An Economic Look at the Promise of CO₂ Capture, Storage and Utilization

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USAEE Energy Transitions in the 21st Century

Roundtable Session 10:
The Promise of Carbon Capture, Storage and Utilization

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Overview of Carbon Capture, Utilization and Storage (CCUS)

Point Source of CO₂

Utilization and Storage

High Value Products

Carbon Use and Reuse

Geological Storage

Enhanced Oil Recovery

CO\textsubscript{2} Sources Amenable to Capture

A variety of point sources, as well as air, lend themselves to CO\textsubscript{2} capture.

- **Coal Power Plant**: 11-14% CO\textsubscript{2}, ~2 psia CO\textsubscript{2}
- **Gas Power Plant**: 4-6% CO\textsubscript{2}, ~0.7 psia CO\textsubscript{2}
- **Air Capture**: 0.04% CO\textsubscript{2}, ~0.006 psia CO\textsubscript{2}
- **NG Processing Plant**: 99% CO\textsubscript{2}, ~23.3 psia CO\textsubscript{2}, CO\textsubscript{2} vent
- **Ammonia Plant**: 99% CO\textsubscript{2}, ~22.8 psia CO\textsubscript{2}, Stripping vent
- **Ethanol Plant**: 100% CO\textsubscript{2}, ~18.4 psia CO\textsubscript{2}, Distillation gas
- **Cement Plant**: ~22.4% CO\textsubscript{2}, ~3.3 psia CO\textsubscript{2}, Kiln off-gas

The revised Section 45Q tax credits are motivating electric power companies (and other investors) to reexamine their business models for CCUS, including evaluating:

- How the Section 45Q tax credit could change power plant dispatch and revenues.
- Value of the tax credit compared to the costs of CCUS, and
- Ability to monetize the tax credits with a third party.

This presentation draws on a more comprehensive article entitled “Reconsidering CCS in the U.S. Fossil-Fuel Fired Electricity Industry Under Section 45Q Tax Credits,” available from Wiley Journal of Greenhouse Gases: Science & Technology.
CCUS Business Models

Three basic business models are available to an electricity company considering CCUS for one of its electricity generation units (EGUs):

- **Integrated Business Model.** “Doing it all by yourself.”
- **Third Party Business Model.** “Let someone else do it.”
- **Joint Venture Business Model.** “Let’s do it together,” particularly with a CO$_2$ EOR operator.
The PetraNova JV (NRG and JX) has installed post-combustion CO₂ capture on a 240 MW coal-fired unit at WA Parish power plant.

Approximately 75 MMcfd of captured CO₂ is transported and used for EOR at Hilcorp’s West Ranch oil field with an oil production goal of 15,000 B/D.
Assessing the Business Models

Identifying the most advantageous CCUS business model requires information on four key topics.

- **Operational change for the EGU.** With CO$_2$ capture and 45Q tax credits, the EGU may have a significantly higher annual capacity utilization factor compared to other EGUs in the system.

- **Cost of CO$_2$ Capture.** The lessons learned on CO$_2$ capture at Sask Power’s Boundary Dam and NRG’s WA Parrish power plants plus recent FEED studies provide pathways toward much lower costs for CO$_2$ capture.

- **Cost of CO$_2$ Storage.** A high-quality geologic storage complex located close to a power plant can provide low cost CO$_2$ storage.

- **Value of CO$_2$ for EOR.** Numerous variables (e.g., price of oil, costs of transportation, quality of the EOR project, etc.) enter into the value proposition for selling CO$_2$ supplies to or entering into a JV for EOR.
Installation of CO₂ capture increases the incremental power generation cost of the EGU from $25/MWh to $32/MWH.

With a CO₂ emission rate of 1.09 mt of CO₂ per MWh and a $50/mt 45Q “bounty”, the EGU receives $54/MWh, making its incremental cost of producing electricity negative ($32/MWh – ($54/MWh)).

With negative net costs per MWh, the EGU operates at capacity -- 3 million MWh per year versus 2 million MWh per year without CO₂ capture.

The EGU now has a net annual revenue margin of $141 million, $131 million per year higher than without CO₂ capture. This would provide an additional $1,570 million over 12 years ($1,100 million discounted at 7%).

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### An Illustrative Coal-Fueled Unit: With and Without CO₂ Capture

<table>
<thead>
<tr>
<th></th>
<th>Coal-Fueled EGU</th>
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<tbody>
<tr>
<td></td>
<td>No Capture</td>
</tr>
<tr>
<td>Heat Rate (MMBtu/MWh)</td>
<td>10</td>
</tr>
<tr>
<td>Cost of Fuel ($/MWh)*</td>
<td>20</td>
</tr>
<tr>
<td>Variable O&amp;M ($/MWh)</td>
<td>5</td>
</tr>
<tr>
<td>Total Incremental Cost ($/MWh)</td>
<td>25</td>
</tr>
<tr>
<td>CO₂ Capture (tonne/MWh)</td>
<td>-</td>
</tr>
<tr>
<td>Value of Captured CO₂ @ $50/mt($/MWh)</td>
<td>-</td>
</tr>
<tr>
<td>Value of Electricity When Generating ($/MWh)</td>
<td>30</td>
</tr>
<tr>
<td>Net Margin When Generating ($/MWh)</td>
<td>5</td>
</tr>
<tr>
<td>Generation of Electricity (MM MWh/yr)</td>
<td>2</td>
</tr>
<tr>
<td>Net Revenue Margin (million $ / yr)</td>
<td>10</td>
</tr>
<tr>
<td>Increase in Net Revenues Margin (million $ / yr)</td>
<td>+131</td>
</tr>
</tbody>
</table>

