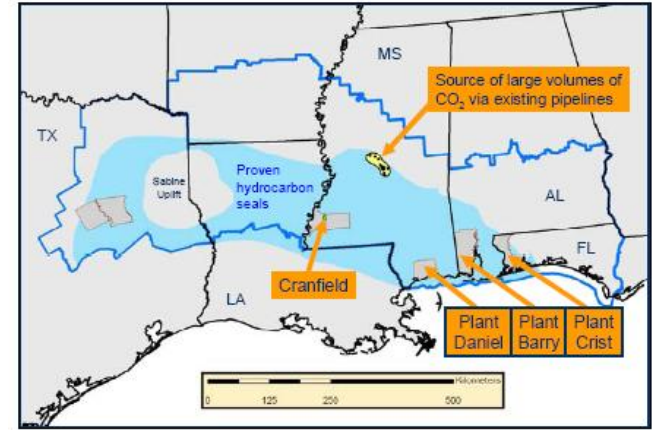
- Jackson Dome (natural source) delivered via Denbury Resources' Sonat CO₂ pipeline

CO₂ 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



Southeast Regional CS Partnership

Plant Barry Site Large-Scale Project

Target Formation

- Upper Paluxy Formation

CO₂ Source

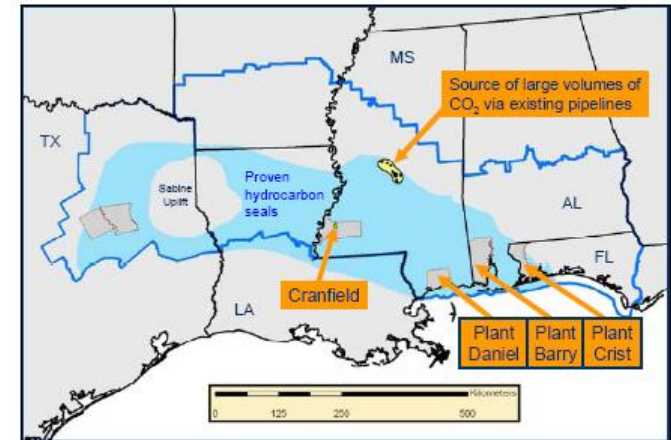
- Southern Company's Plant Barry Power Station

CO₂ 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)
- CO₂ injection expected to start (March 2012)



Midwest Geological Sequestration Consortium

Decatur Site Large-Scale Project

Target Formation

- Mt. Simon Sandstone

CO₂ Source

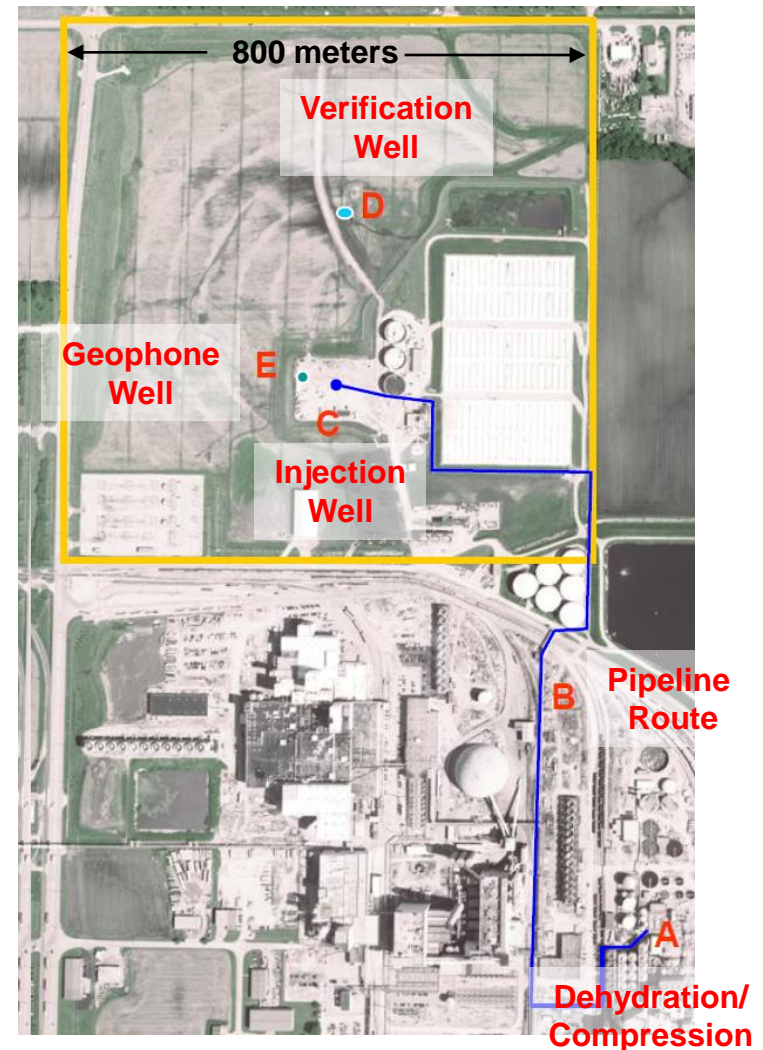
- ADM's Ethanol Production Facility

CO₂ 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.
- CO₂ 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..



Midwest Regional CS Partnership

Michigan Site Large-Scale Project

Target Formation

- St. Peter Sandstone or Niagaran Reef

CO₂ Source

- Core Energy provider per Natural Gas Processing Facility

CO₂ 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



CO₂ Compression Facility

Plains CO₂ Reduction Partnership

Fort Nelson Site Large-Scale Project

Target Formation

- Elk Point Group/Sulphur Point Formation

CO₂ Source

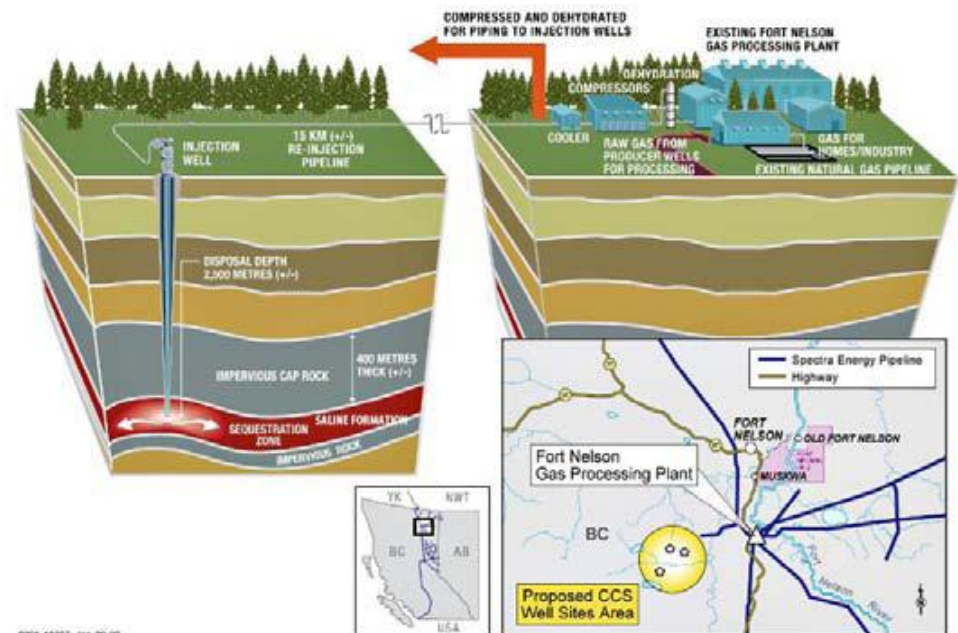
- Spectra Energy's Fort Nelson Natural Gas Processing Plant

