CO$_2$ UTILIZATION FOR EOR AT OIL FIELDS IN INDONESIA

SUGIHARDJO

Research and Development Centre for Oil and Gas Technology “LEMIGAS”
Background

World Energy-Related CO₂ Emissions by Fuel Type

- The rising of CO₂ emissions:
  - The Increasing Petroleum Industry
  - The heavy reliance on fossil fuels
  - Deforestation
  - Population and economic growth

Background (cont’d)

- The declining of oil production in Indonesia
- GOI’s oil production target for 2010 is only 1.1 Million Bpd
- Depleted oil and gas reservoirs

Total OOIP: 61.1 BSTB

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Background (cont’d)

- Build-up Stage
- Plateau Stage
- Decline Stage

- Peak 1977
- Peak 1995

- Other PSC’s

Chevron Pacific
Indonesia

- Million barrels

- 1966 to 2002
Background (cont’d)

IOR Concepts

Effort to force additional petroleum out of the pores in the reservoir rock

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Background (cont’d)

Advantages of CO₂ EOR

- Dramatic Improvement of Oil Recovery
- CO₂ is Ultimate Injectant with Proven Effects/Superior to Gas & Water

Ultimate Oil Recovery (Typical)

- Secondary Recovery 30 % of OOIP
- CO₂ Injection 45 % of OOIP

- Saving Natural Gas Consumption
- Environmental and Economic Effect

Reduction of CO₂ Emission ⇒ New Initiative (Kyoto Protocol)
CO2 Sources

Depleted Oil Reservoirs

PHILIPPINES

Bontang LNG Plant

Natuna

South Sumatra

East Kalimantan

West Jawa

CO2 Separation

Storage Capacity: 38 – 152 MtCO2
Oil Recovery: 265 – 531 Million bbl

Storage Capacity: 18 – 36 MtCO2
Oil Recovery: 84 – 167 Million bbl
Project Activity Diagram

Laboratory Tests
- Miscibilities Studies
- PVT Studies
- Extraction Experiments
- Core Flooding Experiments

Study of CO₂ Sources, Capture and Transportation

Simulation of Laboratory Experiments

Reservoir Simulations

Reservoir Data & Geological Data from Oil Field

Economic Analyses, Summary & Conclusions
Oil Fields Selection
FOR CO$_2$-EOR

Reservoir Parameters
- Viscosity
- Gravity
- Composition
- Oil Saturation
- Formation Type
- Net Thickness
- Ave. Permeability
- Depth
- Temp

EOR Methods
- Nitrogen and Flue Gas
- Hydrocarbon
- CO2
- Immiscible gas
- Micellar/ASP/Alkaline
- Polymer
- Combustion
- Steam
- Surface Mining

Choose the best method
### Oil Fields Selection (cont’d)

<table>
<thead>
<tr>
<th>Reservoir Parameter</th>
<th>Screening Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Gravity</td>
<td>API &gt; 22, 36 a</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Cp &lt; 10, 1.5</td>
</tr>
<tr>
<td>Composition</td>
<td>High percent of C5 to C12</td>
</tr>
<tr>
<td>Oil Saturation</td>
<td>%PV &gt; 20, 55</td>
</tr>
<tr>
<td>Formation Type</td>
<td>Sand St. or Carbonate</td>
</tr>
<tr>
<td>Net Thickness</td>
<td>ft Wide Range</td>
</tr>
<tr>
<td>Average Permeability</td>
<td>mD NC</td>
</tr>
<tr>
<td>Depth</td>
<td>ft &gt; 2.500 a</td>
</tr>
<tr>
<td>Average Temperature</td>
<td>°F NC</td>
</tr>
</tbody>
</table>
Oil Fields Selection (cont’d)

INDONESIA PETROLEUM WORKING AREAS 2008

Total Working Areas = 200
## Oil Fields Selection (cont’d)

