Evaluating, Risking, and Ranking Carbon Sequestration Buoyant Traps with Application to Nearshore Gulf of Mexico

MADDIE LAIDLAW
Masters Saturday April 30, 2022
CCS in the Gulf Coast

- CCS can play a vital role in reducing carbon emissions
- US Gulf Coast is an attractive region to develop CCS
  - Cost lies in capturing emissions
  - Uncertainty lies within subsurface reservoirs
- How should CCS developers identify high-quality sequestration prospects?
Outline

I. Evaluating
   ◦ Previous Prospect Inventories
   ◦ Creating a New Inventory

II. Risking
   ◦ Geologic Risk
   ◦ Above Ground Risk

III. Ranking
Carbon Storage Prospect Inventory

What is a CCS Prospect?

• Individual subsurface sequestration opportunities
• Allowing fault seal expands...
  o Volume of carbon that can be sequestered per prospect
  o Number of prospects to choose between

First Edition TexLa CCS Prospect Inventory

• Used map-based fetch & closure analysis to identify traps
• Excludes the potential for fault seal
• Doesn’t reflect our knowledge of GOM stratigraphy

(DeAngelo Unpublished, DeAngelo 2019)
Incorporate real Miocene geologic data...
Incorporate real Miocene geologic data...

... to identify buoyant traps & fetches...
Incorporate real Miocene geologic data...

... creating a Multi-Reservoir Prospect Inventory

... to identify buoyant traps & fetches...
Quantifying Prospect Risk

Subsurface Risk

- How much?
- How fast?
- How secure?
Quantifying Prospect Risk

Subsurface Risk
- How much? Capacity
- How fast? Injectivity
- How secure? Confining Zone
Quantifying Prospect Risk

Above-Ground Risk
- Financial
- Political
- Permitting

Subsurface Risk
- How much? Capacity
- How fast? Injectivity
- How secure? Confining Zone

Introduction
Prospect Evaluation
Subsurface Risk
Above-Ground Risk
Ranking
Conclusions
Capacity Risk

How much CO$_2$ can a prospect store?

**Dynamic Estimate**

**Uncertainty**

**EASiTool Simulator**

- Closed form analytical solution for capacity
- Considers pressure, reservoir properties, fluid properties
- Gives sensitivity analysis & multi-well capacity results

![Graph showing probability distribution of single well dynamic capacity](image-url)
Injectivity Risk

At what rate can the reservoir store CO$_2$?

- Reservoir Thickness
- Reservoir Permeability
- Reservoir Pressure
- Reservoir Continuity

Vertical: Net to Gross Ratio (NTG)
Lateral: Fault Compartmentalization

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Thickness</th>
<th>Pressure</th>
<th>Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

multidisciplinary studies for interdisciplinary solutions
Prospect Differentiation

- Evaluate **relative** costs of sequestration between prospects
- Identify prospects to that are most likely to support upstream capture costs

Discounted Cash Flow Model Inputs

- Values sequestration portion of the projects
- Capacity & Injectivity estimates from EASiTool modelling
- Technical expenses from published sources
- Revenues based on current and potential future 45Q tax credit policies

---

Prospect Value ($ / ton)

Cost of Carbon Capture from a High-Concentration Stream ($25/ton)

<table>
<thead>
<tr>
<th>Prospect Number</th>
<th>NPV ($ / tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$10.31</td>
</tr>
<tr>
<td>2</td>
<td>$11.27</td>
</tr>
<tr>
<td>3</td>
<td>$9.96</td>
</tr>
<tr>
<td>4</td>
<td>$9.80</td>
</tr>
<tr>
<td>5</td>
<td>$11.22</td>
</tr>
<tr>
<td>6</td>
<td>$6.67</td>
</tr>
<tr>
<td>7</td>
<td>$5.07</td>
</tr>
<tr>
<td>8</td>
<td>$7.70</td>
</tr>
<tr>
<td>9</td>
<td>$(18.38)</td>
</tr>
<tr>
<td>10</td>
<td>$(5.37)</td>
</tr>
<tr>
<td>11</td>
<td>$(42.57)</td>
</tr>
</tbody>
</table>

* Values using $50/ton 45Q Credit Value
Ranking with CRS Maps

Composite Risk Segment (CRS) Mapping

- Adapted from a hydrocarbon industry ranking tool
- Flexible to incorporate any risk elements possible
- Intuitive, spatial display of risk
- Provides broad prospect differentiation

Overlaying Risk Colours

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Injectivity</th>
<th>Confinement</th>
<th>Subsurface Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest</td>
<td>Low</td>
</tr>
<tr>
<td>Average</td>
<td>High</td>
</tr>
<tr>
<td>Highest</td>
<td></td>
</tr>
</tbody>
</table>
Estimated Monetary Value ($MM)

• Quantitative, risk-weighted measure of value

• Dependent on "Chance of Success" composite value of all geologic risk scores

• Allows for finer-scale prospect differentiation

Varying Chance of Success’s Impact on Ranking

Prospect Evaluation ➔ Subsurface Risk ➔ Above-Ground Risk ➔ Ranking ➔ Conclusions
Conclusions

**Study Goals**

- Improve TexLa prospect inventory using real geology
- Quantify geological and Above-Ground risk factors
- Identify prospects with the maximum probability of success

**Study Conclusions**

- Identified larger CCS opportunities with multi-reservoir potential within the TexLa Miocene section
- Risking workflow that is repeatable and based on commonly available data
- Ranking prospects focuses developers on highest-quality prospects
Acknowledgements

Thank you to...

• My thesis committee: Alex, Sue & Frank for your advice, input, and encouragement
• GCCC Researchers & EER Program for the academic and fellowship support
• Friends & Family for a wonderful two years!

US DOE NETL

This material is based in part upon work supported by the Department of Energy under DOE Award Numbers DE-FE0031558 and DE-FE0031830.

Disclaimer: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Acknowledgements

Thank you to Gulf Coast Carbon Center Sponsors:
Evaluating, Risking, and Ranking Carbon Sequestration Buoyant Traps with Application to Nearshore Gulf of Mexico

MADDIE LAIDLAW
Masters Saturday April 30, 2022
Trap Risk

Does the subsurface structure collect CO₂?

Trap Type Classification

- 4 Way Dip (4WD)
- 3 Way Fault (3WF)

Determine fault offset: reservoir thickness ratio

- Offset: Thickness > 2
- Offset: Thickness ~ 2
- Offset: Thickness < 2

Prospect 1 – 3WF

Seismic data courtesy of SEI Inc.,
Interpretation belongs to the University of Texas at Austin
Seal Risk

Does the lithology prevent the vertical migration of CO$_2$?

Intercepting Wells Production History

- Gas Field
- Oil Field
- Dry Wells

Proven Gas Seal
Proven Oil Seal

Oligocene Charge Access Review

Unlikely Charge
Likely Charged
Well Leak Risk

Has the Gulf’s hydrocarbon exploration history impacted a prospect’s ability to hold CO$_2$?

# Wells & Well Age

- Modern Wells, Observed < Expected
- Modern Wells, Reported ~ Expected
- Modern Wells, Reported Wells > Expected
- Pre-1967 wells present
- Pre-1935 wells present
Financial Risk

Introduction

Prospect Evaluation

Subsurface Risk

Above-Ground Risk

Ranking

Conclusions

multidisciplinary studies for interdisciplinary solutions
