Carbon Capture, Utilization, and Storage (CCUS) and its Feasibility in Louisiana

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Oil/Gas Industry and Sustainability

• “Although it was CERAWeek by IHS Markit, it often sounded more like climate week.” E&E News, March 18, 2019

• “Shell CEO: Climate change is our biggest issue”, IHS CERAWeek, March 7, 2019

• “Oxy CEO: Next gen companies need to be at least carbon neutral”, Houston Business Journal, March 13, 2019

• “Chevron, Oxy invest in CO₂ removal technology”, REUTERS, Jan 9, 2019
CCUS

• Carbon capture, utilization, and storage (CCUS) involves capturing man-made carbon dioxide (CO₂) at its sources and storing it permanently underground with potential utilization.

• Projections by IEA show that CCUS will need to account for 6 Gton of CO₂ emissions reduction worldwide by 2050.

Folger, 2018
CCS Captured CO₂ (Gt/yr) – North America

Shell sky scenario, 2019
Large-scale CCUS projects worldwide

- **Boundary Dam Carbon Capture and Storage** (Saskatchewan, Canada)
- **Sleipner CO₂ Storage** (Norway)
- **Snohvit CO₂ Storage** (Norway)
- **CNPC Jilin Oil Field CO₂ EOR** (China)
- **Sinopec Qilu Petrochemical CCS** (China)
- **Uthmaniannah CO₂-EOR Demonstration** (Saudi Arabia)
- **Yanchang Integrated Carbon Capture and Storage** (China)
- **Abu Dhabi CCS Project** (Abu Dhabi, UAE)
- **Gorgon Carbon Dioxide Injection** (Australia)
- **Petrobras Santos Basin Pre-Salt Oil Field CCS** (Brazil)
- **Petra Nova Carbon Capture** (Texas, United States)
- **Air Products Steam Methane Reformer** (Texas, United States)

Source: iea.org

www.GISreportonline.com
At ~220 million tons of CO₂ emissions, Louisiana ranks fifth in the U.S.
U.S./Louisiana CO\textsubscript{2} Emissions per Sector

U.S.
- Transportation, 36.5%
- Electric Power, 34.0%
- Industrial, 19.3%
- Residential, 5.7%
- Commercial, 4.5%

Louisiana
- Transportation, 22.3%
- Electric Power, 16.9%
- Industrial, 58.9%
- Residential, 0.8%
- Commercial, 1.0%

EPA, 2016.
Industrial CO$_2$ emissions by category

- Chemical Manufacturing, 46%
- Petroleum and Coal Products, 42%
- Natural Gas Processing, 6%
- Paper Manufacturing, 3%
- Primary Metal Manufacturing, 2%
- Food, Beverage and Tobacco, 0.4%
- Nonmetallic Minerals, 0.2%
- Wood Products, 0.05%
- Fabricated Metal, 0.02%

Industrial CO$_2$ emissions by category

Louisiana CO$_2$ Sources > 0.1 MtCO$_2$/yr

EPA, 2017
Top Ten South Louisiana Industrial Sources

Dismukes et al., 2019
CCUS in Louisiana

- Onshore vs. offshore
- Saline aquifers vs. hydrocarbon-bearing formations
Identified saline storage sites

Dismukes et al., 2019
Common features

- Multiple storage zones with stacked sand systems
- Thick zones (up to several hundred ft.)
- High porosity and high permeability
- Normal hydrostatic pressure $\sim 0.465$ psi/ft

<table>
<thead>
<tr>
<th></th>
<th>Cum oil (MMSTB)</th>
<th>Cum gas (BSCF)</th>
<th>Total wells</th>
<th>Currently prod. wells*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayou Sorrel</td>
<td>44</td>
<td>190</td>
<td>176</td>
<td>3</td>
</tr>
<tr>
<td>Paradis</td>
<td>156</td>
<td>1350</td>
<td>411</td>
<td>16</td>
</tr>
</tbody>
</table>

* Current production intervals are deeper than 10,000 ft
Bayou Sorrel

SONRIS Interactive Map

Disclaimer: This data is not to be used for legal purposes.

Date: 12/21/2017
Bayou Sorrel Petrophysical Data

**Zone Depth (ft)**

Average thickness = 998 ft

**Porosity**

Average Porosity = 0.28

**CO₂ Density (kg/m³)**
Paradis
Paradis Petrophysical Data

Zone Depth (ft)

- Average thickness = 350 ft

Porosity

- Average Porosity = 0.3

CO₂ Density (kg/m³)
## Storage capacity

### Static Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bayou Sorrel</th>
<th>Paradis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average depth to top of potential storage zone (ft)</td>
<td>7300</td>
<td>4300</td>
</tr>
<tr>
<td>Average thickness of potential storage zone (ft)</td>
<td>990</td>
<td>350</td>
</tr>
<tr>
<td>Average porosity of potential storage zone (fraction)</td>
<td>0.280</td>
<td>0.300</td>
</tr>
<tr>
<td>Average CO2 density (kg/m3)</td>
<td>771.1</td>
<td>714</td>
</tr>
<tr>
<td>Static storage efficiency (fraction)</td>
<td>0.020</td>
<td>0.020</td>
</tr>
<tr>
<td>Static storage capacity (Mt)</td>
<td>133</td>
<td>84</td>
</tr>
<tr>
<td>Static capacity per unit volume (Kg/m3)</td>
<td>4.318</td>
<td>4.284</td>
</tr>
</tbody>
</table>

