Work Progress High CO₂ Gas Reservoir in INDONESIA (PERTAMINA)

Presented:
Putu Suarsana, Ph.D
BDC EP ASCOPE
PERTAMINA
(ips3150@pertamina-ep.com)

CCOP EPPM PROGRAM – Workshop on Development Of Natural Gas Resources with High CO₂ & Carbon Storage (CCS)
in CCOP – 17-20 March 2009
Bali Indonesia
Outlines

• Gas Supply & Demand in ASEAN Region
• High CO$_2$ Gas Reservoir Description
• Source of CO$_2$ gas Generation in Indonesia
• High CO$_2$ Gas Development
Deliverability

• To Report The High CO₂ Gas Reservoir Development In Indonesia (PERTAMINA)

• To Develop Gas Reservoir Which Contain High CO₂

• To Utilize The CO₂ To Increase The Production

• To Have environmental Benign
Observations on the data for TAGP Conceptual Masterplan 2007

Regional Supply Vs Demand (Base Case) (inclusive supply from E Natuna)

Observations:

- There is a widening supply gap from 2017 rising to more than 12,000 mmscfd by 2025.

- This shortfall reflects declining gas reserves causing gas supply to plateau and starts to decline while at the same time demand continues to rise strongly.

- This shortfall could be addressed by new discoveries in the region, or by increased imports of LNG Gas consumption.

  (E&P BD has been informed to study at ASCOPE level how best we can further increase supply)

  (East Natuna commercialisation is key at ASCOPE level)

- While finalising masterplan, demand figures constantly increases
Alternative Sources of Gas
Proposed by: ASCOPE BDC EP

- High CO2 Gas Reservoir
- Coal Bed Methane (CBM)
High $\text{CO}_2$ Concentration Gas Field

- Marginal Field
- Non Hydrocarbon Reservoir
- Unconventional Reservoir
- Supercritical Reservoir

- High $\text{CO}_2$ Content Gas:
  - Incombustible Matter
  - Possible climate changes
  - Corrosion
Development Purposes of High CO2 Gas Reservoir:

- To Produce Marketable Gas
- To Produce Feed Gas for LNG Plants
- To Produce Gas Oil, Kerosene, Naphtha
- Environmental Friendly Gas Fuel
- Producing - Unconventional Reservoir
- CO2 Flooding
Considered Marginal Field

Considered as Marginal Field:

• Hydrocarbon Volume: …. BSCF?
• Field Location: - Water Depth?
  - Remote Area?
  - Conflict Area?

• Structure Complexity

• Fluid Contain: - High CO2 Concentration
  - High H2S Concentration
  - Heavy Oil, Gas,
Reservoir Fluid Classification

- WATER RESERVOIRS: “WATER”: \( \text{H}_2\text{O} + \text{Cl}^- \)
- HYDROCARBON RESERVOIRS: \( \text{C}_1-\text{C}_{30}^+ > 75 \text{ mol}\% \), Impurities: \( \text{H}_2\text{S}, \text{CO}_2 \)
  1. Black Oil
  2. Volatile Oil
  3. Condensate
  4. Wet Gas
  5. Dry Gas

- NON HYDROCARBON RESERVOIRS
  - \( [\text{CO}_2] > 70 \text{ mol}\% \)
  - \( [\text{C}_1-\text{C}_{30}^+] < 30 \text{ mol}\% \)
## Types of Reservoir Fluid

<table>
<thead>
<tr>
<th>Type</th>
<th>Dry Gas</th>
<th>Wet Gas</th>
<th>Gas Condensate</th>
<th>Volatile Oil</th>
<th>Black Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apperance in</td>
<td>Colourless</td>
<td>Colourless</td>
<td>Colourless</td>
<td>Brown Liquid</td>
<td>Black viscous liquid</td>
</tr>
<tr>
<td>Surface</td>
<td>Gas + some</td>
<td>Gas + some clear</td>
<td>+ significant clear</td>
<td>some red/green colour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>clear liquid</td>
<td>liquid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial GOR</td>
<td>no liquids</td>
<td>&gt;15000</td>
<td>3000-15000</td>
<td>2500-3000</td>
<td>100-2500</td>
</tr>
<tr>
<td>(scf/stb)</td>
<td>&gt;= 100000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¹API</td>
<td>-</td>
<td>60-70</td>
<td>50-70</td>
<td>40-50</td>
<td>&lt;40</td>
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<tr>
<td>Gas S.G</td>
<td>0.60-0.65</td>
<td>0.65-0.85</td>
<td>0.65-0.85</td>
<td>0.65-0.85</td>
<td>0.65-0.8</td>
</tr>
<tr>
<td>Composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mol%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₁</td>
<td>96.3</td>
<td>88.7</td>
<td>72.7</td>
<td>66.7</td>
<td>52.6</td>
</tr>
<tr>
<td>C₂</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>C₃</td>
<td>0.4</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>3.5</td>
</tr>
<tr>
<td>C₄</td>
<td>0.17</td>
<td>1.3</td>
<td>2.5</td>
<td>3.3</td>
<td>1.8</td>
</tr>
<tr>
<td>C₅</td>
<td>0.04</td>
<td>0.6</td>
<td>1.8</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>C₆</td>
<td>0.02</td>
<td>0.2</td>
<td>2</td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td>C₇+</td>
<td>0</td>
<td>0.2</td>
<td>5</td>
<td>11</td>
<td>27.9</td>
</tr>
</tbody>
</table>
Example of High CO$_2$ Concentration