CO₂ 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



Plains CO₂ Reduction Partnership

Bell Creek Site Large-Scale Project

Target Formation

- Colorado Group/Muddy Sandstone Formation

CO₂ Source

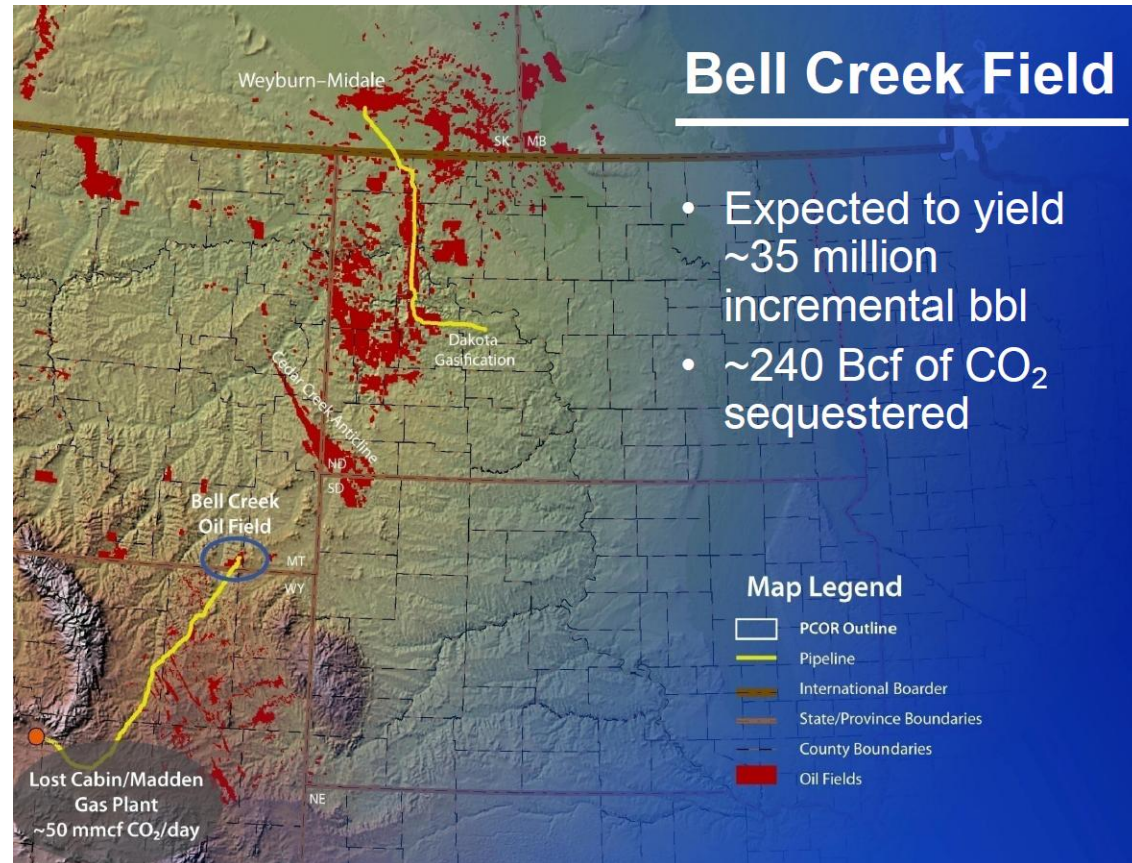
- Lost Cabin/Madden Gas Plant operated by Conoco Phillips

