An Overview of Current Carbon Dioxide Capture and Geologic Storage (Sequestration) Activities in Texas

Tip Meckel
Research Associate
Gulf Coast Carbon Center
Bureau of Economic Geology
The University of Texas at Austin
BUT IT IS ALSO ABOUT THE ENVIRONMENT…

Must satisfy energy demand within environmental constraints:
What do people care about most?

Figure 5.1. What are your top three environmental concerns? (Q2b)
Average perceived health risks

Austin, TX (N=105)

Dayton, TX (Frio site)  
N=31
AND IT IS ALSO ABOUT ECONOMICS…
Where will the electricity come from?

The electricity production mix, GLO50 scenario

Key point: Electricity production from power plants equipped with CCS increases to over a third of total production by 2050

Source: IEA
Decarbonized Energy Benefits

Environment:
Atmospheric benefits of capturing and storing CO2

Energy:
CO2 – EOR (Enhanced oil recovery), EGR

Economy:
Jobs, taxes, infrastructure, development, etc.
Current level of activity is intense

- **Legislative (110th Congress)**
  - 100+ Congressional actions addressing aspects of global warming, climate change, carbon sequestration, etc.
  - Lieberman-Warner Proposal (Cap & Trade= 19% by 2020, 20% by 2050)
    - first comprehensive climate change measure to clear a congressional panel
  - Bingaman – CCS Bill
    - *The topic of carbon capture and storage is central to the future of coal in the United States and our future energy policy*’
  - Salazar / Bunning: National CO2 Storage Capacity Assessment Act
  - Dingell / Boucher White Paper (Cap & Trade)

- **Regulatory / Legal**
  - IOGCC; RGGI
  - “*Kansas Permit Denial Prompts Legal Fight Echoing Nationwide CO2 Debate*”

- **Industrial/Markets**
  - Trading: European and Chicago Climate Exchange
    - The carbon market grew in value to an estimated $30 billion in 2006
  - FutureGen & FutureGen-like projects
  - TxCCSA

- **Research**
  - DOE / NETL Regional Partnerships
    - BEG – Gulf Coast Carbon Center
TEXAS AND GREENHOUSE GASES

Where Texas ranks nationally in carbon dioxide emissions from fossil-fuel burning, in millions of tons per year:

1. Texas 723.2
2. California 422.3
3. Pennsylvania 288.7
4. Ohio 278.1
5. Florida 263.2
6. Indiana 253.8
7. Illinois 250.3
8. New York 233.1
9. Michigan 212.4
10. Louisiana 182.2

Where Texas ranks worldwide:

1. United States 6,517.0
2. China 5,188.8
3. Russia 1,857.2
4. Japan 1,391.2
5. India 1,227.7
6. Germany 950.4
7. Texas 723.2
8. Canada 648.1
9. United Kingdom 639.0
10. South Korea 547.6

Figures are the most recent available: 2001 for U.S. states, 2004 for countries. Texas' worldwide rank does not change if 2001 figures for countries are used.

SOURCE: U.S. Energy Information Administration
Some Major Geologic Projects Underway
(1 Million TPY CO₂, ~ 100 MW Coal Power Plant)

**Weyburn CO₂ EOR Project**
- Pan Canadian Resources / Encana
- 200-mile CO₂ pipeline from Dakota Gasification Plant
- 130M barrels oil over 20-year project

**Sleipner North Sea Project**
- Statoil
- Currently monitoring CO₂ migration
- MCS imagine a success

Also: In Salah, Algeria (BP)
Gorgon, Australia (Chevron; 100 Mt)
Seven regional partnerships

**SECARB: Regional Involvement:**

100+ Participants

Member States (Executive, Legislative and Regulatory) Industry and Electric Utilities Universities and National Laboratories NGOs and Trade Associations

- Characterize the potential carbon sequestration sinks in the Southeast;
- Conduct field verification studies in the most promising geologic formations in the region;
- Advance the state of the art in monitoring, measurement and verification techniques and instrumentation; and
- Develop sequestration technologies and characterize geologic sinks for future readiness.