<table>
<thead>
<tr>
<th>NO.</th>
<th>COMPANY</th>
<th>FIELD</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CHEVRON</td>
<td>ATTAKA</td>
<td>SOUTH KALIMANTAN</td>
</tr>
<tr>
<td>2</td>
<td>PERTAMINA</td>
<td>SANGATTA</td>
<td>SOUTH KALIMANTAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JATIBARANG</td>
<td>WEST JAWA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TUGU BARAT</td>
<td>WEST JAWA</td>
</tr>
<tr>
<td>3</td>
<td>MEDCO</td>
<td>KAJI SEMOGA</td>
<td>SOUTH SUMATERA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JENE</td>
<td>SOUTH SUMATERA</td>
</tr>
</tbody>
</table>
Laboratory Evaluation

- MMP Determination
- Viscosity Reduction
- Swelling of Oil
- Oil Composition Lighter
- RF Incremental Determination
MMP Determination

SLIM TUBE

[Graph showing MMP determination with the point of MMP = 2150 psi highlighted.]
Increasing Ps and Swelling of Oil

**SATURATION PRESSURE VS CO2 INJECTION RELATIONSHIP**

- Initial Saturation Pressure

**SWELLING OF OIL**

- Initial Saturation Pressure

- LEMIGAS
Viscosity Reduction

Viscosity of CO₂ Oil Rich

- Ps=835
- CO₂ Ps=1250
- CO₂ Ps=1380
- CO₂ Ps=1500
- CO₂ Ps=1658
- CO₂ Ps=1850

Pressure (Psig) vs. Viscosity (Cp)

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## Oil Composition Lighter

<table>
<thead>
<tr>
<th>Components</th>
<th>Original Reservoir Oil Mol %</th>
<th>CO₂-Oil System I Mol %</th>
<th>CO₂-Oil System II Mol %</th>
<th>CO₂-Oil System III Mol %</th>
<th>CO₂-Oil System IV Mol %</th>
<th>CO₂-Oil SystemnV Mol %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>0.770</td>
<td>26.558</td>
<td>33.687</td>
<td>39.778</td>
<td>47.494</td>
<td>55.958</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.010</td>
<td>0.007</td>
<td>0.007</td>
<td>0.006</td>
<td>0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.300</td>
<td>2.442</td>
<td>2.205</td>
<td>2.003</td>
<td>1.746</td>
<td>1.465</td>
</tr>
<tr>
<td>Propane</td>
<td>4.820</td>
<td>3.567</td>
<td>3.221</td>
<td>2.925</td>
<td>2.550</td>
<td>2.139</td>
</tr>
<tr>
<td>i-Butane</td>
<td>1.960</td>
<td>1.451</td>
<td>1.310</td>
<td>1.190</td>
<td>1.037</td>
<td>0.870</td>
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<tr>
<td>n-Butane</td>
<td>2.770</td>
<td>2.050</td>
<td>1.851</td>
<td>1.681</td>
<td>1.466</td>
<td>1.229</td>
</tr>
<tr>
<td>i-Pentane</td>
<td>2.010</td>
<td>1.488</td>
<td>1.343</td>
<td>1.220</td>
<td>1.064</td>
<td>0.892</td>
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<tr>
<td>n-Pentane</td>
<td>1.540</td>
<td>1.140</td>
<td>1.029</td>
<td>0.935</td>
<td>0.815</td>
<td>0.684</td>
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<tr>
<td>Hexane</td>
<td>2.760</td>
<td>2.043</td>
<td>1.844</td>
<td>1.675</td>
<td>1.460</td>
<td>1.225</td>
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<tr>
<td>Heptane+</td>
<td>62.800</td>
<td>46.479</td>
<td>41.968</td>
<td>38.113</td>
<td>33.230</td>
<td>27.873</td>
</tr>
<tr>
<td></td>
<td><strong>100.000</strong></td>
<td><strong>100.000</strong></td>
<td><strong>100.000</strong></td>
<td><strong>100.000</strong></td>
<td><strong>100.000</strong></td>
<td><strong>100.000</strong></td>
</tr>
</tbody>
</table>
RF Incremental Determination