CO₂ 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



Southwest Regional Partnership on CS

Gordon Creek Site Large-Scale Project

Target Formation

- Navajo Sandstone

CO₂ Source

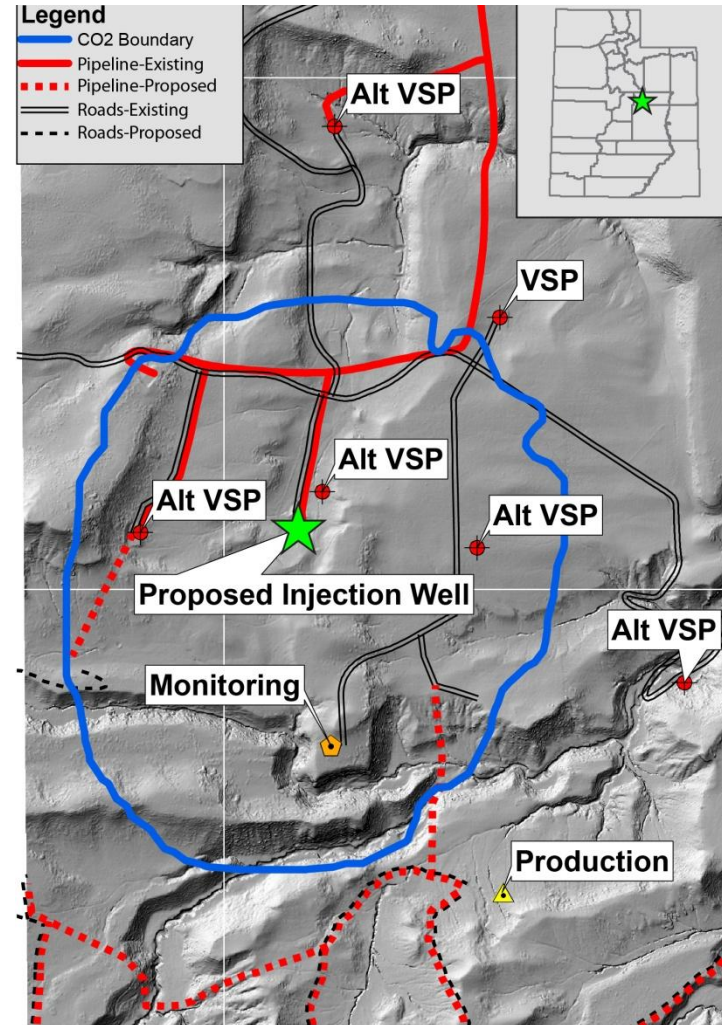
- Natural CO₂ Source

CO₂ 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

CO₂ Source

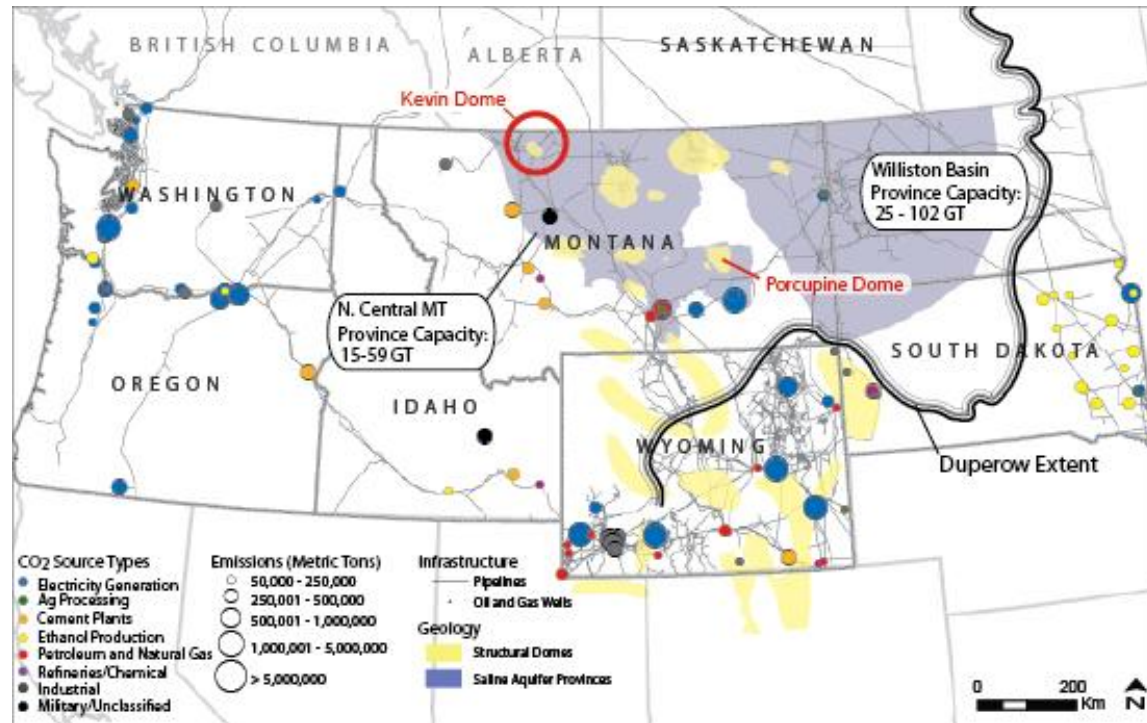
- Natural CO₂ Source

CO₂ Injection Amount

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

Current Status

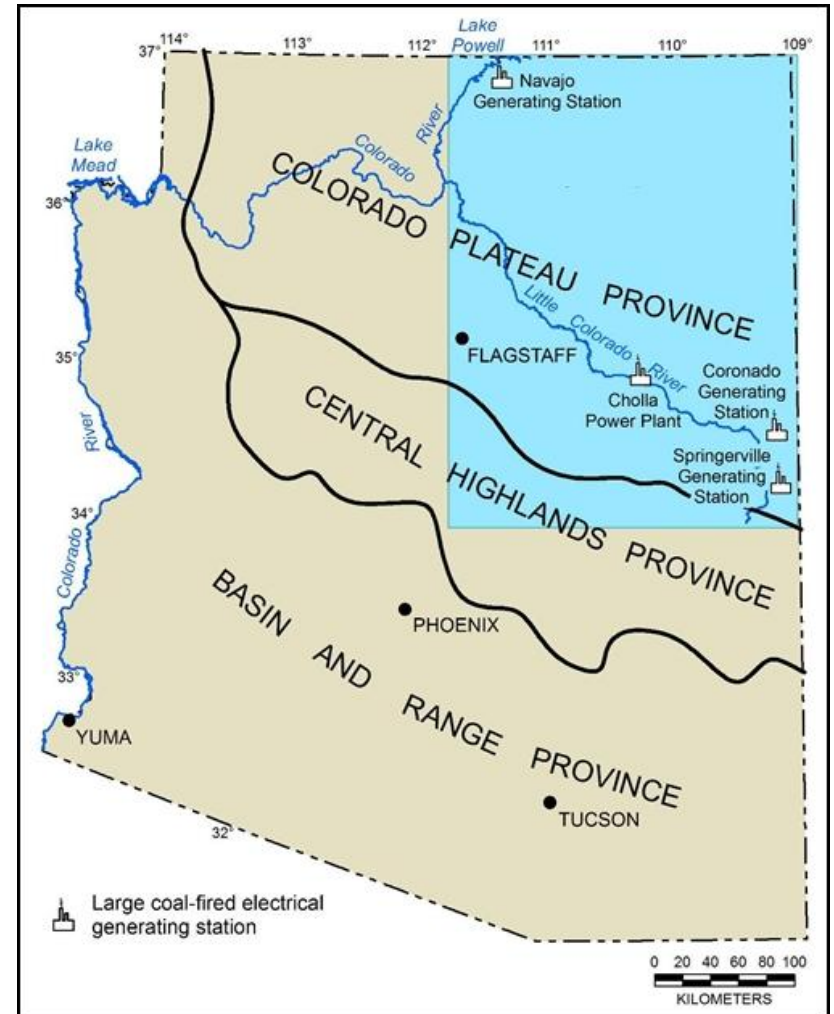
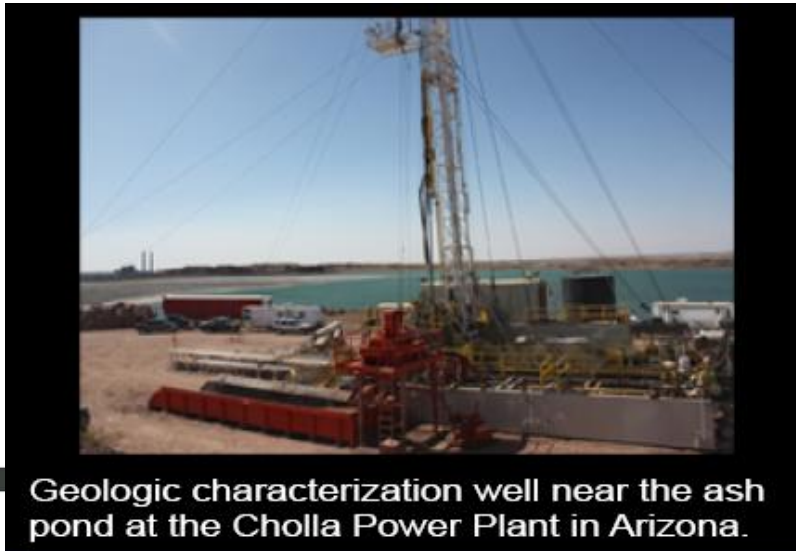
- Project Re-negotiation Complete
- Conducting NEPA Activities
- Preparing Permit Applications



