Southeast Regional Carbon Sequestration Partnership: Regional Sequestration Capacity

Presented by:

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Gulf Coast Carbon Center (GCCC)

Sponsors

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Entergy
Schlumberger
PRAXAIR
Marathon Oil Corporation
Chevron
Kinder Morgan
NRG

The University of Texas at Austin
John A. & Katherine G. Jackson School of Geosciences
THE US IS THE SAUDI ARABIA OF COAL

What are the Implications for the Oil Industry

• High oil prices and National Security will drive gasification of coal and production of synthetic diesel for DOD

• Environmental NGO’s driving power companies to decarbonize fuel…. CO₂ sequestration

• Cheap CO₂ available for EOR
Denbury EOR

Existing Denbury pipelines

Planned Denbury pipelines

Denbury Sources

- Jackson Dome - Earliest source of CO₂
- Cranfield earliest large volume saline injection

Selecting the early large volume storage site in the SECARB region
Saline Aquifers - Deep Portions of Geologic Units with High TDS Water

Sink requirements:

1. Dense CO₂ (Deeper than 800m (2600 ft) under normal T & P gradient.
2. Porous and permeable unit of known geometry.
3. Integrity of overlying seal.
4. Below underground sources of drinking water (USDW), water greater than 10,000 mg/L total dissolved solids (TDS).
Optimizing CO$_2$ Storage

![Graph showing CO$_2$ bulk volume residual (kgm/m$^3$) vs. Depth (ft)].

- Maximum storage capacity

The graph illustrates the relationship between CO$_2$ bulk volume residual and depth, highlighting the maximum storage capacity at a certain depth.
Schematic Cross Section Appalachian Plateau to Coastal Plain

Figure 6. The Paleozoic rocks range from flatlying to intensely folded. They are separated from crystalline rocks of the Piedmont and Blue Ridge physiographic provinces by faults. The Coastal Plain strata that overlie older rocks are nearly flat.

Deep River Basin in North Carolina

Source: Luongo (1987) Va. Tech Thesis, Figure 17 – interpretation based on seismic data

Source: Thayer (2006)

EXPOSED TRIASSIC BASINS
LOW POTENTIAL

Source: Luongo (1987) Va. Tech Thesis, Figure 17 – interpretation based on seismic data
Potential Geologic (Saline Reservoir) Sinks for CO$_2$ Generated in the Carolinas

<table>
<thead>
<tr>
<th>POTENTIAL SINK</th>
<th>CAPACITY (Gt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Georgia Basin</td>
<td>~15</td>
</tr>
<tr>
<td>Offshore Subseafloor</td>
<td>~193</td>
</tr>
<tr>
<td>Mt. Simon Formation</td>
<td>~3</td>
</tr>
<tr>
<td>Knox Dolomite</td>
<td>~32</td>
</tr>
<tr>
<td>Florida Tuscaloosa</td>
<td>~10</td>
</tr>
</tbody>
</table>

Source: MIT (2006)
Seismic Line Offshore Cape Fear, NC

Modified from Grow et al. (1988); Hutchinson et al. (1982); and Hutchinson et al. (1997)
CO₂ Storage - SE Atlantic Coast

Appalachian Plateau  
HIGH POTENTIAL

Valley and Ridge  
LOW POTENTIAL

Blue Ridge  
LOW POTENTIAL

Piedmont  
LOW POTENTIAL

Exposed Rift Basins  
LOW POTENTIAL

Coastal Plain  
HIGH POTENTIAL

Offshore Subseafloor  
HIGH POTENTIAL

Modified from Fenneman and Johnson (1946); NOAA (2006); Scripps (2006); and Olsen et al. (1991).
Regional Opportunities for Deep Saline Storage

- Gulf wedge is the most significant sequestration target in the Southeast.
  200 billion tons plus
- Other sequestration targets in the Southeast lack seals and storage volume.
The Lower Tuscaloosa Massive Sand Unit and Mississippi Test Site Locations
CO₂-EOR Candidate Reservoirs
- Key Element in the Gulf Coast
Explanation

Texas coallignite mines
2004 production
- 0 - 2 Million
- 2 - 4 Million
- 4 - 9 Million

EOR target 30 miles from lignite mines
EOR_MSTB
- 0 - 6211
- 6212 - 34729
- 34730 - 68652
- 68653 - 322532

