Best Practices for CCS
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Sequestration Technology Manager
Sequestration Division Director (Acting)

Presentation Overview

• DOE’s Program Summary (where do BPM’s fit)
• Transferring lessons learned from the field
• Purpose of DOE’s BPM
• DOE’s Best Practice manuals update
• Other DOE Programmatic Documents
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 100s of years of storage

### Validation Phase (2005-2011)

- 20 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

### Development Phase (2008-2018+)

- 9 large scale injections (over 1 million tons each)
- Commercial scale understanding
- Regulatory, liability, ownership issues
Transferring Lessons Learned from the Field

Small-Scale Geologic Field Tests

<table>
<thead>
<tr>
<th>RCSP</th>
<th>Formation Type</th>
<th>Geologic Province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Sky</td>
<td>Saline</td>
<td>Columbia Basin</td>
</tr>
<tr>
<td>MGSC</td>
<td>Oil-bearing</td>
<td>Illinois Basin</td>
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<tr>
<td></td>
<td>Saline</td>
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<tr>
<td></td>
<td>Coal seam</td>
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<tr>
<td></td>
<td>(200 - 1,000 tons)</td>
<td></td>
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<tr>
<td></td>
<td>Basalt formation</td>
<td>(1,000 tons)</td>
</tr>
<tr>
<td>MRCSP</td>
<td>Saline</td>
<td>Cincinnati Arch, Michigan Basin, Appalachian Basin</td>
</tr>
<tr>
<td>PCOR</td>
<td>Oil-bearing</td>
<td>Keg River, Duperow, Williston Basin</td>
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<tr>
<td></td>
<td>Coal seam</td>
<td></td>
</tr>
<tr>
<td>SECARB</td>
<td>Oil-bearing</td>
<td>Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin</td>
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<tr>
<td></td>
<td>Saline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coal seam</td>
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<tr>
<td>SWP</td>
<td>Oil-bearing</td>
<td>Paradox Basin, Aneth Field, Permian Basin, San Juan Basin</td>
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<tr>
<td></td>
<td>Coal seam</td>
<td></td>
</tr>
<tr>
<td>WESTCARB</td>
<td>Saline</td>
<td>Colorado Plateau</td>
</tr>
</tbody>
</table>

Saline formations
(3,000 to 60,000 tons)
Depleted oil fields
(50 to 500,000 tons)
Coal Seams
(200 - 1,000 tons)
Basalt formation
(1,000 tons)

Completed 17 Injections
Over 1.35 M Tons injected

Project moved to Phase III
(Injection 2010/2011)
Terrestrial Sequestration Field Tests

- Tree-plantings
- No-till farming
- Wetlands restoration
- Land management: grasslands, grazing lands
- Fire management
- Forest preservation
- Monitoring, verification, and accounting (MVA) technologies

Terrestrial Project Categorization

- Agricultural soils
- Soil Reclamation
- Afforestation
- Accounting/Aggregation
- Wetlands Reclamation

RCSP Phase III: Development Phase

Major Milestone - Large-Volume Geologic Field Tests

- Nine large-volume tests
- One Injection initiated 2009

Over 1,000,000 Tons injected at SECARB site
**DOE’s Best Practice manuals update**

**Best Practice Manuals**

**Communicating Lessons Learned**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Monitoring, Verification and Accounting</td>
<td>2009</td>
<td>2017</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><strong>Simulation and Risk Assessment</strong></td>
<td>2010</td>
<td>2017</td>
<td>2020</td>
</tr>
<tr>
<td><strong>Well Construction, Operations and Completion</strong></td>
<td>2010</td>
<td>2017</td>
<td>2020</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>2010</td>
<td><strong>2016 – Post MVA Phase III</strong></td>
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</tbody>
</table>
Best Practice Manuals (BPMs) are Important Program Outputs

- BPMs demonstrate to the public, regulators and policymakers that geologic storage is a safe effective GHG control technology.
- BPMs provide technical 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.

