CO₂ ENHANCED OIL RECOVERY IMPROVEMENT IN CONVENTIONAL FIELDS USING RICH GAS
DE-FE0031789

U.S. Department of Energy National Energy Technology Laboratory
Oil and Gas Virtual Project Review Meeting
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Research Hypothesis: The injection of a blend of rich hydrocarbon gas and CO$_2$ into an oil reservoir will reduce molecular weight selectivity, lower minimum miscibility pressure and viscosity of the oil, and improve gas solubility, resulting in an overall improvement in EOR performance.
Project Goal: Determine the effect of injecting blended CO₂ and rich gas into an active CO₂ EOR field to improve production performance.

Project Objectives: The goal will be accomplished by completing several specific research objectives:

- Determine the quantity, transportation, compression, and injection needs for a field-based injection test.

- Inject blended CO₂ and rich gas in the Bell Creek Field for incremental recovery and associated CO₂ storage.

- Develop field-based data to determine the effects of rich gas additives in CO₂ on oil production.

- Use laboratory experiments to determine the potential for varying compositions of rich gas blended with CO₂ to improve oil recovery in other conventional reservoirs currently undergoing CO₂ EOR.

- Develop business case scenarios to assess the potential for using rich gas added to CO₂ at other EOR locations in the United States.
### FUNDING AND PROJECT PERFORMANCE DATES

<table>
<thead>
<tr>
<th></th>
<th>BP1 ($) 10/1/2019–3/31/2021</th>
<th>BP2 ($) 4/1/2021–9/30/2024</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Federal</td>
<td>Nonfederal</td>
<td>Federal</td>
</tr>
<tr>
<td>DOE</td>
<td>$2,184,364</td>
<td>–</td>
<td>$5,789,517</td>
</tr>
<tr>
<td>Schlumberger</td>
<td>–</td>
<td>$334,400</td>
<td>–</td>
</tr>
<tr>
<td>CMG</td>
<td>–</td>
<td>$212,993</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>$2,184,364</td>
<td>$547,393</td>
<td>$5,789,517</td>
</tr>
<tr>
<td>Total Cost Share %</td>
<td>80%</td>
<td>20%</td>
<td>80%</td>
</tr>
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Note: **Denbury** – Additional collaboration in the form of field support, infrastructure development, design and implementation, gas supply, and injection/production operations.

**Oneok** – Committed to working with Denbury and EERC to source rich gas for EOR test.
Previous laboratory and modeling work showed ethane can solvate a wider MW range of hydrocarbons than CO$_2$ alone, which could lead to more oil from the reservoir with better efficiency.

Blending rich gas components with CO$_2$ may provide means of improving oil recovery in fields either undergoing or planned for tertiary recovery.

Use of rich gas or rich gas–CO$_2$ blends for flooding operations can greatly reduce the quantity of CO$_2$ needed for EOR injection.
TECHNICAL APPROACH/PROJECT SCOPE

• Task 1.0 – Project Management and Planning

• Task 2.0 – Engineering Design
  – 2.1 – Rich Gas Source, Compression, and Transportation Evaluation
    DP: Go/no-go decision based on whether rich gas source is secured 12/31/2020
  – 2.2 – Core and Fluid Laboratory Evaluations
  – 2.3 – Blended CO₂-Rich Gas Injection Modeling and Simulation
  – 2.4 – Injection/Monitoring Program Design
TECHNICAL APPROACH/PROJECT SCOPE (CONT.)

• Task 3.0 – Field Operations and Monitoring (BP2)
  – 3.1 – Field Preparation
  – 3.2 – Field Validation and Monitoring
  – 3.3 – Rich Gas Supply Monitoring
  – 3.4 – Sample Analysis
  – 3.5 – Field Validation Decommissioning Activities

• Task 4.0 – Business Case for Blended CO₂-Rich Gas Utilization
  – 4.1 – Laboratory Studies
  – 4.2 – Data Management and Machine Learning Studies
  – 4.3 – Modeling and Simulation
  – 4.4 – Business Case Analysis
**PROJECT SCHEDULE WITH KEY MILESTONES**

| M2 | Injection Site Verified |
| M3 | Rich Gas Source Secured |
| M4 | Field Preparation Completed |
| M5 | All Core Samples Obtained |
| M8 | Blended CO₂-Rich Gas Injection Completed |
| M9 | Validation Test Fluid Sample Analyses Completed |

