Evaluation of CO2-EOR Injection and Its Potential Application to Indonesia

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## Outlines

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Introduction: Worldwide CO₂-EOR Project (as of 2012)

As of end of Q1-2012, there have been approximately 136 active projects of CO2-EOR fully-sanctioned and in-progress in five different countries.

Of this, ~89% (n=121) of the CO2-EOR projects were rolled-out within the continental USA (Texas, Wyoming, Oklahoma, Michigan, Mississippi, Montana, Louisiana and Utah).
**CO₂-EOR Project (1/3): US EOR Projects**

*The CO₂-EOR is a proven, mature technology and is accelerating in commercial application. There have been more CO₂ projects than any other EOR flood.*

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**EOR Production in the Continental USA (as of Apr-2012)**

- Steam and miscible gas projects combined account for more than 86% of the total EOR which account for nearly 9 of every 10 successful EOR projects.
- CO₂ miscible eclipses steam in US EOR production.
- Operators tried more than 200 polymer and surfactants projects during the 1980’s, but the results were disappointed.

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- EOR projects require high upfront investments and continuous reservoir monitoring.
- Most of EOR projects tie to oil prices except CO₂ projects.
CO₂-EOR Project (2/3): CO₂ Sources

The implementation of EOR processes has historically been a challenging task due to the limited availability of CO₂ supplies.

US Map of Lower 48 States: CO₂ Source and Pipeline Networks

- There are three possible CO₂ sources: (1) gas reservoirs containing high percentage of CO₂; (2) industrial or anthropogenic sources; and (3) natural CO₂ reservoirs.
- Depending on the purity, the source gas would require processing in order to bring the CO₂ concentration high enough (>95%) for pipeline quality and EOR process.

Natural CO₂ Sources

- CO₂ is commonly found in association with igneous events both volcanic and plutonic.
- CO₂ originates from the outgassing of deep magma chambers.
- CO₂ migrates upward via deep faults, fractures & reservoir horizons.
CO₂-EOR Project (3/3): Permian Basin CO₂ EOR Production

The oil & gas producing regions of the Permian Basin, in New Mexico and West have an original oil endowment of 95.4 billion barrels. Of this, ~61.7 billion barrels of oil will be “stranded”, following the use of today’s oil recovery practices.

### 20 Years of Oxy¹ EOR Production

- A major portion of this “stranded oil” is in reservoirs that appear to be technically and economically amenable to EOR using CO₂ injection.
- The single largest barrier to expanding CO₂ flooding in the Basin is the lack of substantial volumes of reliable and affordable CO₂. This is despite the fact that several supply market responses have been taken to attempt to address this limitation.

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### US Permian Basin

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¹Occidental Energy
Examples of CO$_2$ Flood Response in TX Permian Basin
EOR Cost Structure: Permian Basin

*It is economically evident today that the Permian EOR can operate at cash cost as low as $22.00 per BOE.*
Fundamental CO$_2$ Floods (1/2)

Why CO$_2$?

- Miscible at lower pressures than nitrogen or methane
- Cheaper and more plentiful than LPG/enriched gas
- Density closer to reservoir fluids (oil/water)
- Immiscible characteristics
- Soluble in water
- The price of CO$_2$ allows water to be used as the chase fluid

CO$_2$ in Action – Miscible WAG Flood

- CO$_2$ mixes with oil much like turpentine cleans paint from a brush.
- Inter-phase mass transfer typically yields NGL rich gas production.
- Chase water injection helps control mobility and gas recycle.
A successful operation requires coordination of the entire process from development of the CO2 source to production and separation.

Then, after injection and production, oil, water, and gas are separated, allowing the CO2 to be extracted from the separator gas, re-processed to purify CO2, dehydrated before re-compressed to raise its pressure for injection.
Stages of a CO₂ Flood Evaluation (1/4)

**CO₂ flood project has to go through series of studies to reduce the risk associated with the project.**

- **Phase I Screening**: Feasible? Yes → Stop, No → Feasible?
- **Phase II Screening**: Profit? No → Stop, Yes → Risk?
  - Risk? High → Project Design w/ Simulation
  - Risk? Low → Proposal
- **Proposal**: Profit? No → Stop, Yes → Proposal

**Data**
- Field Ave Data
- High-grade area Sweet Spots
- Detailed Reservoir Characterization

**Tools**
- Rules of Thumbs
- Screening Model/Prophet/Analogs
- Full Field Simulation

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Stages of a CO₂ Flood Evaluation (2/4)

Phase 1 Screening

<table>
<thead>
<tr>
<th>Distance from CO₂ Pipeline/Source</th>
<th>Heterogeneity/Loss Zones</th>
<th>Miscibility</th>
<th>Lease Considerations</th>
<th>Heterogeneity/Loss Zones</th>
<th>Composition</th>
<th>Formation Type</th>
<th>Residual Oil</th>
<th>Positive Factors</th>
<th>Negative Factors</th>
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<tbody>
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<td></td>
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<td></td>
<td></td>
<td>High Percentage of C2-C12 (Intermediate Components)</td>
<td>Sandstone or Carbonate</td>
<td>&gt;20%</td>
<td>Good waterflood performance (good sweep efficiency, reasonable throughput rates and good voidage balance)</td>
<td>Severe reservoir heterogeneity, adjacent loss zones (gas caps), dominant fracture systems</td>
</tr>
</tbody>
</table>

