Update on Status and Progress in the DOE CCS Program

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U.S. Department of Energy
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U.S. DOE CCS RD&D Program Portfolio

Core R&D
- Post-Combustion Capture
- Pre-Combustion Capture
- Oxycombustion Capture and Chemical Looping
- Geologic Storage Technologies
- Monitoring, Verification and Accounting (MVA)
- Simulation and Risk Assessment
- CO₂ Use/Reuse

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

Technology Solutions

Pilot Tests and Storage Infrastructure
- Capture Technology Pilot Tests
  - National Carbon Capture Center
- Small-Pilot Tests (~ 1 MW)
- Large Pilot Tests (10+ MW)

Regional Carbon Sequestration Partnerships
- Characterization
- Validation
- Development

Benefits
- Validate and test 2nd gen and transformational capture tech.
- Human capital
- Stakeholder networking
- Regulatory policy development
- Visualization knowledge center
- Best practices development
- Public outreach and education

Lessons Learned

Demo Projects and Global Collaboration
- Domestic Demo Projects
  - Clean Coal Power Initiative
  - Industrial CCS Projects
  - FutureGen 2.0
- International Demonstration Projects
  - Canada (Weyburn, Zama, Ft. Nelson)
  - Norway (Sleipner and Snovhit)
  - Germany (CO2Sink)
  - Australia (Otway)
  - Africa (In-Salah)
  - Asia (Ordos Basin)

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

Lessons Learned

Goals: Develop robust technologies to reduce capture and storage cost, and conduct field tests to validate long-term, safe storage
CO₂ Capture
Requires Multiple Technologies and Multiple Scientific and Engineering Disciplines

This is the primary pathway to steep cost reductions
DOE CCUS Demonstration Projects

Focus – Large-scale commercial demonstration of CCUS integrated with coal power generation and industrial sources.
## Major Demonstration Projects

<table>
<thead>
<tr>
<th>Recipient</th>
<th>Project</th>
<th>Location</th>
<th>DOE Funding</th>
<th>Status</th>
<th>Storage Type</th>
<th>CO₂ Seq. (Metric Tons Per Year)</th>
<th>Storage Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Products</td>
<td>Steam Methane Reformer Hydrogen Production</td>
<td>Port Arthur, TX</td>
<td>$284M</td>
<td>Operations</td>
<td>EOR</td>
<td>~925,000</td>
<td>2013</td>
</tr>
<tr>
<td>Southern Company Services (Kemper)</td>
<td>Integrated Gasification Combined Cycle (IGCC)</td>
<td>Kemper County, MS</td>
<td>$270M</td>
<td>Under Construction</td>
<td>EOR</td>
<td>~3,000,000</td>
<td>2014</td>
</tr>
<tr>
<td>Archer Daniels Midland</td>
<td>Ethanol Fermentation CO₂</td>
<td>Decatur, IL</td>
<td>$141M</td>
<td>Under Construction</td>
<td>Saline</td>
<td>~900,000</td>
<td>2014</td>
</tr>
<tr>
<td>NRG Energy (Petra Nova) WA Parish</td>
<td>Retrofit Pulverized Coal plant</td>
<td>Thompson, TX</td>
<td>$167M</td>
<td>Financing</td>
<td>EOR</td>
<td>1,400,000</td>
<td>2016</td>
</tr>
<tr>
<td>Summit Texas Clean Energy Project</td>
<td>Integrated Gasification Combined Cycle Polygeneration</td>
<td>Penwell, TX</td>
<td>$450M</td>
<td>Financing</td>
<td>EOR</td>
<td>2,200,000</td>
<td>2017</td>
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<tr>
<td>Leucadia Energy, LLC</td>
<td>Methanol from Petcoke Gasification</td>
<td>Lake Charles, LA</td>
<td>$261M</td>
<td>Front End Engineering &amp; Design</td>
<td>EOR</td>
<td>~4,500,000</td>
<td>2017</td>
</tr>
<tr>
<td>FutureGen 2.0</td>
<td>Oxycombustion Pulverized Coal Boiler Retrofit</td>
<td>Meredosia, IL / Morgan County, IL</td>
<td>$1B</td>
<td>Front End Engineering &amp; Design</td>
<td>Saline</td>
<td>1,000,000</td>
<td>2017 (est.)</td>
</tr>
<tr>
<td>Hydrogen Energy California (HECA)</td>
<td>Integrated Gasification Combined Cycle Polygeneration</td>
<td>Kern County, CA</td>
<td>$408M</td>
<td>Front End Engineering &amp; Design</td>
<td>EOR</td>
<td>2,570,000</td>
<td>2019 (est.)</td>
</tr>
</tbody>
</table>
Regional Carbon Sequestration Partnerships (RCSPs)