West Coast Regional CS Partnership

Regional Characterization Efforts

Colorado Plateau and Sacramento Basin



Best Practice Manuals (BPMs)

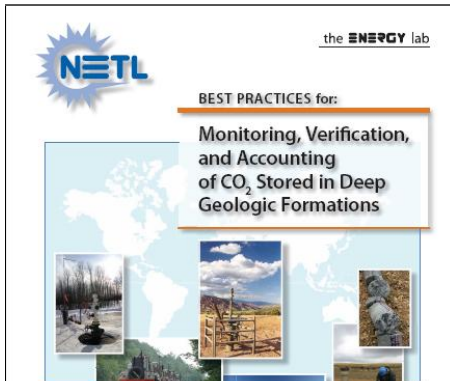
Important Program Outputs

- **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**



CCS Best Practice Manuals

Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned

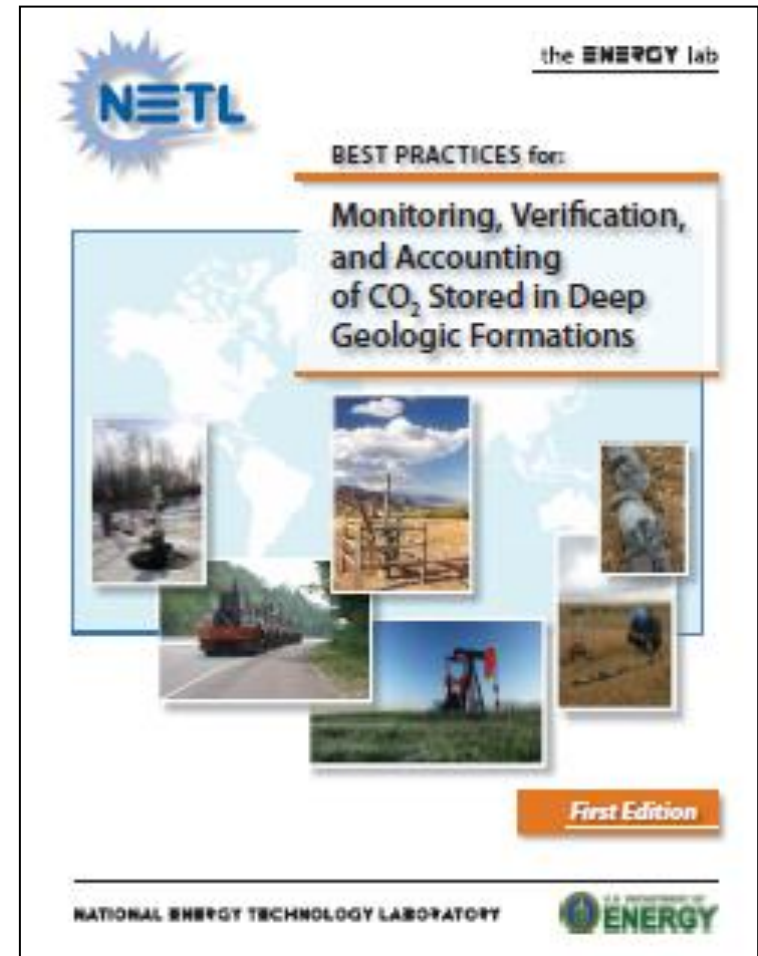


Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting	2009 2012	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation 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*

Monitoring, Verification, and Accounting of CO₂ Stored in Deep Geologic Formations

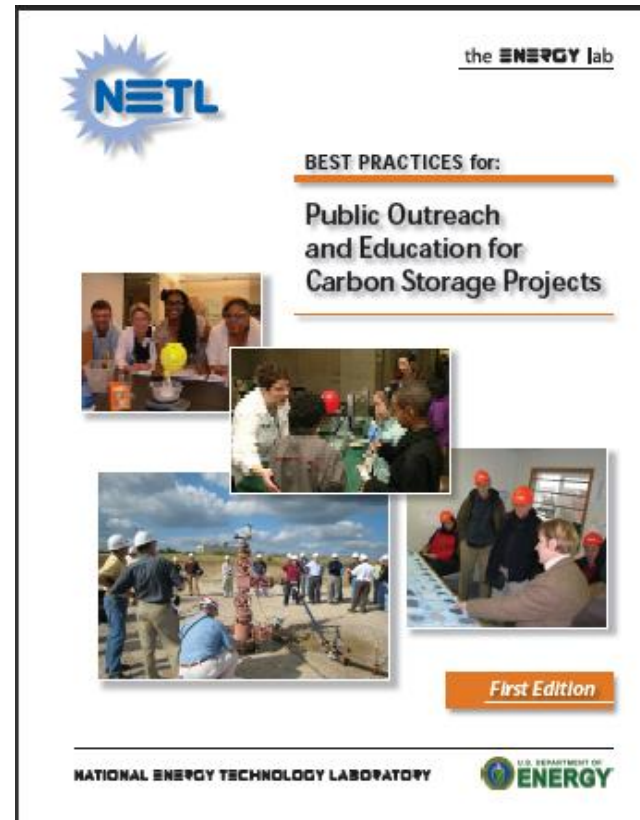
- **Based on DOE Supported and leveraged monitoring activities**
 - RCSP Program
 - Core R&D
 - International Projects
 - Industrial applications
- **Regulatory requirements and associated monitoring needs**
- **35 Technologies divided into:**
 - Primary
 - Secondary
 - Additional
- **To be Updated 2011/2012**



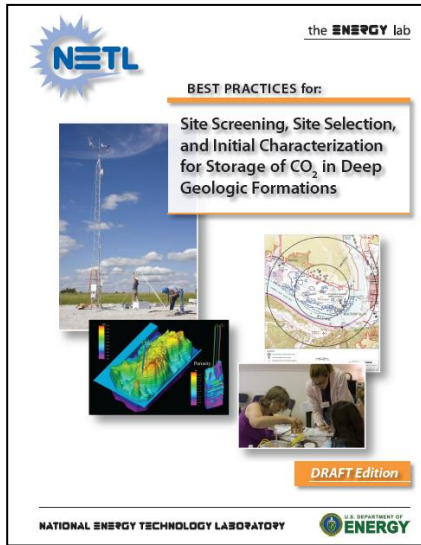
Public Outreach and Education for Carbon Storage Projects