<table>
<thead>
<tr>
<th>Partnership</th>
<th>Partnership Lead</th>
<th>States Represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest Regional Carbon Sequestration Partnership</td>
<td>Battelle Memorial Institute</td>
<td>IA, KY, MI, MD, OH, PA, WV</td>
</tr>
<tr>
<td>An Assessment of Geologic Carbon Sequestration Options in the Illinois Basin</td>
<td>The Board of Trustees of the University of Illinois, Illinois State Geological Survey</td>
<td>IL, IN, KY</td>
</tr>
<tr>
<td>Southeast Regional Carbon Sequestration Partnership</td>
<td>Southern States Energy Board</td>
<td>AL, AR, FL, GA, LA, MS, NC, SC, TN, TX, VA</td>
</tr>
<tr>
<td>Southwest Regional Carbon Sequestration Partnership</td>
<td>New Mexico Institute of Mining and Technology</td>
<td>AZ, CO, KS, NE, NM, OK, TX, UT, WY</td>
</tr>
<tr>
<td>West Coast Regional Carbon Sequestration Partnership</td>
<td>State of California, California Energy Commission</td>
<td>AK, AZ, CA, NV, OR, WA</td>
</tr>
<tr>
<td>Big Sky Regional Carbon Sequestration Partnership</td>
<td>Montana State University</td>
<td>ID, MT, SD, WY</td>
</tr>
<tr>
<td>Plains CO2 Reduction Partnership</td>
<td>University North Dakota - Energy &amp; Environmental Research Center</td>
<td>IA, MO, MN, ND, NE, MT, SD, WI, WY</td>
</tr>
</tbody>
</table>
Gulf Coast Carbon Center (GCCC)

Mission: Global leadership in research and economic implementation of large scale greenhouse gas sequestration.

GCCC Team:
Ian Duncan, Susan Hovorka, Tip Meckel, Becky Smyth, J. P. Nicot, Jeff Paine + 4 new post-docs, MA student, URA
Steve Bryant & Gary Rochelle (UT- Chem. Eng.)

Sponsors
Overview of Geological Storage Options

1. Depleted oil and gas reservoirs
2. Use of CO₂ in enhanced oil and gas recovery
3. Deep saline formations — (a) offshore (b) onshore
4. Use of CO₂ in enhanced coal bed methane recovery

Image from CO2-CRC
What are subsurface prospects for storing CO2?
An average point source can be 1-10 million tons/year

