CCS Capacity Building Workshop

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

October 2011
**U.S. DEPARTMENT OF ENERGY • OFFICE OF FOSSIL ENERGY**
**NATIONAL ENERGY TECHNOLOGY LABORATORY**

**CARBON SEQUESTRATION PROGRAM with ARRA Projects**

### Core R&D
2012 Structure
- Geologic Storage
- Monitoring, Verification, and Accounting (MVA)
- Simulation and Risk Assessment
- CO₂ Utilization
- ARRA: University Projects

**Benefits**
- Reduced cost of CCS
- Tool development for risk assessment and mitigation
- Accuracy/monitoring quantified
- CO₂ capacity validation
- Indirect CO₂ storage

### Infrastructure

**Regional Carbon Sequestration Partnerships**
- Characterization
- Validation
- Development

- ARRA: Development of Technology Transfer Centers
- ARRA: Site Characterization

**Other Small and Large-Scale Projects**

**Benefits**
- Human capital
- Stakeholder networking
- Regulatory policy development
- Visualization knowledge center
- Best practices development
- Public outreach and education

### Global Collaborations

**Benefits**
- Knowledge building
- Project development
- Collaborative international knowledge
- Capacity/model validation
- CCS commercial deployment

- 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)
Sequestration Program Total Funding

2011 Program Statistics

Diverse research portfolio

93 Active R&D Projects

60 ARRA Projects (FY10 -$120M )

Strong industry support
~ 39% cost share on projects

FY12 Request for Program Funding does not include Pre-Combustion Capture
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 Kansa, 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
- 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, Paulsson 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
Optimizing Storage through Fluids Management

• Water may be extracted for reservoir management:
  – Avoid impact to other mineral rights
  – Increased storage volume.
  – CO$_2$ distribution and pressure management

• Significant engineering challenges for wide-scale beneficial use
  – Quality; quantity; cost
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

Characterization Phase (2003-2005)
Search of potential storage locations and CO₂ 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
RCSP Phase II: Validation Phase
Small-Scale Geologic Tests

Saline formations
(3,000 to 60,000 tons)

Depleted oil fields
(50 to 500,000 tons)

Coal Seams
(200 – 18,000 tons)

Basalt formation
(1,000 tons)

<table>
<thead>
<tr>
<th>RCSP</th>
<th>Geologic Province</th>
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<tbody>
<tr>
<td>Big Sky</td>
<td>Columbia Basin</td>
</tr>
<tr>
<td>MGSC</td>
<td>Illinois Basin</td>
</tr>
<tr>
<td>MRCSP</td>
<td>Cincinnati Arch, Michigan Basin, Appalachian Basin</td>
</tr>
<tr>
<td>PCOR</td>
<td>Keg River, Duperow, Williston Basin</td>
</tr>
<tr>
<td>SECARB</td>
<td>Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin</td>
</tr>
<tr>
<td>SWP</td>
<td>Paradox Basin, Aneth Field, Permian Basin, San Juan Basin</td>
</tr>
<tr>
<td>WESTCARB</td>
<td>Colorado Plateau</td>
</tr>
</tbody>
</table>
RCSP Phase III: Development Phase
Large-Scale Geologic Tests

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

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

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

Note: Some locations presented on map may differ from final injection location.
## Development Phase

**Scaling Up Towards Commercialization**

|-------------|------|------|------|------|------|------|------|------|------|------|------|

### Stage 1 - Site Operations
- Site selection and characterization;
- Permitting and NEPA compliance;
- Well completion and testing;
- Infrastructure development.

### Stage 2 - Injection Operations
- CO₂ procurement and transportation;
- Injection operations;
- Monitoring activities.

### Stage 3 - Post-Injection Operations
- Site closure;
- Post-injection monitoring;
- Project assessment.

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

Bell Creek Field
- Expected to yield ~35 million incremental bbl
- ~240 Bcf of CO$_2$ sequestered

*Map Legend*
- PCOR Outline
- Pipeline
- International Border
- State/Province Boundaries
- County Boundaries
- Oil Fields

Lost Cabin/Madden Gas Plant  
~50 mmcf CO$_2$/day
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

CO$_2$ Source
• Natural CO$_2$ Source

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 CO₂-EOR.

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

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<tbody>
<tr>
<td>Monitoring, Verification and Accounting</td>
<td>2009 2012</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Public Outreach and Education</td>
<td>2009</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Site Characterization</td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Geologic Storage Formation Classification</td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td><strong>Simulation and Risk Assessment</strong></td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td><strong>Well Construction, Operations and Completion</strong></td>
<td>2011</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>2010</td>
<td>2016 – Post MVA Phase III</td>
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</tbody>
</table>

**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**
**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

<table>
<thead>
<tr>
<th>Geologic Formation Classes</th>
<th>High Potential</th>
<th>Medium Potential</th>
<th>Lower or Unknown Potential</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Deltaic</td>
<td>Shelf Clastic</td>
<td>Shelf Carbonate</td>
</tr>
<tr>
<td>Large Scale</td>
<td>–</td>
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</tr>
<tr>
<td>Small Scale</td>
<td>3</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Characterization</td>
<td>1</td>
<td>–</td>
<td>8</td>
</tr>
</tbody>
</table>

**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 InSalah
- Technology utilized for monitoring at MGSC Phase III Decatur site, TRE and Kansas small injection project, Kansas Geological Survey
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
Hundreds of Years of Storage Potential

U.S. Emissions ~ 6 GT CO\textsubscript{2} yr (all sources)

- **Oil and Gas Fields**: 143 GT CO\textsubscript{2} Storage Resource
- **Saline Formations**: 1,653 - 20,213 GT CO\textsubscript{2} Storage Resource
- **Unmineable Coal Seams**: 60-117 GT CO\textsubscript{2} Storage Resource

Knowledge Sharing
National Carbon Sequestration Database and Geographic Information System (NATCARB)
Knowledge Sharing

Integrating “corporate knowledge” from the Regional Partnerships

ARRA Regional Technology Training

Worldwide CCUS Project Database

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

RCSPs Working Groups

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

Carbon Sequestration Reference Shelf

www.netl.doe.gov
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