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

Development Phase (2008-2018+)
8 large scale injections (over 1 million tons each)
Commercial scale understanding
Regulatory, liability, ownership issues
Small-Scale Geologic Field Tests (Completed)

Saline Formations
(3,000 to 60,000 metric tons)
Oil and Natural Gas Reservoirs
(50 to 500,000 metric tons)
Unmineable Coal
(200 to 18,000 metric tons)
Basalt Formations
(1,000 metric tons)

Completed 19 Injections
Over 1.2 MMT Injected
### 2011: RCSPs Large-Volume Field Projects

**Validating Technologies and Methods**

<table>
<thead>
<tr>
<th>RCSP</th>
<th>Geologic Province</th>
<th>Injection Volume (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Big Sky – Moxa Arch-Nugget Sandstone</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>MGSC – Illinois Basin-Mt. Simon Sandstone</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>MRCSP – Michigan Basin-St. Peter Sandstone</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>PCOR - Powder River Basin-Bell Creek Field</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>PCOR – Horn River Basin-Carbonates</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>SECARB – Gulf Coast – Cranfield Field-Tuscaloosa Formation</td>
<td>~1,500,000</td>
</tr>
<tr>
<td>7</td>
<td>SECARB – Gulf Coast – Paluxy Formation</td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>SWP – Regional Jurassic &amp; Older Formations</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>WESTCARB – Central Valley</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Map Key:***
- Injection Ongoing
- Injection Scheduled 2011-2015

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

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**Table Key:**
- Core Sampling Taken
- Injection Drilled
- Injection Started
- Core Sampling Taken
### 2014: RCSRs Large-Volume Field Projects

**Validating Technologies and Methods**

<table>
<thead>
<tr>
<th>RCSR</th>
<th>Geologic Province</th>
<th>Injected Volume (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Big Sky - Kevin Dome-Duperow Formation</td>
<td>TBD</td>
</tr>
<tr>
<td>2</td>
<td>MGSC - Illinois Basin-Mt. Simon Sandstone</td>
<td>&gt;704,000</td>
</tr>
<tr>
<td>3</td>
<td>MRCSP - Michigan Basin-Niagara Reef</td>
<td>&gt;408,000</td>
</tr>
<tr>
<td>4</td>
<td>PCOR - Powder River Basin-Muddy Sandstone</td>
<td>&gt;240,000</td>
</tr>
<tr>
<td>5</td>
<td>PCOR - Horn River Basin-Carbonates</td>
<td>TBD</td>
</tr>
<tr>
<td>6</td>
<td>SECARB - Gulf Coast - Tuscaloosa Formation</td>
<td>&gt;3,500,000</td>
</tr>
<tr>
<td>7</td>
<td>SECARB - Gulf Coast – Paluxy Formation</td>
<td>&gt;100,000</td>
</tr>
<tr>
<td>8</td>
<td>SWP - Anadarko Basin-Morrow Sandstone</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>WESTCARB - Regional Characterization</td>
<td></td>
</tr>
</tbody>
</table>

Note: Some locations presented on map may differ from final injection location.
Southeast Regional Carbon Sequestration Partnership

Cranfield Field Project

- First large scale storage project
- In collaboration with Denbury Resources
- Over 3.5 MMT injected for storage

- Extensive MVA plan to account for stored CO\textsubscript{2} in the injection zone:
  - 4-D geophysics (ERT, VSP)
  - Geochemical (U-tube technology)
  - Field pressure monitoring
  - Distributed temperature
  - Wireline logging
Southeast Regional Carbon Sequestration Partnership
Citronelle-Plant Barry Field Project

