A CO$_2$ Industry in the Gulf Coast

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Acknowledgments

- DOE
- BEG: Sue Hovorka, Ian Duncan...
- GCCC Members
- FutureGen Texas Team
- BEG Global Collaborators
- Many others
Outline

• Setting the Stage
• Emissions and Storage
• Forming a CO₂ Industry
Global Consumption Trends

- H/C<1 (Wood, Coal)
- H/C~2 (Oil)
- H/C>4 (Natural Gas, Hydrogen, Nuclear, Sustainables)

Global Demand for Fossil Fuels

1999 Energy Use (Exajoules)

Global Consumption Trends

H/C<1 (Wood, Coal)
H/C~2 (Oil)
H/C>4 (Natural Gas, Hydrogen, Nuclear, Sustainables)

Converging Forces

- **Environment**: $\text{CO}_2$ is a major greenhouse gas.

- **Energy**: $\text{CO}_2$ Enhanced Oil Recovery (EOR), hydrogen, power, other.

- **Economy**: Wellhead oil and natural gas value, taxes, jobs, infrastructure.
The “Stick”

- Climate is changing
- Negative impacts exceed positive
- Therefore CO₂ is “bad”
- Popular to “do something” about it
- Emissions regulations lead cap and trade markets
- Industry and economy... deal with it

Industry/ Government < 1
The “Carrot”

- Climate is changing and has been for a few billion years
- Anthropogenic CO2 is background noise
- Keep pumping out the GHGs
- Public and Environment… adapt and get on with it

Industry/ Government > 1
The “Cabbage”
(Hurts if it hits you, but you can still eat it…)

- Climate changing
- Anthropogenic CO2 partially responsible
- CO2 can be an economic product
- Government incentives guide industry
- Commerce takes over
- Energy/ Environment/ Economy benefit

Industry/ Government ~ 1
The GCCC is seeking to balance industry and government by bridging science, markets, and policy to facilitate development of an economically viable CO2 sequestration industry in the Gulf Coast.

BP
Chevron
Entergy
Jackson School
Kinder Morgan
Marathon
NRG
Praxair
Schlumberger
Outline

• Setting the Stage
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U.S. CO2 Sources and Sinks

Power generation (IEA)
Pure CO₂ sources (IEA data)
Oil and Gas (USGS)
Coal (USGS)
Brine Aquifers >1000m

Source: Gulf Coast Carbon Center
Eastern Texas Sources and Sinks

**CO₂ Sources**
- Coal-fired power plant
- Gas-fired power plant
- Refinery
- Ammonia plants
- Iron and steel
- Cement
- Oil reservoirs suitable for EOR

Source: Gulf Coast Carbon Center
Emissions and Storage

- The world emits ~ 25.6 Gt of CO$_2$ annually
- The U.S. emits ~ 5.7 Gt of CO$_2$ annually
- Texas emits ~ 700 MMt of CO$_2$ annually.
- Brines found in sandstones from Alabama to Mexico border (37,000 km$^3$) at 4000-12,000 ft saturated at 1% CO$_2$ would hold ~ 220 Gt
US CO2 EOR

- Annual U.S. consumption is ~ 7 BSTB and production is ~ 3.2 BSTB
- 2 Bcf/ day of CO$_2$ currently injected for EOR in U.S. (20% anthro)
- Current U.S. CO$_2$ EOR production ~205 mbopd
EOR “Facts”

- Gulf Coast contains 767 oil and gas reservoirs that would benefit from EOR
- Average price of CO$_2$ is $14-17$/ ton (<$1/ mcf)
- Permian Basin
  - Injects $\sim$ 30 MMt/ y ($450$ million of CO$_2$/ yr)
  - 9 Tcf over 33 years recovered $\sim$ 1 Bbo EOR in 33 yrs
  - A 500 MW coal power plant produces $\sim$4 MMt/ y
- Sacroc:
  - Injects 13.5 MMt/ y and withdraws 7MMt/ y.
  - Since 1972, “accumulated” 55 MMt.
  - Sacroc has a 175 MW power facility
- WAG (15-20% ) vs. Gravity Stable (50% EOR)
CO2-EOR
Qualified Reservoirs

Data Sources
BEG
RRC
Texas EOR

~ 700 million tons CO$_2$ minimum storage outside of Permian Basin in Texas as a direct result of EOR.