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**



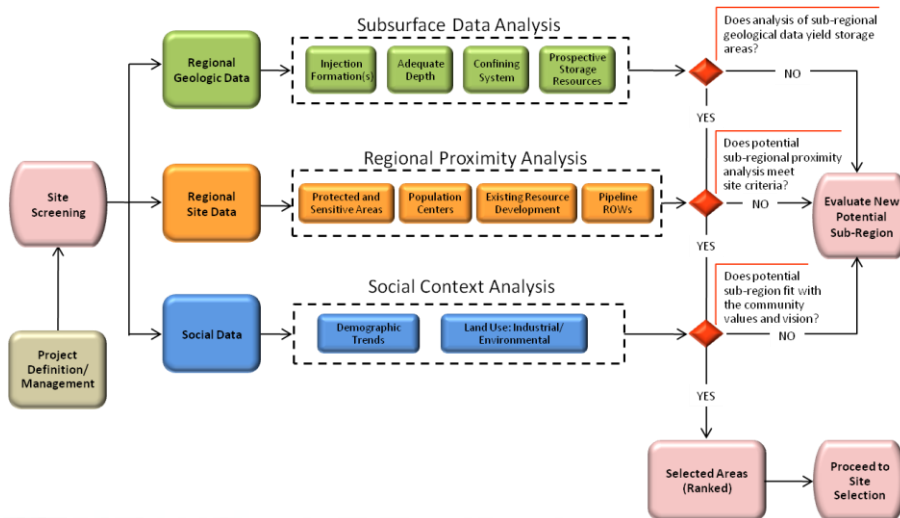
Site Screening, Site Selection, and Initial Characterization



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

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

- Integrating Exploration Phase evaluation processes into one consistent (industry standard) framework, terminology and guidelines for communicating “project” related storage estimates
- Framework integrates processes and lessons learned from RCSP field projects into the Classification
- Provide stakeholders and greater sequestration community process and guidelines for site evaluation



***Adapted from SPE_WPC_AAPG_SPEE*

Geologic Storage Formation Classification

Validating United States Storage Potential Targeting Geologic Reservoir Classes

Matrix of Field Activities in Different Formation Classes

Geologic Formation Classes	High Potential					Medium Potential				Lower or Unknown Potential	
	Deltaic	Shelf Clastic	Shelf Carbonate	Strandplain	Reef	Fluvial Deltaic	Eolian	Fluvial & Aluvial	Turbidite	Coal	Basalt (LIP)
<i>Large Scale</i>	–	1	–	–	1	3	–	1	–	–	–
<i>Small Scale</i>	3	2	4	1	2	–	–	2	–	5	1
<i>Characterization</i>	1	–	8	6	–	3	3	2	2	–	1

Notes:

The number in the cell is the number of investigations per depositional environment.

Large Scale Field Tests – Injection of over 1,000,000 tons of CO₂.

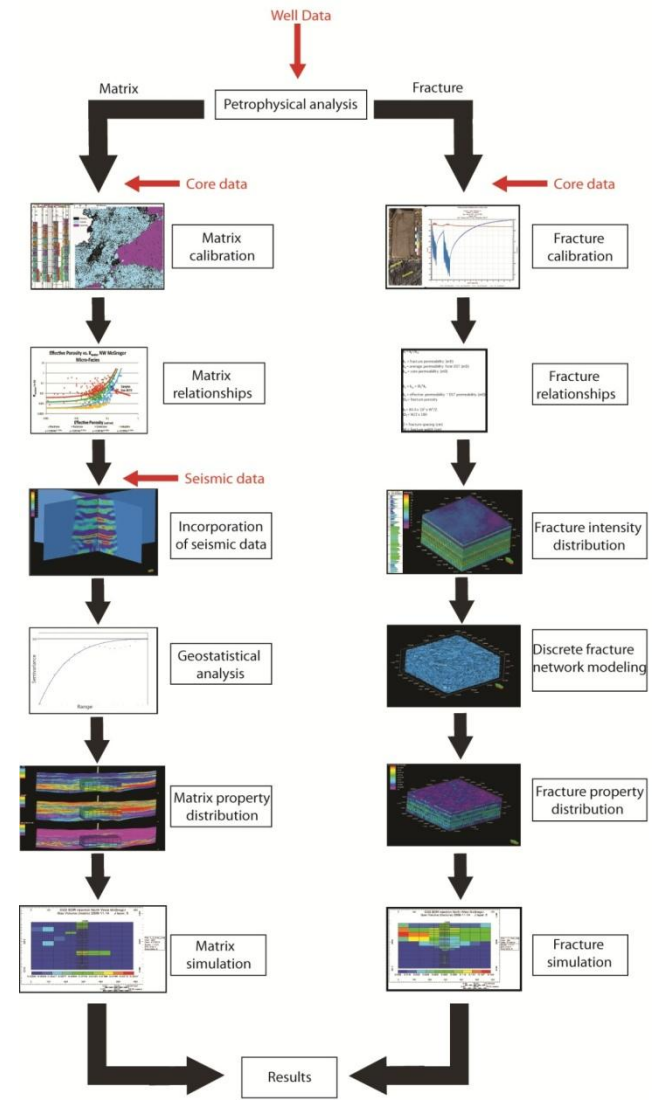
Small Scale Field Tests – Injection of less than 500,000 tons of CO₂.

Site Characterization – Characterize the subsurface at a location with the potential to inject at least 30,000,000 tons of CO₂.

Reservoir potentials were inferred from petroleum industry data and field data from the sequestration program.

Risk Assessment and Simulation

- **Fundamentals of Risk Analysis**
 - Risk Assessment /Management
 - Tools and Modeling Efforts
- **Numerical Simulations**
 - Hydrologic, geomechanical, thermal, geochemical and biological
- **Application of Risk Analysis and Numerical Simulations in the RCSP Initiative**
 - Case histories
- **Inform MVA Plans, validate performance, quantify risks for project management and liability**



Well Construction and Operations (November 2011)