Core Holder

RECOVERY FACTOR OF COREFLOOD TEST AT INJECTION PRESSURE OF 2250 PSIG

Core flooding Rig

Initial Gasflood

Waterflood

Gas Breakthrough

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<table>
<thead>
<tr>
<th>Well</th>
<th>8D-67E</th>
<th>8D-67E</th>
<th>8D-67E</th>
<th>8D-67E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug No</td>
<td>41</td>
<td>38</td>
<td>65</td>
<td>73</td>
</tr>
<tr>
<td>Psp (md)</td>
<td>3210</td>
<td>4460</td>
<td>5890</td>
<td>4730</td>
</tr>
<tr>
<td>Por (%)</td>
<td>30.5</td>
<td>31.0</td>
<td>29.6</td>
<td>29.7</td>
</tr>
</tbody>
</table>
### Field Selection for Simulation Study

<table>
<thead>
<tr>
<th>FIELD</th>
<th>WELL</th>
<th>MMP PSIG</th>
<th>COREFLOOD RF (% Sor)</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTAKA</td>
<td>B-19</td>
<td>2150</td>
<td>90.00</td>
<td>EAST KALIMANTAN</td>
</tr>
<tr>
<td></td>
<td>UB-1</td>
<td>3150</td>
<td>No. CF</td>
<td></td>
</tr>
<tr>
<td>SANGATTA</td>
<td>ST-77</td>
<td>2800</td>
<td>93.26</td>
<td>EAST KALIMANTAN</td>
</tr>
<tr>
<td>JATIBARANG</td>
<td>JTB-137</td>
<td>2575</td>
<td>96.37</td>
<td>WEST JAWA</td>
</tr>
<tr>
<td>TUGU BARAT</td>
<td>TGB-06</td>
<td>3000</td>
<td>52.67</td>
<td></td>
</tr>
<tr>
<td>KAJI SEMOGA</td>
<td>KS-100</td>
<td>2420</td>
<td>70.00</td>
<td>SOUTH SUMATERA</td>
</tr>
<tr>
<td>JENE</td>
<td>Jene-12</td>
<td>3200</td>
<td>91.33</td>
<td></td>
</tr>
</tbody>
</table>

- Sangatta : LEMIGAS
- Jene : LEMIGAS
- Jati Barang : PERTAMINA

**Selected For Simulation Study**
Simulation Process

- Select Well Data
- Variogram Analysis
- Extract Marker Data
- Surface Structure
- 3D Seismic
- Rock Core
- Petrophysics
- Geological

- Reservoir Model
- Upscaling
- Reservoir Simulation
- Lemigas
Sangata Field Simulation

ATTAKA UNIT
(289km²)

BADAK UNIT

NILAM UNIT

OFFSHORE MAHAKAM BLOCK
(5,112km²)

LEMGAS
Sangata Field Simulation
Jene Field Simulation
Jene Field Simulation
CO₂ Storage – EOR Potential

Rule-of-Thumb Approach (historical experience)

- Incremental Oil Recovery (% OOIP)
  - 8-16 %
- Gross CO₂ Utilization (Mcf/Bbl)
  - 5-10 Mcf/Bbl
- Net/Gross Utilization Ratio (fraction)
  - 0.5
Plan of Implementation (cont’d)

Preparation of Implementation

- Estimating Enhanced Oil Production by Laboratory Tests & Studies
- Estimating CO$_2$ Delivery Cost
- Studying Total Project Economics
- Studying the Merit of CDM Scheme
Plan of Implementation (cont’d)

Concept of CO₂ Emission Reduction and Utilization In Bontang Area

- **Existing Facilities**
  - CO₂ (Off Gas) → CO₂ Compression & Dehydration
  - 4,300 T/D

- **Bontang LNG Plant**
  - Flue Gas → CO₂ Recovery → CO₂ → CO₂ Compression & Dehydration
  - 16,000 T/D

- **Neighbor Oil Fields**
  - ATTAKA, HANDIL, BEKAPAI, SANGATTA, Etc.
  - CO₂ Pipeline (8~20”)
  - 2,000 psig

- **CO₂ Pipeline**
  - Oil Production Incremental
Conclusions

• CO₂ emission especially from Petroleum Industries must be re-injected to follow CDM Scheme

• EOR is the only method to increase oil recovery and offset of cost only project for emission reduction

• Indonesia may build up work cooperation with other countries to implement CO₂-EOR project at Indonesian oil field
THANK YOU