- CC2 EOR candidate reservoir
- Texas railroads
- 30 mile buffer - coal/lignite mines
- US coal
- County boundary
- State boundary

0  75  150  300 mi
N
Looking at Miscible EOR from a Production Standpoint

New Miscible CO2 EOR Potential

- Alabama: 98
- Mississippi: 89
- Louisiana: 1,500
- Texas Gulf Coast: 3,027
- Total: 4,714

Mark Holtz, GCCC
Converting CO$_2$-EOR to Storage

- Permanently store CO$_2$ in reservoir after EOR has been completed
- Reservoir characterization and simulation for long-term storage
- Long-term measurement, monitoring, and verification (MMV) systems.
Storage Capacity associated with CO₂ EOR

New CO₂ Storage Capacity

- Mississippi: 87 Million Metric Tons
- Alabama: 115 Million Metric Tons
- Louisiana: 1,114 Million Metric Tons
- Texas Gulf Coast: 1,362 Million Metric Tons
- Total: 2,679 Million Metric Tons
CO₂ EOR Is not “The Answer” …

• Volume of CO₂ that could be sold for EOR is large but inadequate to solve the GHG issue (1 to 2 billion tons of storage)

• CO₂ EOR is useful only in areas oil production, and is most useful only in certain reservoirs with lighter oil, moderate depth, unitized, with reasonable sweep efficiency.
...but CO$_2$ EOR is a great beginning

• Economic or near economic in current market, depending on cost of CO$_2$
• Acceptable to public
• Other major benefits (domestic energy production, taxes, employment)
• Build infrastructure that can be used long term for large volume CO$_2$ disposal = stacked storage
SECARB Phase II Geographic Region & Field Test Site Locations

- **Coal Seam Project**
  - Site selection pending
  - Near Tuscaloosa, Alabama

- **Stacked Storage Project**
  - Cranfield Test Site
  - Southwest Mississippi

- **Mississippi Test Site**
  - Mississippi Power’s Plant Daniel
  - Near Escatawpa, Mississippi
Saline Reservoir Units and Seals (Southeast Mississippi)

**Potential CO₂ Storage Units:**
- Lower Tuscaloosa Massive Sand Unit (U. Cretaceous)
- Dantzler (Washita-Fredricksburg) Formation (L. Cretaceous)

**Confining Units (Seals):**
- Midway Shale
- Selma Chalk/Navarro Fm.
- Austin Formation (Fm.)
- Marine Tuscaloosa

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Sub-Units</th>
<th>Hydrology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronelle Fm.</td>
<td></td>
<td>Freshwater Aquifers</td>
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<tr>
<td>Graham Ferry Fm.</td>
<td></td>
<td>Freshwater Aquifers</td>
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<tr>
<td>Pascagoula Fm.</td>
<td>Hattiesburg Fm.</td>
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<tr>
<td>Catahoula Fm.</td>
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<tr>
<td>Vicksburg</td>
<td>Red Bluff Fm.</td>
<td>Saline Reservoir</td>
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<td>Jackson</td>
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<td>Minor Reservoir</td>
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<td>Claiborne</td>
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<td>Saline Reservoir</td>
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<tr>
<td>Wilcox</td>
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<tr>
<td>Midway Shale</td>
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<td>Saline Reservoir</td>
</tr>
<tr>
<td>Navarro Fm.</td>
<td>Taylor Fm.</td>
<td>Saline Reservoir</td>
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<tr>
<td>Austin Fm.</td>
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<td>Confining unit</td>
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<tr>
<td>Eagle Ford Fm.</td>
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<td>Confining unit</td>
</tr>
<tr>
<td>Upper Tuscaloosa</td>
<td>Interbeds Massive Sand</td>
<td>Minor Reservoir</td>
</tr>
<tr>
<td>Lower Tuscaloosa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washita – Fredricksburg</td>
<td>Dantzler Fm.</td>
<td>Saline Reservoir</td>
</tr>
<tr>
<td>“Limestone Unit”</td>
<td></td>
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</tbody>
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Coal Seam Sequestration Opportunities

Field Test 2.0: Kentucky, Virginia and West Virginia

COAL RANK
- Medium volatile bituminous
- Low volatile bituminous
- High volatile bituminous
- Coalbed methane well

SECARB

FT2a
Coal Seam Sequestration Opportunities

Field Test 2.0: Black Warrior Basin, Alabama
LEARNING BY DOING

- **MMV** (Monitoring, Mitigation, Verification)
- Economic Modeling
- Permitting
- Liability, Ownership Issues
Aims of MMV