Guidance for Potential Project Developers

Initial Site Screening and Characterization

Refine Detailed Site Development Plan

Site Preparation

Drilling and Construction

Injection Operations

Post-Injection Operations

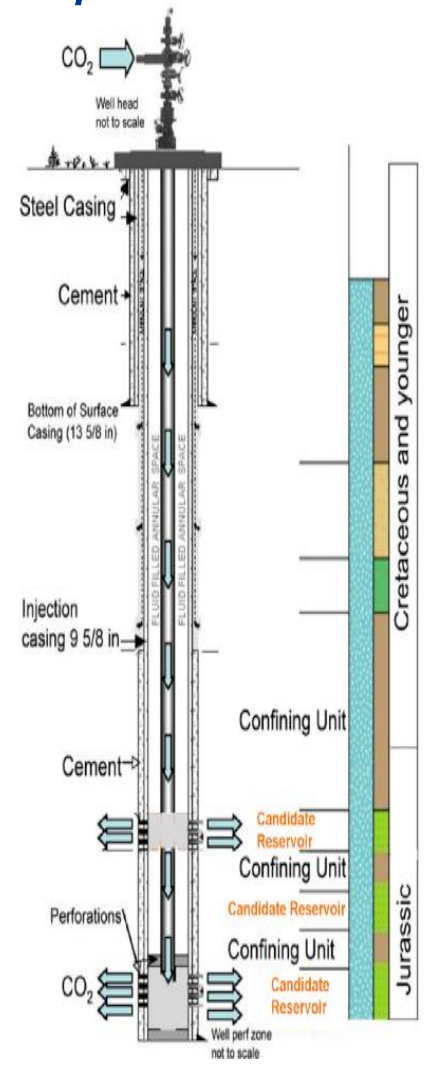
Injection Design
Project Cost Revisions
Permitting

Site Security & Access
Injection Site Layout
Well Pad Preparation

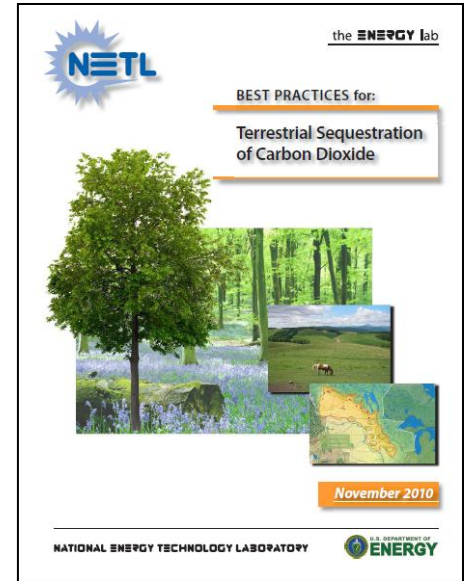
Well Drilling
Logging/Formation Testing
Well Construction/Development
Well Evaluation

Injection System Completion
Pre-Injection Baseline Monitoring
Injection Operations

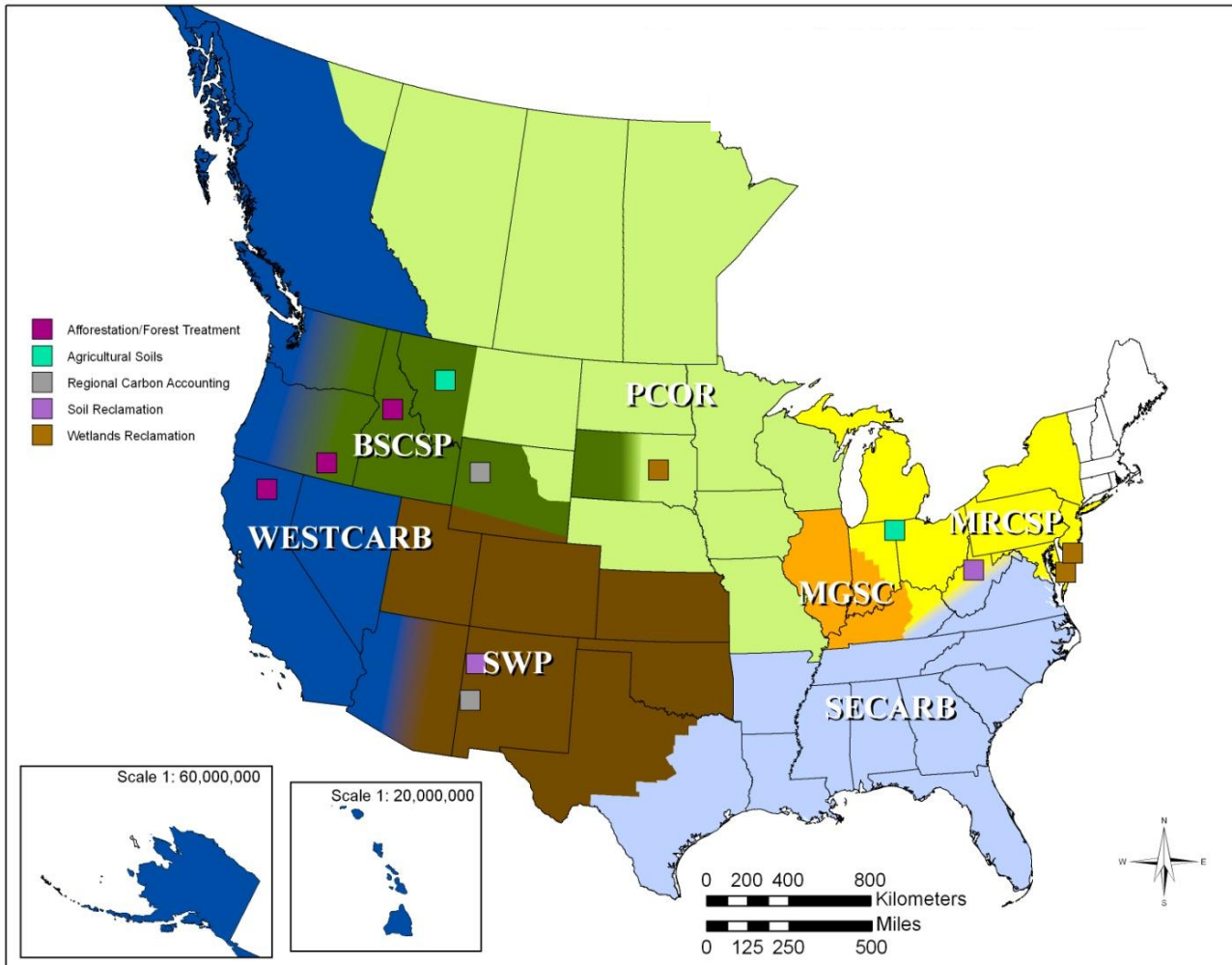
LT MVA
Well P&A
Surface Site Closure



RCSP Validation Phase: Terrestrial Field Tests

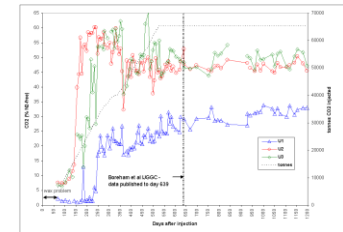
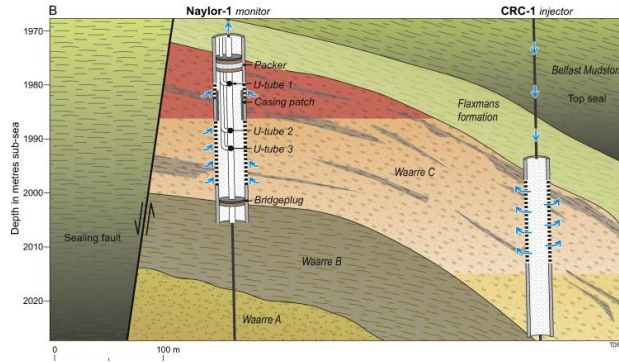
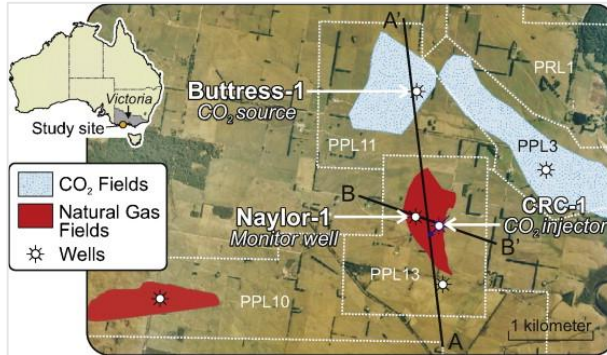