TX: 732+ Mt/yr total

100’s of years of potential storage

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Fields</th>
<th>Cumulative Recovery</th>
<th>Conventional CO₂ Storage Capacity</th>
<th>Technically Recoverable Oil from CO₂ EOR</th>
<th>Additional CO₂ Storage Capacity**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Assessed</td>
<td>Oil (Million Bbls)</td>
<td>Gas (Bcf)</td>
<td>(Million Metric Tons)</td>
</tr>
<tr>
<td>Alabama</td>
<td>133</td>
<td>63</td>
<td>622</td>
<td>1,856</td>
<td>344</td>
</tr>
<tr>
<td>Florida</td>
<td>23</td>
<td>8</td>
<td>556</td>
<td>0</td>
<td>109</td>
</tr>
<tr>
<td>Mississippi</td>
<td>110</td>
<td>101</td>
<td>1,346</td>
<td>5,300</td>
<td>399</td>
</tr>
<tr>
<td>Louisiana</td>
<td>964</td>
<td>331</td>
<td>11,847</td>
<td>117,697</td>
<td>6,781</td>
</tr>
<tr>
<td>Arkansas</td>
<td>42</td>
<td>42</td>
<td>1,394</td>
<td>1,415</td>
<td>250</td>
</tr>
<tr>
<td>Virginia</td>
<td>49</td>
<td>49</td>
<td>–</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>Tennessee</td>
<td>213</td>
<td>213</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Federal Offshore</td>
<td>1,337</td>
<td>1,001</td>
<td>15,843</td>
<td>176,466</td>
<td>17,754</td>
</tr>
<tr>
<td>Texas</td>
<td>678</td>
<td>678</td>
<td>12,510</td>
<td>29,373</td>
<td>4,005</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3,549</td>
<td>2,486</td>
<td>44,118</td>
<td>332,196</td>
<td>29,652</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saline Formations</th>
<th>CO₂ Storage Capacity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Billion Cubic Feet (Bcf)</td>
<td></td>
<td></td>
<td>Million Metric Tons</td>
<td>High Estimate P(85)</td>
<td>Low Estimate P(85)</td>
</tr>
<tr>
<td>Gulf Coast Basins</td>
<td>13,419,989</td>
<td>3,356,017</td>
<td>710,264</td>
<td>177,557</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuscaloosa Group</td>
<td>813,456</td>
<td>203,364</td>
<td>43,040</td>
<td>10,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodbine and Paluxy Formations</td>
<td>962,633</td>
<td>240,654</td>
<td>50,933</td>
<td>12,733</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pottsville Formation</td>
<td>210,414</td>
<td>52,599</td>
<td>11,133</td>
<td>2,783</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mt. Simon Sandstone</td>
<td>94,500</td>
<td>23,625</td>
<td>5,000</td>
<td>1,250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potomac Group</td>
<td>88,376</td>
<td>222,094</td>
<td>47,004</td>
<td>11,751</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Carolina-Georgia Basins</td>
<td>597,070</td>
<td>149,272</td>
<td>31,591</td>
<td>7,898</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar Keys, Lawson Formations</td>
<td>2,098,694</td>
<td>524,683</td>
<td>111,042</td>
<td>27,751</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore Atlantic (Unit 120)</td>
<td>6,732,936</td>
<td>1,683,234</td>
<td>356,240</td>
<td>89,060</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore Atlantic (Unit 90)</td>
<td>586,656</td>
<td>146,664</td>
<td>31,040</td>
<td>7,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25,604,724</td>
<td>6,602,206</td>
<td>1,397,287</td>
<td>349,323</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current CO₂ – EOR Infrastructure

[Map showing infrastructure locations such as LaBarge, McElmo Dome, Sheep Mountain, Bravo Dome, Gas Plants, Ammonia, and Jackson Dome.]
Figure 4.9. Does EOR change your opinion of CCS in Texas? (Q10)
Industrial CO2 sources and oil fields with EOR potential
EOR with CO2 can serve as an economic driver in establishing the infrastructure for long-term, larger-volume storage in underlying brine formations.
Areas with Miscible CO₂ EOR Potential

- CO₂-EOR candidate reservoirs
- Existing CO₂ pipelines
- Additional oil-production area with CO₂-EOR production and potential
- Major oil plays

Bureau of Economic Geology
Miscible CO$_2$ EOR resource potential in the Gulf Coast

By State

Holtz and others (2005)
CO₂ Sequestration capacity in miscible oil reservoirs along the Gulf Coast

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)
Frio Test CO₂ Storage in Brine
Frio Brine Pilot Site
Two Test Intervals

- **Purpose:** demonstrate feasibility and monitoring techniques, evaluate model predictions

- **Setting:** salt dome flank, Frio sandstone, 5,000 ft depth.

- **Scope:** 100’s of tons over weeks

- **Monitoring:** tracers, pressure and temperature, logs, seismic

Fresh-water (USDW) zone protected by surface casing

Injection zones:
- First experiment in 2004: Frio “C”
- Second experiment in 2006: Frio “Blue”

Oil production
Frio Pilot Injection: Phase II

- 500 Tons
- Tracer studies: 4 PFT's and two methanated partitioning tracers (ORNL)
- Geochemical lab (USGS): aqueous tracers and in-line pH and cond.
- On-site Gas Chromatograph (UT-PE)
- U-Tube (LBNL): water & gas @ reservoir conditions in both wells, on-site Mass Spectrometer (SF5, Kr, Xe)
- Cross-well seismic (LBNL) continuous
- Hosting CSIRO-AUS deuterated methane tracer test (Otway)
- Visitors: MIT, Battelle, Taisei Corp (Japan), China Pet. Corp (Taiwan).
Time-Lapse Changes in Water Saturation (Sw)