CO$_2$ EOR recovery in Texas outside of the Permian Basin is estimated at 5.7 bbo

At $60$ oil:

- wellhead value: $342$ billion
- wellhead taxes: $30$ billion
- other taxes: $22$ billion
- economic activity: $498$ billion
Residual Oil Resources in Texas (Non Permian Basin)

> 38 Billion STB In Place
5-6 BSTB Recoverable (~ 15%)

- Gulf Coast
- Texas Cretaceous Margin
- East Texas
- North Central Texas

Data Source: BEG
EOR Candidates

Data Source
BEG

Legend
- Texas CO2 EOR candidate reservoirs
- Texas oil producing area
- Texas state boundary

0 50 100 200 Miles
N
Leveraging BEG’s STARR Program

STARR receives $1.5 million/yr from Texas to assist operators to increase oil and gas production on state lands.

Funds for reservoir characterization and engineering studies of potential CO2 EOR projects.

GCCCC will work jointly with the STARR program to evaluate/implement CO2 EOR projects.
CO2 sequestration is a cornerstone of FutureGen.

CO2 will be used for EOR to offset development cost, speed implementation, and allow duplication.

Very large volume of CO2 storage in brine formations beneath reservoir footprints

Source: Gulf Coast Carbon Center
Outline

• Setting the Stage
• Emissions and Storage
• Forming a CO$_2$ Industry
Forming a CO2 Industry

- Get it: Capture
- Change it: Compress
- Move it: Transport
- Store it: Sequester
- Prove it: MMV
- Check it: Model Impact
It Starts with Capture

• Retrofit Existing Facilities
• Build New

For FutureGen to succeed — have an impact on a scale that matters in a time frame that matters — will require flexible fuels and near-term propagation of FutureGen-like facilities.

Industry/Government ~ 1
Low cost & high purity CO₂ sources available in the near-term

Source-sink paired demonstration study

Capture from large sources (retrofitted power plants & new IGCC w/ capture)

Source: Gulf Coast Carbon Center
IGCC w/ CO2 Capture

High btu coal
Low btu coal
Lignite
Petroleum Coke
Refinery Co-products

Oxygen

Gasifier

Syngas

Steam Turbine

Combustion Turbine

Electricity

Steam

Shift Reactor

Hydrogen

Particulate Removal

CO2

Sulfur

Solids and Co-products

Slag/Soot

Modified from Eastman Chemical
Coal Resources

Data Sources
BEG
RRC
USGS

Half of the nation’s reserves are in low btu coal, lignite and pet coke
**Incentives/ Clean Credits**

<table>
<thead>
<tr>
<th>CO2-EOR Resource (B bbls)</th>
<th>Oil Price ($/bbl)</th>
<th>Wellhead Value (B $)</th>
<th>Severance Taxes ($B, 4.6%)</th>
<th>Ad Valorem Taxes ($B, 3.95%)</th>
<th>Jobs Created</th>
<th>Economic Value (Wellhead Value x 2.91)</th>
<th>Franchise Taxes ($B, 0.18%)</th>
<th>Sales Taxes ($B, 2%)</th>
<th>CO2-EOR Resource (B bbls)</th>
<th>CO2 Sequestered (metric tons, tonnes)</th>
<th>CO2 Sequestered (Gigatonne, Gt)</th>
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<tr>
<td>5.7</td>
<td>30</td>
<td>$171</td>
<td>$8</td>
<td>$7</td>
<td>$30</td>
<td>19.1 jobs per $1MM Wellhead Value</td>
<td>$0.9</td>
<td>$10</td>
<td>800,565,000</td>
<td>726,112,455</td>
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<tr>
<td>5.7</td>
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<td>$50</td>
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<td>$1.5</td>
<td>$28</td>
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*Calculations based on the TX RRC's *General Model of Oil and Gas Impact on the Texas Economy* derived from the Comptroller's Input-Output model of the Texas economy.

Severance and Ad Valorem Taxes from Wellhead Value; Indirect Taxes from Economic Value.

**State Revenue**

<table>
<thead>
<tr>
<th>$/bbl</th>
<th>Wellhead Taxes</th>
<th>Other Taxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$30</td>
<td>$15 billion</td>
<td>$11 billion</td>
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<tr>
<td>$40</td>
<td>$19 billion</td>
<td>$14 billion</td>
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<tr>
<td>$50</td>
<td>$24 billion</td>
<td>$19 billion</td>
</tr>
<tr>
<td>$60</td>
<td>$30 billion</td>
<td>$22 billion</td>
</tr>
</tbody>
</table>

**Incentives/ Credits for Capture**

@ $70/ton capture = $51 billion

@ $20/ton capture = $15 billion
Needs and Unknowns

- Incentives and clean energy credits
- Public Education
- Talent

- What happens when we scale from 1 Mt to 1 MMt to 1 GT?
Summary

• Climate drives the conversation
• Governments create incentives and support research
• Industry implements at commercial scales
• Science and engineering are vital
  – implementation costs are extreme
  – timing is critical
  – missteps are costly
• Start in regions where impact can be felt the soonest and the most
Thanks!