- All field Phase II field tests completed in FY2011
- Best Practices Manual Published FY2011
- Limited Phase III monitoring activities

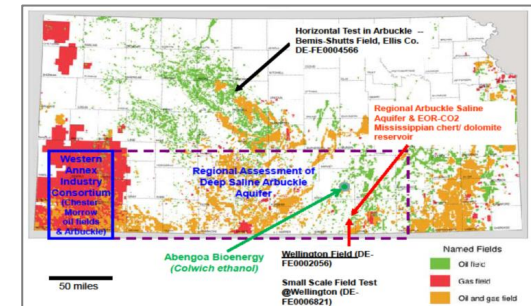
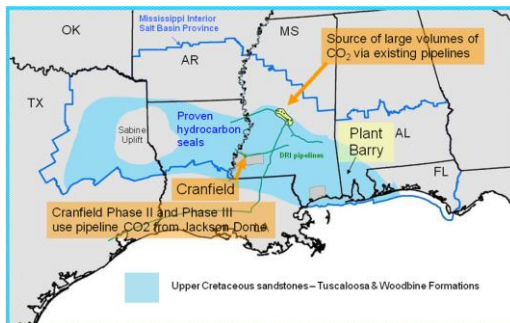


Global Collaboration Technology Transfer

U-Tube Fluid Sampler

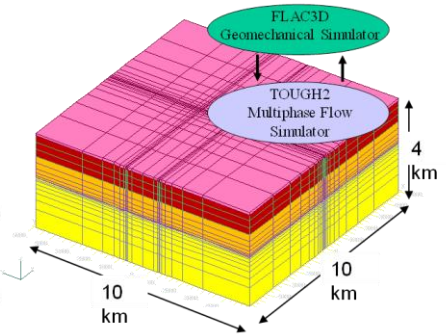
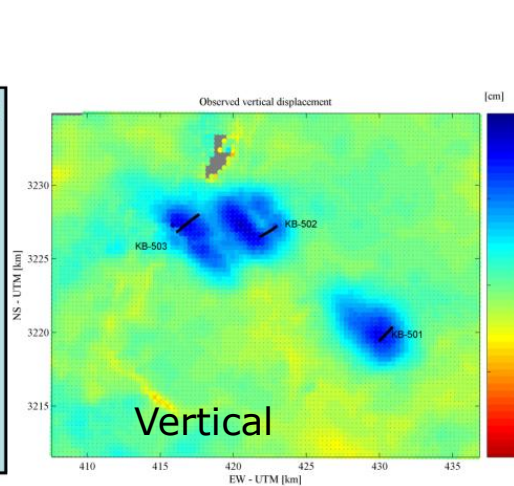
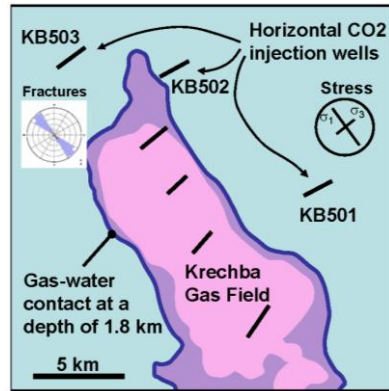
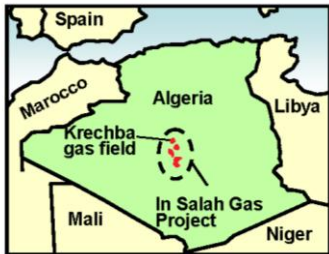


- U-Tube samples fluids in borehole for geochemical monitoring of CO₂ injection
- Deployed by Lawrence Berkeley National Laboratory at Otway
- Technology utilized for monitoring at SECARB's Phase III Cranfield test, Big Sky's Kevin Dome, and Kansas small injection project, Univ. of Kansas Center for Research

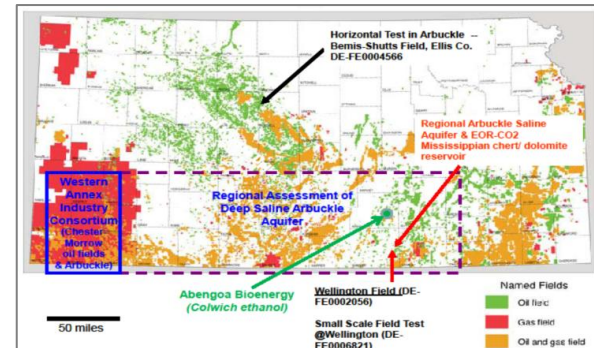


Global Collaboration Technology Transfer

InSAR

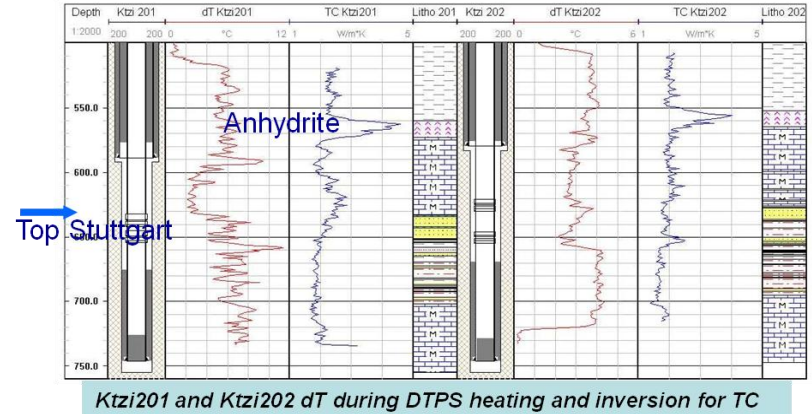
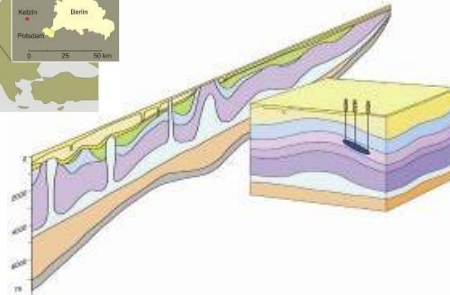
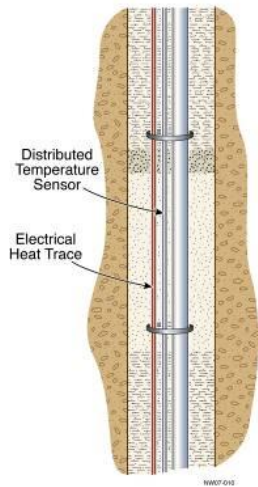