- **Indonesia:**
  Natuna Field: 71 mol% CO$_2$ - Gas Zone
  45 mol% CO$_2$ - Oil Zone
  West Java: 45% - 75% mol CO$_2$

- **Argentina:** El-Trapial Field 45-75% mol CO$_2$

- **Romania:** Up to 95% mol CO$_2$
High-CO2-Concentration Reservoir
Unconventional Gas Reservoir

- Natuna Gas Main Composition:
  - CH4: 26 Mol%
  - CO2: 71 Mol%

- Non Marketable Gas:
  - Natuna Gas Heating Value: 350 Cals./scf
  - Marketable gas Heating Value: >1000 Cals/scf
  - CO2: <10 Mol%
  - Power Plant can accept: 17 Mol%

- Non Feed Gas for LNG Plant:
  - High CO2’ Low Methane
  - Arun Gas: Methane: 68 Mol% CO2: 14 Mol%
High-CO$_2$-Concentration Reservoir

“Unconventional Gas Reservoir”

• High Technology to Handle the reservoir
• Additional treatment to put in the market
Corrosion Problem

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \quad \text{(Carbonic Acid)}
\]

\[
\text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \quad \text{(Bicarbonate Acid Ion)}
\]

\[
\text{HCO}_3^- \rightarrow \text{H}^+ + \text{CO}_3^{++} \quad \text{(Carbonic Ion)}
\]
Special Handling if there is $\text{H}_2\text{S}$

- Attention on Drilling, Testing, Production
- High $\text{CO}_2$ gas difficult to burn, $\text{H}_2\text{S}$ will spread on surface
Is This Marginal Enough?
Do we give up?
**CO$_2$ GENERATION**

- Decarboxylation of Coal
  \[
  C_cH_bO_o \rightarrow C_{(0.691c-x)}H_{(b-0.0806c-2y)}O_{(o-2x-y)} + (CH2)_{0.210c} + 0.099c \text{ CH}_4 + x \text{ CO}_2 + y \text{ H}_2\text{O}
  \]

- Calcite Dissolution
  \[
  \text{CaCO}_3 + 2 \text{ H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}
  \]
High CO2 Research – Pertamina

1. CO2 separation with Single Stage Cryogenic, CO2 injection to Separate Aquifer. ExxonMobil + Pertamina
   Field: Natuna, [CO2]: 72 mol%

2. CO2 separation with Multi Stage Cryogenic, CO2 recycling to the Reservoir. Pertamina + Texas A&M University
   Field: Natuna, [CO2]: 72 mol%

3. CO2 + Methane → Gas To Liquid (GTL). Pertamina + JNOC. Field: Muara Bulian, [CO2]: 40 Mol%.

4. CO2 Flooding. Pertamina + Lemigas + ITB. West Java Field

5. Future: Combination of 2 and 3.
Single Stage Cryogenic

- Producing Natural Gas with CO$_2$ 72 Mol% 
- CO$_2$ separation with Single Stage Cryogenic 
- CO$_2$ injection to Separate Aquifer. 
- Company: ExxonMobil + Pertamina 
- Field: Natuna 
- Initial Gas In Place: 222 TSCF Raw gas, 40 TSCF C1 
- Product: Natural Gas with CO$_2$ 17 Mol% 
- Market: Power Plant
Single Stage Cryogenic

Natural Gas [CO2] 17 Mol% MMscf/D

Sep I P1, T1

CO2 MMscf/D

MMscf/D

Natuna Reservoirs

Natural Gas, [CO2] 72 Mol %

Aquifer

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Multi Stage Cryogenic

- Producing Natural Gas with CO$_2$ 72 Mol%
- CO$_2$ separation with Multi Stage Cryogenic
- CO$_2$ Recycling
- Company: Pertamina + Texas A&M University
- Field: Natuna, West Java Field
- Initial Gas In Place: 222 TSCF Raw gas, 40 TSCF C1
- Product: Natural Gas with CO$_2$ <<10 Mol%
- Market: Not Specific
Multi Stage Cryogenic