### Dynamic Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bayou Sorrel</th>
<th>Paradis</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of wells</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Dynamic Capacity (Mt)</td>
<td>129</td>
<td>124</td>
</tr>
<tr>
<td>Storage efficiency (fraction)</td>
<td>0.019</td>
<td>0.043</td>
</tr>
<tr>
<td>Dynamic capacity (Kg/m3)</td>
<td>4.20</td>
<td>9.29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Transmissive Faults</th>
<th>Non-transmissive Faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of wells</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Dynamic Capacity (Mt)</td>
<td>124</td>
<td>71</td>
</tr>
<tr>
<td>Storage efficiency (fraction)</td>
<td>0.043</td>
<td>0.025</td>
</tr>
<tr>
<td>Dynamic capacity (Kg/m3)</td>
<td>9.29</td>
<td>5.33</td>
</tr>
</tbody>
</table>
Offshore CCUS

- As part of SECARB offshore GoM partnership, currently looking at CCUS potential in Louisiana state waters

- The evaluation focuses on active and depleted O/G fields and potentially associated CO₂ EOR as well as saline storage resources
Why CCUS in Louisiana?

- Stable high-purity, large-volume point sources of CO2 implying lower CO2 capture cost
- Existing transport infrastructure
- Access to large number of hydrocarbon fields that are depleted or near primary depletion
- Wealth of data for detailed subsurface characterization
- Stacked sand-shale system enabling simultaneous EOR and storage while minimizing risk of leakage because of thick continuous sand and shale layers
- Synergy with gas storage projects that has become essential to manage the excessive volumes of produced shale gas
- Potential for offshore storage to minimize human exposure
- Low risk of seismicity

Composite type log, South Marsh Island Block 128 field, offshore Louisiana
Challenges/Barriers

- CO2 containment – well leakage
- CO2 containment – fault leakage
- CO2 plume extension
- Cost-effective monitoring
- Storage zone boundary conditions
- Injectivity: limiting overpressure, scaling

Cavanagh et al., 2014

Chadwick and Noy (2010)
Furre and Eiken (2014)
Mao, Y. L., M. Zeidouni, and R. Askari (2017a), Effect of leakage pathway flow properties on thermal signal associated with the leakage from CO2 storage zone, Greenh Gases, 7(3), 512-529.


Molina, O. M., and M. Zeidouni (2018), Analytical Model to Detect Fault Permeability Alteration Induced by Fault Reactivation in Compartmentalized Reservoirs, Water Resources Research, 54(8), 5841-5855.

Molina, O. M., and M. Zeidouni (2018), Detection of Fault Reactivation in Compartmentalized Reservoirs Using Pressure Transient Analysis, in SPE Western Regional Meeting, edited, p. 18, Society of Petroleum Engineers, Garden Grove, California, USA.

Mosaheb, M., and M. Zeidouni (2017a), Above-Zone Pressure Response to Distinguish Between Fault and Caprock Leakage, in 2017 Western Regional Meeting, edited, Society of Petroleum Engineers, Bakersfield, California, USA.
References


Tran, N., and M. Zeidouni (2018), Pressure transient technique to constrain CO2 plume boundaries, Environ Earth Sci, 77(21), 736.

References


Zeidouni, M., M. Pooladi-Darvish, and D. W. Keith (2011a), Analytical models for determining pressure change in an overlying aquifer due to leakage, Energy Procedia, 4(0), 3833-3840.


Zeidouni, M., N. H. Tran, and M. D. Munawar (2017), Interpretation of above-zone pressure influence time to characterize CO2 leakage, Greenh Gases, 7(6), 1050-1064.

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CO2 Utilization

NARUC, 2018
Fault structure

Two-component fault idealization:

− Fault core
− Fault damage zone

Source: Maher, 2018
Identified saline storage sites

- Norco area (Shell refinery)
- Donaldsonville area (CF industries ammonia plant)
- Paradis
- Bayou Sorrel
Well leakage

Celia et al., 2005

AMES Geology, 2019
Fault leakage

Smith, 1960
Fault leakage

Representative dip-oriented structural cross-section through Texas waters (Nicholson, 2012)
CO$_2$ plume extent

Cavanagh et al., 2014

Chadwick and Noy (2010)
Furre and Eiken (2014)
Leak identification

Leaky well

Leaky fault

Leaky caprock

Mosaheb and Zeidouni, 2018
Well/fault leakage detection

Mao and Zeidouni, 2017

Zulqarnain et al., 2018
Fault leakage monitoring and detection

Fault anisotropy results in linear flow which can be identified through above-zone pressure analysis.

Mosaheb and Zeidouni (2018)
Fault reactivation is associated with permeability enhancement the effect of which is observable in the pore pressure signal at the injection well.
Pressure monitoring for plume extent

Three techniques are presented to monitor and analyze pressure to obtain information on the CO₂ plume