- InSAR satellite imagery and geomechanical modeling to monitor ground displacement
- Evaluated by Lawrence Berkeley and Lawrence Livermore National Labs for In Salah
- Technology utilized for monitoring at MGSC Phase III Decatur site, TRE and Kansas small injection project, Kansas Geological Survey

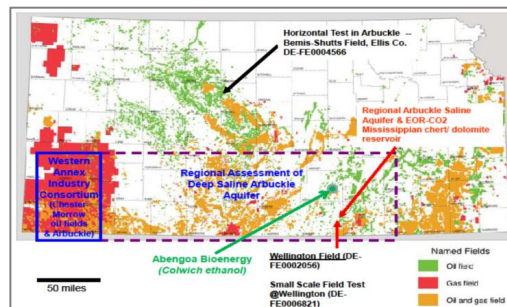
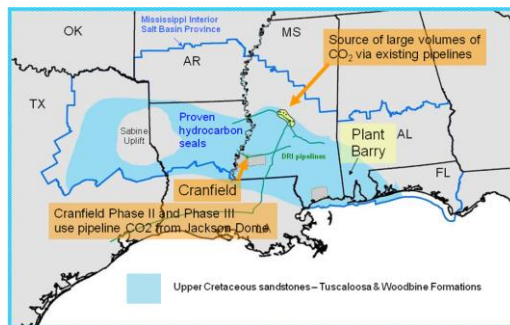


Global Collaboration Technology Transfer

DTPS Sensor

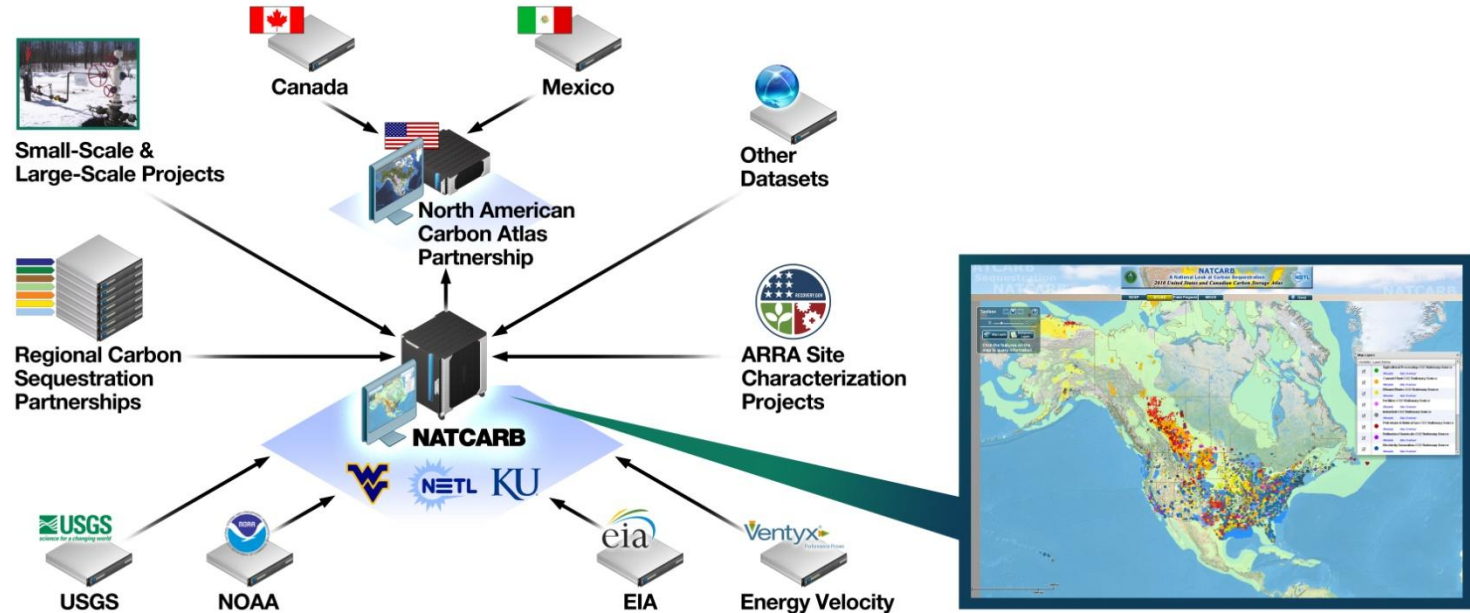


- Distributed Thermal Perturbation Sensor (DTPS) to monitor CO₂ injection
- Deployed by Lawrence Berkeley National Laboratory at CO₂SINK and Otway
- Technology utilized for monitoring at SECARB's Phase III Cranfield and Plant Barry large injection tests, and Kansas small injection project



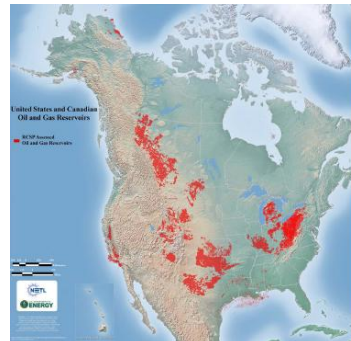
Knowledge Sharing

National Carbon Sequestration Database and Geographic Information System (NATCARB)



Hundreds of Years of Storage Potential

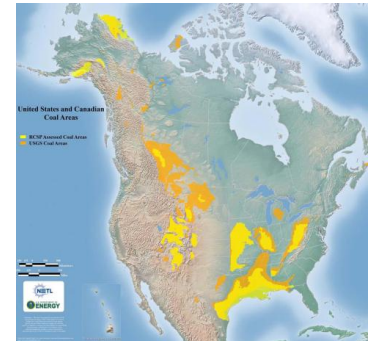
U.S. Emissions ~ 6 GT CO₂/yr (all sources)



Oil and Gas Fields
143 GT CO₂
Storage Resource



Saline Formations
1,653 - 20,213 GT CO₂
Storage Resource



Unmineable Coal Seams
60-117 GT CO₂
Storage Resource

Knowledge Sharing

Disseminating information through the Regional Partnerships



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