1 Minimum Miscibility Pressure is the key parameter for the design and operations of successful CO₂ flood.
Stages of a CO₂ Flood Evaluation (3/4)

Following the extant best practices, CO₂-EOR has been demonstrated to be profitable in commercial scale application for ~30 years mostly in the Permian Basin of West Texas.

<table>
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<th>CO₂ FLOOD PROJECT</th>
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<td>Quality Assurance (Project Management, Communication and Stakeholder Management)</td>
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<table>
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<tr>
<th>SCREENING</th>
<th>RESERVOIR DESCRIPTION</th>
<th>FLOOD PREDICTION</th>
<th>CO₂ SUPPLY</th>
<th>FACILITIES</th>
<th>ECONOMIC EVALUATION</th>
</tr>
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<tbody>
<tr>
<td>Reservoir Depth</td>
<td>Original Oil In Place (OOIP)</td>
<td>Incremental Recovery</td>
<td>CO₂ Purchases</td>
<td>Surface</td>
<td>Upfront Investment</td>
</tr>
<tr>
<td>Operating Pressure</td>
<td>Depositional Model</td>
<td>Process Design</td>
<td>Trunk Line to Project</td>
<td>Wells</td>
<td>Upgrading/Additions</td>
</tr>
<tr>
<td>Fluid Analysis</td>
<td>Depth</td>
<td>Flowstreams</td>
<td>Negotiations</td>
<td>Gas Processing</td>
<td>CapEx/OpEx</td>
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<tr>
<td>PVT Analysis</td>
<td>Porosity</td>
<td>Purchased CO₂ and Water</td>
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<td>Slim Tube</td>
<td>Permeability</td>
<td>Water Disposal</td>
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<td>Frac Pressure</td>
<td>Critical Saturations</td>
<td>Injectivity</td>
<td></td>
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<tr>
<td>Economic Throughput</td>
<td>Relative Permeability Data</td>
<td>Timing</td>
<td></td>
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<td></td>
<td>Pressure</td>
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Following the extant best practices, CO₂-EOR has been demonstrated to be profitable in commercial scale application for ~30 years mostly in the Permian Basin of West Texas.
Stages of a CO₂ Flood Evaluation (4/4)

Flow Process for Designing CO₂ Project

Conceptual Plans
- Data gathering and reviewing CO₂ flood project in the area/region

Preliminary Designs
- Development plans
- Facility specification
- Economic analysis

Final Designs
- Optimum development plan based on the best technically feasible and economically attractive scenarios that meets the corporate objectives
Mapping of Indonesia CO₂ EOR Potentials (1/4): North Sumatra Basin

- **CO₂ Source:** Kuala Langsa Field: 10 TCF; ~83% CO₂
- **CO₂-EOR Candidates:** Fields near this CO₂ source
Mapping of Indonesia CO₂ EOR Potentials (2/4): South Sumatra Basin

- **CO₂ Source:**
  - Corridor Wells show high CO₂ volumes

- **CO₂-EOR Candidates:**
  - Central Sumatra Fields
  - South Sumatra Fields
  - West Java Basin
Mapping of Indonesia CO₂ EOR Potentials (3/4): East Java Basin

**East Java Basin**

- **CO₂ Source:**
  - Jambaran-Tiung Biru
  - 2.53 TCF IGIP
  - ~85-165 MMCFD CO₂ rate for 5 years

- **CO₂-EOR Candidates:**
  - Fields near this CO₂ source
  - Sukowati Field
  - 303 MMSTB OOIP
  - 34% RF
  - 40% CO₂ in gas stream
Mapping of Indonesia CO₂ EOR Potentials (4/4): Natuna Basin

**Natuna Basin**

- **CO₂ Source:**
  - Natuna D Alpha Field Offshore
  - 160 TCF Overpressured CO₂
  - 5200’ Column: 60-80% CO₂
  - Porous and Permeable Limestone
  - Facies at 10,000’

- **CO₂-EOR Candidates:**
  - Offshore Malaysia Fields 300-500 Miles
  - To East: Potentially Large Opportunities
  - Onshore Brunei: Declining Seria Field:
    - 2 MMMBO OOIP
    - Entirely Offshore PL
  - Exploration Synergy
Conclusions

- CO₂-EOR is proven and the most promising EOR techniques.
- With the availability of CO₂ Sources, many mature and declining oil fields throughout Indonesia become prime target for CO₂-EOR application.
Closing Note from Ariska Putri Pertiwi, Miss Grand International 2016

“Indonesia, we did it”
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