Monitoring, Verification, and Accounting of CO₂ Stored in Deep Geologic Formations (Jan 2009)

- 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
Public Outreach is Key for Project Success (Jan 2010)

- Focused on project developers
- 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 (June 2010)

- 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**
Risk Assessment and Simulation (Dec 2010)

- Fundamentals of risk assessment
  - CCS risks
  - Tools and approaches
- Simulation of subsurface processes
  - Hydrologic, geomechanical, thermal, geochemical and biological
- RCSP experience in application of risk assessment and simulation
  - Case histories
- Inform MVA Plans, validate performance, quantify risks for project management and liability

Well Construction and Operations (Dec 2010)

Guidance for Potential Project Developers

- Project Planning Activities
  - Financial Planning
  - Continue Public Outreach
  - Project Review
  - Access Issues
  - Project Design
  - Project Plans
  - Permit Requirements
  - Siting and Permits
- Site Preparation
  - Site Security
  - Site Access
  - Facility Layout
  - Well Locations
  - Well Pad Preparation
  - Piping
- Drilling and Completion Operations
  - Well Drilling
  - Well Construction
  - Well Development/Stimulation
  - Evaluation and Testing
  - Pre-Injection Baseline Monitoring
- Injection Operations
  - Review of Drilling Results
  - Justification for Additional Wells
  - Equipment
  - Injection Process
  - Mitigation Activities
  - Produced Water
- Post Injection Operations
  - Long Term MVA
  - Plugging and Abandonment
  - Site Closure
Terrestrial Sequestration is the storage of CO₂ in soils and plants.

Research focused on improving management practices resulting in an increase in the amount of CO₂ that can be stored in soils and plants.

Best Practice Manual

Purpose:
To provide information for those considering terrestrial sequestration projects and those considering regulations/legislation governing carbon emissions caps.

Topics covered include:
- Land types and management methods that can maximize carbon storage in vegetation and soil.
- Analytical techniques necessary for management verifications of terrestrially stored carbon.
- Status of GHG trading and the institutions involved.
- Case studies of the RCSPs terrestrial field trials.

Geologic Reservoir Classes for CO₂ Storage
Depositional Environment Affects CO₂ Behavior in Reservoirs

- **Architectural** framework created during deposition affects the behavior of CO₂ in a reservoir
  - Flow
  - Chemical reactions
  - Pressure
  - Injectivity
  - Containment
  - Efficiency

- **CO₂ Storage Classification System** focuses future R&D field test efforts

Reservoir Depositional Classification Schematic
### Field Testing CO₂ Storage Classes

<table>
<thead>
<tr>
<th>Matrix of Field Activities in Different Reservoir Classes</th>
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<tbody>
<tr>
<td><strong>Large Scale Field Tests</strong></td>
</tr>
<tr>
<td>High Potential Reservoirs</td>
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<tr>
<td>Medium Potential Reservoirs</td>
</tr>
<tr>
<td>Lower or Unknown Potential Reservoirs</td>
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<tr>
<td>- 1 - 1 - 3 - 1 - 1 - 1 - - - -</td>
</tr>
<tr>
<td><strong>Small Scale Field Tests</strong></td>
</tr>
<tr>
<td>3 2 4 1 2 - - 2 - 5 1</td>
</tr>
<tr>
<td><strong>Site Characterization</strong></td>
</tr>
<tr>
<td>1 - 8 6 - 3 3 2 2 - - - -</td>
</tr>
</tbody>
</table>

### DOE/NETL Advanced CO₂ Capture R&D Program: Technology Update (September 2010)

- This comprehensive handbook provides an update on DOE/NETL R&D efforts on advanced CO₂ capture technologies for coal-based power systems.
- Prepared by the Existing Plants and Sequestration R&D Programs, the report tracks the progress of DOE/NETL pre-combustion, post-combustion, and oxy-combustion technologies for CO₂ capture.
- The handbook is available for download on the NETL website at these two locations:

DOE/NETL Advanced CO₂ Capture R&D Program: Technology Update (September 2010)

- Chapter 1: Introduction stressing the importance of developing cost-effective advanced CO₂ capture technologies.
- Chapter 2: Description of DOE/NETL’s CO₂ capture R&D program.
- Chapter 3: Overview of the three basic configurations for CO₂ capture – pre-combustion, post-combustion, and oxy-combustion.
- Chapter 4: Provides some of the basic scientific principles and important operating parameters for the various CO₂ capture technologies.
- Chapters 5 through 10 report on the status of DOE/NETL’s R&D efforts for pre-combustion capture; post-combustion capture; oxy-combustion; oxygen production; chemical looping; and advanced compression, respectively.
- Chapter 11: Review of DOE/NETL’s CO₂ capture R&D collaborations.

Appendix: Provides detailed information on the status and results of the current portfolio of DOE/NETL’s CO₂ capture R&D projects.
FY 2011 Programmatic Documents

- Carbon Sequestration Atlas of the United States and Canada
- DOE CCS Roadmap
- Carbon Sequestration R&D Program Plan
- Carbon Sequestration Project Portfolio updates – 50+ new projects

For More Information About the NETL Sequestration Program

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

Reference Shelf
- Annual Regional Carbon Sequestration Partnerships Meetings

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