- 12 years 0% discount (million$) | $1,570
- 12 years 7% discount (million$) | $1,100

*Assumes $2/MM Btu for final cost.
Capital Costs for Retrofitting a Coal-Fueled Power Plant with CO₂ Capture

Drawing on the Shand CCS feasibility study and a similar study by CO2CRC in Australia, and after adjusting for plant size and U.S. dollars, the capital costs (TASC) for retrofitting a 400 MW coal-fueled power plant with CO₂ capture range from $1.1 to $1.2 billion.

<table>
<thead>
<tr>
<th>Net Power Output (MW)</th>
<th>Shand CCS Feasibility Study (1)</th>
<th>CO2CRC 2017 Study (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>U.S.</td>
</tr>
<tr>
<td>270</td>
<td>$786</td>
<td>$877</td>
</tr>
<tr>
<td>400</td>
<td>($CAN)</td>
<td>($U.S.)</td>
</tr>
<tr>
<td>450</td>
<td>($CAN)</td>
<td>($AUS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant Costs</th>
<th>Shand CCS Feasibility Study (1)</th>
<th>CO2CRC 2017 Study (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct (million)</td>
<td>$786</td>
<td>$877</td>
</tr>
<tr>
<td>TASC (million)</td>
<td>$986</td>
<td>$1,100</td>
</tr>
</tbody>
</table>

*$1US equals $1.34 Canadian; **$1 US equals $1.41 Australian.

Cost of Geologic CO$_2$ Storage: Gulf Coast

Geologic characterization of the U.S. DOE/NETL and Mississippi Power sponsored CarbonSAFE project (ECO$_2$S) site in the Gulf Coast shows that the site has a storage capacity of nearly 1,000 million metric tons. (Three stacked saline formations covering 50 mi$^2$).

Assuming storage of 3 million metric tons per year for 30 years and installation/operating costs of $135 million, the cost of CO$_2$ storage is $1.50$/metric ton (excluding CO$_2$ trunklines).
Using CO\textsubscript{2} Enhanced Oil Recovery for CCUS

Economically Viable CO\textsubscript{2} Storage Capacity (million metric tons)

<table>
<thead>
<tr>
<th>1. Conventional Oil Fields</th>
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<tbody>
<tr>
<td>▪ Lower-48 Onshore</td>
<td>15,300</td>
</tr>
<tr>
<td>▪ Alaska</td>
<td>2,000</td>
</tr>
<tr>
<td>▪ Lower-48 Offshore</td>
<td>?</td>
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</tbody>
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<table>
<thead>
<tr>
<th>2. Residual Oil Zones</th>
<th></th>
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<tbody>
<tr>
<td>▪ Permian Basin</td>
<td>18,600</td>
</tr>
<tr>
<td>▪ Other Basins</td>
<td>?</td>
</tr>
</tbody>
</table>

| 3. Shale/Tight Oil        | ? |

| Total                     | 35,900 |

While still only partly defined, the opportunity for productively using (and storing) CO\textsubscript{2} for EOR is vast – in conventional oil fields, the ROZ, and shale/tight oil formations.

With a comprehensive CO\textsubscript{2} pipeline system, CO\textsubscript{2} EOR could use (and store) 500 to 1,000 million metric tons annually in the critical year 2040 to 2050 time period.

CO\textsubscript{2} EOR provides lower oil related CO\textsubscript{2} emissions than other domestically produced or imported oil.
Lack of CO₂ transportation between sources and oil fields is the critical “missing link” for producing oil and storing CO₂ with EOR.

The study – “Making Carbon a Commodity” – proposed a comprehensive U.S. CO₂ pipeline system linking CO₂ captured from power plants with oil fields.
Concluding Comments

Incorporating wide-scale use of CCS/CCUS into an industrial decarbonization strategy would provide many benefits:

- Enables existing electric power and industrial assets to remain commercially viable.
- Promotes a socially just low-carbon energy transition, enabling carbon-intensive industrial regions to maintain employment and vitality.
- With availability of a 45Q tax credit (plus other support), provides a lower overall cost for decarbonizing energy.
- When linked with Enhanced Oil Recovery, CCUS provides lower oil related CO₂ emissions*, supports domestic energy security, creates new industrial activity and jobs, and provides additional state and federal revenues.

*More CO₂ will be stored by EOR than the CO₂ content of the oil produced.
An Economic Look at the Potential of CO2 Capture, Utilization and Storage

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