- Largest fully integrated capture (25MW) and storage project in the U.S.—MHI KS-1 amine process
- Southern Company’s Plant Barry Power Station
- UIC Class V permit with Class VI requirements
- Projected CO₂ Injection Amount~250,000 MT
- CO₂ injection started August 20, 2012. >100,000 MT injected to date
Midwest Geological Sequestration Consortium
Illinois Basin – Decatur Field Project

- First large scale (1MMT) saline test on land from ethanol fermentation facility
- Dehydrated and compressed to 1500 PSI
- Injecting 1,000 MT per day since Nov 2011
- Over 700,000 MT injected as of January 2014
- Geology
  - Storage Formation: Mount Simon Sandstone
  - Seal: 500 feet of Eau Claire Shale
  - Designed to meet UIC Class VI requirements
• Niagaran Reefs (Northern Michigan) closely-spaced, highly compartmentalized
• Core Energy – NG Processing Plant
  – Antrim Shale Gas ~ 15% CO₂
• CO₂ Injection 1 MMT over 4 years, in 3 categories of reefs
  – Active Reefs – February 2013
  – Depleted Reef (Dover 33) – April 2013
  – New Production Reefs – Fall 2014
• Over 400,000 metric tons injected to date
Plains CO₂ Reduction Partnership
Bell Creek Field Project

- Injection of 1 MMT of CO₂ commenced in June 2013

- Extensive MVA plan to account for stored CO₂ in the injection zone:
  - Based in Site Characterization, Modeling, and Risk Assessment
  - Surface, near-surface and subsurface monitoring

- Goals of Extensive MVA program:
  - Verify site security and identify any potential fluid migration pathways
  - Track CO₂ plume movement to determine ultimate fate of CO₂
  - Evaluate efficiency of CO₂ Storage in an active EOR field.
Southwest Regional Partnership
Farnsworth Unit Field Project

- Project is being conducted in conjunction with an active EOR field that began in 2010 and will expand until 2015

- Two anthropogenic sources will be used—Agrium (Fertilizer Plant-Borger, TX) and Arkalon (Ethanol Plant-Liberal, KS)

- Extensive monitoring of injected 1 MMT into the Morrow Sandstone over five years begun late 2013

- Project completed initial 3D seismic survey in early February 2013
ARRA Site Characterization Projects

- University of Wyoming; Rock Springs Uplift / Moxa Arch; SW Wyoming; Saline
- University of Utah; Cretaceous, Jurassic, and Pennsylvanian Sandstone; Colorado and Utah; Saline
- Terralog Technologies USA Inc.; Wilmington Graben; Offshore Los Angeles; Saline, Oil, & Gas
- University of Illinois; Cambro-Ordovician Strata; IL, IN, KY, MI; Saline
- University of Kansas Center for Research Inc.; Ozark Plateau; SW Kansas; Saline and Oil
- University of South Carolina Research Foundation; South Georgia Rift Basin; South Carolina; Saline
- University of Texas at Austin; Gulf of Mexico Miocene; Offshore Texas; Saline
- Sandia Technologies, LLC; Triassic Newark Basin; NY and NJ; Saline
- University of Alabama; Black Warrior Basin; NW Alabama; Saline
Leveraging DOE’s competency in science-based prediction for engineered–natural systems to build confidence in the business case for CO₂ storage.

Building toolsets and the calibration & validation data to quantify …

- Potential impacts related to release of CO₂ or brine from the storage reservoir
  - Potential geomechanical impacts due to injection of CO₂
Knowledge Sharing Products

North American Carbon Atlas and NATCARB

Oil and Gas Fields
226 billion MT CO₂
Storage Resource

ARRA Regional Technology Training

Best Practices Manuals

RCSPs Working Groups
- Geological and Infrastructure
- Monitoring, Verification, Accounting
- Simulation and Risk Assessment
- Capture and Transportation
- GIS and Database
- Water
- Public Outreach and Education
Key Takeaways

• Barriers to CCS exist, but can be addressed

• DOE has taken leadership role in helping address the key issues of:
  – Cost of capture and energy penalty
  – Storage capacity and permanence
  – Infrastructure development
  – Data and knowledge sharing

• Large-scale injection projects will help validate and provide confidence

• International partnerships are important in leveraging experience, expertise, and knowledge
Thank You!

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