CO₂ migrating up-dip leaving dissolved CO₂ in water

Injection Well

Observation Well
CO$_2$ Saturation Observed with Cross-well Seismic Tomography vs. Modeled

Tom Daley and Christine Doughty, LBNL
Traveltime Response to CO2 Injection

Real time detection using continuous source cross-well seismic

[From Daley et.al. 2007, in press]
Gulf Coast Stacked Storage Field Test

Phase 2: $4.9M, Observation well & logging campaign
Phase 3: $38M, 2 monitoring wells, multiple injectors, 1 Mt/yr
Proven hydrocarbon seals

Source of large volumes of CO₂ via existing pipelines

Geographic Focus of SECARB Phase III Program

Proposed Jewett FutureGen Injection Site

Cranfield

Sabi

Geographic Focus of SECARB Phase III Program

Plant Daniel

Plant Barry

Plant Crist
Phase III Early Test: Brine interval

Phase 2: Ongoing – Sept 2009
Phase 3: Now through 2017 (2010)
3 MMCFD Injection rates
Phase II: ½ Million Tons/yr
Phase III: 1-1.5 Mt/yr

Key
- Green: Unitized area
- Purple: Pipeline
- Light green: Structure Contour
- Orange: Access roads
- Brown: Tuscaloosa Wells
- Red: Study area
- Yellow: Residual fluids
- Gray: Oil Ring
- Red: Gas Cap

Monteagle Sand
Monitor Sand
Injection Sand
375'

Marine Shale Seal
Cranfield Program Overview

A’

Denbury Cranfield unit

Proposed Phase III Early study area

10,000 ft

Tuscaloosa Formation

Brine

Residual Oil

Inj + Mon

Inj + Mon

Inj + Mon

Monitoring

Oil Prod

Inj

Documented seal

Residual Gas

Phase II Study area

A'

A

Cranfield Program Overview

Shale

Sandstone

"Heterogeneity"
State of the art reservoir characterization and modeling approach

<table>
<thead>
<tr>
<th>SP</th>
<th>TVD</th>
<th>10250</th>
<th>10150</th>
<th>10100</th>
<th>10050</th>
<th>10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>-150</td>
<td>50</td>
<td>2 Res. S (SN)</td>
<td>20</td>
<td>2 Ind. (OHMM)</td>
<td>20</td>
<td>2 Lat (OHMM)</td>
</tr>
</tbody>
</table>

[Graphs and charts related to reservoir characterization and modeling]
SWCARB Regional Partnership

• SACROC
• Impact of 35 years of CO2 injection on USDW?
  • 140 Mt injected
  • 60 Mt recovered
- 275-MW, near-zero-emission gasifier
- Flexible fuel source
- Produces electricity, $H_2$, $>1$MMT CO$_2$ per year
- CO$_2$, H$_2$ pipelines
- Sequester $\geq 90\%$ CO$_2$
- Protocols for CO$_2$ measuring, monitoring, and verification
- Stacked storage
  - EOR
  - Deep brine-bearing fm.
Key Geoscience Research Areas

• Potential negative impacts
  – Interaction with groundwater
  – Brine displacement
  – Leakage: abandoned wells

• Pressure evolution & seal integrity

• Multi-phase fluid flow modeling
Gulf Coast Carbon Center (GCCC)

Mission: *Global leadership in research and economic implementation of large scale greenhouse gas sequestration.*

GCCC Team:
Ian Duncan, Susan Hovorka, Tip Meckel, Becky Smyth, J. P. Nicot, Jeff Paine + 4 new post-docs, MA student, URA
Steve Bryant & Gary Rochelle (UT-Chem. Eng.)

Sponsors
bp
Chevron
Schlumberger
Shell
Kinder Morgan
LCRA
NRG
Marathon
Entergy
Austi Energy
Jackson
Praxair
The University of Texas at Austin School of Geosciences