- Protect **public health and safety**
- Confirmation of the **integrity of engineered saline reservoirs**
- Providing **verification of long term storage volumes** for CO2 credits
- Provide direct tangible evidence for predicting the long term risk of leakage
- Ensure **public acceptance**
Monitoring Zones

- **Atmosphere**
  - Ultimate receptor but dynamic

- **Biosphere**
  - Assurance of no damage but dynamic

- **Soil and Vadose Zone**
  - Integrator but dynamic

- **Aquifer and USDW**
  - Integrator, slightly isolated from ecological effects

- **Above injection monitoring zone**
  - First indicator, monitor small signals, stable.

- **In injection zone - plume**
  - Oil-field type technologies. Will not identify small leaks

- **In injection zone - outside plume**
  - Assure lateral migration of CO\textsubscript{2} and brine is acceptable-far field pressure
MEASUREMENT MONITORING AND VERIFICATION at the Bureau of Economic Geology’s FRI O Pilot Injection Site

Research Funded by DOE NETL and Gulf Coast carbon Center
Frio Brine Pilot Research Team

- Bureau of Economic Geology, Jackson School, The University of Texas at Austin: Susan Hovorka, Mark Holtz, Shinichi Sakurai, Seay Nance, Joseph Yeh, Paul Knox, Khaled Faoud, Jeff Paine
- Lawrence Berkeley National Lab, (Geo-Seq): Larry Myer, Tom Daley, Barry Freifeld, Rob Trautz, Christine Doughty, Sally Benson, Karsten Pruess, Curt Oldenburg, Jennifer Lewicki, Ernie Majer, Mike Hoversten, Mac Kennedy, Paul Cook
- Schlumberger: T. S. Ramakrishna, Nadja Mueller, Austin Boyd, Mike Wilt
- Oak Ridge National Lab: Dave Cole, Tommy Phelps, David Riestberg
- Lawrence Livermore National Lab: Kevin Knauss, Jim Johnson
- Alberta Research Council: Bill Gunter, John Robinson, Bernice Kadatz
- Texas American Resources: Don Charbula, David Hargiss
- Sandia Technologies: Dan Collins, “Spud” Miller, David Freeman; Phil Papadeas
- BP: Charles Christopher, Mike Chambers
- SEQuRE – National Energy Technology Lab: Curt White, Rod Diehl, Grant Bromhall, Brian Stratizar, Art Wells
- Paulsson Geophysical – Bjorn Paulsson
- University of West Virginia: Henry Rausch
- USGS: Yousif Kharaka, Bill Evans, Evangelos Kakauros, Jim Thorsen
- Praxair: Joe Shine, Dan Dalton
- Australian CO2CRC (CSIRO): Kevin Dodds, Don Sherlock
- Core Labs: Paul Martin and others
Frio Brine Pilot Site

- Injection interval: 24-m-thick, mineralogically complex Oligocene reworked fluvial sandstone, porosity 24%, Permeability 2.5 Darcys
- Unusually homogeneous
- Steeply dipping 16 degrees
- 7m perforated zone
- Seals – numerous thick shales, small fault block
- Depth 1,500 m
- Brine-rock system, no hydrocarbons
- 150 bar, 53 degrees C, supercritical CO₂
Injection Well  
Observation Well  

Closely spaced measurements in time and space
New tool to do the job: LBNL U-tube instrument to collect high frequency, high quality two-phase samples

Tommy Phelps
Dave Ristenburg
Oak Ridge National Lab

Seay Nance
NETL
SSCB
CO$_2$ Saturation Observed with Cross-well Seismic Tomography vs. Modeled
Rapid Dissolution of CO$_2$ in Field Tests – a significant factor in reducing plume size

Within 2 days, CO2 has dissolved into brine and pH falls, dissolving Fe and Mn
WHAT WE LEARNED

• Monitoring injection of CO$_2$ into relatively homogenous high permeability sandstone confirms validity of our numerical models

• Tools are available off-the-shelf for effective MMV
CONCLUSIONS

• Gulf Coast has largest sequestration capacity in US co-located with major concentration of CO2 emissions

• Florida has moderate potential for Sequestration

• Atlantic coast states have poor potential except offshore
Southeast Regional Carbon Sequestration Partnership

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