Marketable Natural Gas
[CO2] < 10 Mol%

LNG Feed Gas

P1 >= P2 >= P3 >= Pn
T1 >= T2 >= T3 >= Tn

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Natuna Gas Processing

• Selecting Second Stage Separator

<table>
<thead>
<tr>
<th>Component</th>
<th>Mol%</th>
</tr>
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<tbody>
<tr>
<td>CO₂</td>
<td>69.82</td>
</tr>
<tr>
<td>C₇N₂</td>
<td>28.85</td>
</tr>
<tr>
<td>HSC₂</td>
<td>1.28</td>
</tr>
<tr>
<td>C₉⁺</td>
<td>0.05</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Sep I
1300 psig 60 F,

<table>
<thead>
<tr>
<th>Component</th>
<th>Mol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>71.22</td>
</tr>
<tr>
<td>C₇N₂</td>
<td>27.18</td>
</tr>
<tr>
<td>HSC₂</td>
<td>1.43</td>
</tr>
<tr>
<td>C₉⁺</td>
<td>0.17</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Fv = 0.84

Fv

Sep II
P₂, T₂

Fl = 0.16

MMscf/D

Natuna Reservoirs

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Gas To Liquid

- Producing Natural Gas with CO₂ 40 Mol%
- CO₂ + Methane → GTL
- Company: Pertamina + JNOC
- Field: Muara Bulian, Central Sumatra
- Initial Gas In Place: 541 BSCF Raw gas, 324 BSCF C1
- Product: Naphta, Kerosene, Gas Oil
- Market: Not Specific
- Pilot Project:
  - Feed Gas: 6 MMSCFD (incl. CO2 40%)
  - Product: 500 BPD
CO$_2$ Flooding

- Producing Natural Gas with CO$_2$ >80 Mol%  
- CO$_2$ Injection to Oil Reservoir – Miscible Flooding  
- Company: Pertamina, Lemigas, ITB  
- Field: West Java Field (Jati Barang & Tugu Barat)  
- Target: 25-30 % Oil Incremental

- Future Target: Kawengan Field Layer 2,  
  • Gas Source from: Cepu Block

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**CO₂ Flooding**

Amien Process
- Alternative: - Membrane
  - Cyclone
  - Cell

**Comp**

- \( P_{1, T1} \)

**MMscf/D**

**CO₂**

**MMscf/D**

**West Java Field**

Natural Gas, \([\text{CO₂}] > 90\text{Mol\%}\)

**CO₂**

**MMscf/D**

**Jati Barang**

Incremental Oil: 25%

**Future Plan:** CO₂ injection in Kawengan - Central Java, CO₂ From Cepu Block Field
Proposed:
Multi Stage Cryogenic + GTL

- Producing Natural Gas with CO₂ 72 Mol% 
- First Stage CO₂ separation to 40 Mol% 
- [CO₂] 40 mol% + C1 → GTL 
- Next Stage CO₂ separation to 10 Mol% 
- Company: Pertamina + JNOC + ExxonMobil 
- Field: Natuna 
- Initial Gas In Place: 222 TSCF Raw gas, 40 TSCF C1 
- Product:
  - Natural Gas with CO₂ <<10 Mol% 
  - Naphtha, Kerosene, Gas Oil
Multi Stage Cryogenic + GTL

GTL Plant

Naphtha, Gas Oil, Kerosene, Etc

Marketable Natural Gas [CO2] < 10 Mol%

Natural Gas [CO2] 40 Mol%

Sep I P₁, T₁

Sep II P₂, T₂

Sep III P₃, T₃

Sep IV P₄, T₄

P₁ ≥ P₂ ≥ P₃ ≥ Pₙ
T₁ ≥ T₂ ≥ T₃ ≥ Tₙ

Fl

Fv

Fl

Fl

Fl

Natuna Reservoirs

Natural Gas [CO2] 72 Mol%
Conclusions

• High-CO2-Content Reservoir is considered as “Marginal Field”
• High-CO2-Content Reservoir has specific properties
• There are several option processes to optimize the hydrocarbon production
• There are several fields Which contain high CO2 still undeveloped
• Combination of Multi Stage Cryogenic and Gas To Liquid is the best process for High-CO2-Content reservoir
• MSC produces marketable gas with CO2 content less than 10 mol%
• GTL produces Naphtha, kerosene, Gas Oil petrochemical product
• CO2 recycling can avoid global warming from excessive CO2 produced
Thanks