<table>
<thead>
<tr>
<th>Budget Period 1</th>
<th>Budget Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Year 1</td>
<td>Project Year 2</td>
</tr>
<tr>
<td>2019</td>
<td>2020</td>
</tr>
<tr>
<td>M2</td>
<td></td>
</tr>
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<td>M3</td>
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<tr>
<td>M8</td>
<td></td>
</tr>
<tr>
<td>M9</td>
<td></td>
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Field Validation
PROGRESS AND CURRENT STATUS OF PROJECT

Engineering Design
• EERC and Denbury are working toward a gas delivery plan and contract with a gas supplier.
• Core and fluid laboratory evaluations of Bell Creek samples are progressing.
• The injection pattern and site were selected.
• The geologic model for the pilot pattern has been updated, and EOS modeling based on the injection gas composition is complete.
PROGRESS AND CURRENT STATUS OF PROJECT

- Business case development has been initiated.
  - Rock samples were collected for the Rocky Mountain region.
  - Porosity, permeability, thin sections, and MICP are all complete for this set.
  - Additional samples for the Gulf Coast region are being identified and acquired.
  - Data collection for both regions has been initiated.
## PROGRESS AND CURRENT STATUS OF PROJECT

### Characteristics of CO₂ EOR Fields in Proposed Project

<table>
<thead>
<tr>
<th>Field</th>
<th>Basin</th>
<th>Zone</th>
<th>Dominant Lithology</th>
<th>Porosity Range, %</th>
<th>Permeability Range, mD</th>
<th>Thickness, ft</th>
<th>API Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell Creek</td>
<td>Powder River</td>
<td>Muddy</td>
<td>Marine sandstone</td>
<td>25–35</td>
<td>150–1175</td>
<td>30–45</td>
<td>32–41</td>
</tr>
<tr>
<td>Cedar Hills</td>
<td>Williston</td>
<td>Red River</td>
<td>Dolostone</td>
<td>13–23</td>
<td>15</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Tinsley</td>
<td>Mississippi Interior Salt</td>
<td>Woodruff</td>
<td>Shallow marine sandstone</td>
<td>26–28</td>
<td>1040–1300</td>
<td>80–90</td>
<td>32</td>
</tr>
<tr>
<td>Heidelberg</td>
<td>Mississippi Salt</td>
<td>Eutaw</td>
<td>Marine sandstone</td>
<td>28</td>
<td>10–3115</td>
<td>550</td>
<td>23</td>
</tr>
</tbody>
</table>
PLANS FOR FUTURE TESTING/DEVELOPMENT/COMMERCIALIZATION

• The pilot test during BP2 will provide a unique U.S. data set on rich gas EOR, paving the way for larger-scale tests and deployment.
• Positive pilot test results would support the development of infrastructure and a market for stranded rich gas.
• Results would be applicable to develop business cases for other potential target fields.
• Because of the ability to leverage existing oilfield infrastructure, commercial implementation of rich gas EOR could occur quickly.
• Project was successfully initiated in winter 2019.
• Project partners are engaged and involved in discussions pertaining to gas supply and composition.
• Task 2 activity is progressing with core flooding studies conducted for the Bell Creek site. Preliminary posttest fluid analysis supports MW selectivity.
• Task 2 modeling and simulation are ongoing and being updated with new laboratory results.
• Business case development has been initiated through data collection and laboratory analyses.
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APPENDIX
Task 1 – Project Management, Planning, and Reporting

- D1 – Updated Project Management Plan
- D2 – Data Management Plan
- D3 – Workforce Readiness Plan
- D4 – Laboratory Studies of Blended CO₂-Rich Gas
- EOR
- D5 – Data Submitted to NETL EDX

Task 2 – Engineering Design

- 2.1 – Rich Gas Source, Compression, and Transportation Evaluation
- 2.2 – Core and Fluid Laboratory Evaluations
- 2.3 – Blended CO₂-Rich Gas Injection Modeling and Simulations
- 2.4 – Injection/Monitoring Program Design

Task 3 – Field Injection and Monitoring

- 3.1 – Field Preparation
- 3.2 – Field Validation and Monitoring
- 3.3 – Rich Gas Supply Monitoring
- 3.4 – Sample Analysis
- 3.5 – Field Validation Decommissioning Activities

Task 4 – Business Case for Blended CO₂-Rich Gas Utilization

- 4.1 – Laboratory Studies
- 4.2 – Data Management and Machine Learning Studies
- 4.3 – Modeling and Simulation
- 4.4 – Business Case Analyses

Key for Deliverables (D)
- D1
- D2
- D3

Key for Milestones (M)
- M1
- M2
- M3
- DP
- M4
- M5
- M6
- M7
- M8
- M9
- M10

Summary Task
- Activity Bar
- Deliverable (D)
- Milestone (M)
- Decision Point (DP)
- Critical Path