“Technical Challenges and Solutions on Natural Gas Development in Malaysia”

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PETRONAS / PETRONAS CARIGALI

The petroleum Policy and Management (PPM) Project
4th Workshop of the China – Sichuan Basin Case Study

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PETRONAS Corporate Agenda as the driving force

Global Championship

PETRONAS Corporate Agenda

Core pillars
- Integrated Asian Gas and Global LNG
- Capability-driven global E&P
- Superior performing downstream

Triple + elements
- Leadership development
- Capability building
- Mindset and behavior change

• PETRONAS aspires to become one of the global champions
• Both *Integrated Asian Gas and Global LNG* (Demand) and *Capability Driven Global E&P* (Supply) of natural gas are the two core pillars of PETRONAS activities
• Supplemented by strengthening soft issues i.e. Leadership, capability and mindset
PETRONAS: Custodian of Malaysian Oil and Gas Resources

A distinctive resource owner and manager, maximizing value of Malaysia’s hydrocarbon resources

Petroleum Management Unit (PMU)

Facilitates development & production

Monitor all E&P companies

Attract exploration investments

Optimize Malaysian E&P Assets

Reliable gas supplier for domestic power and petrochemicals

Integrated ASEAN gas and Global LNG player

PETRONAS

Malaysian Crude and Gas Production

Malaysian Historical Natural Gas Trend

- Current reserves is in plateau stage
- Gas supply is critical to PGU and MLNG
- Our target is to have a minimum of 100% replacement ratio
- At current production rate, our reserves life is 33 years
PETRONAS continues to strengthen ASEAN energy security

Malaysia-Thailand JDA came on stream and gas is linked to existing PGU gas pipelines

Securing new customers in Singapore with supply coming from PGU network

The Thailand-Malaysia-Singapore linkages will further enhances Trans-ASEAN Gas Pipeline System with Malaysia as the core

Integrated LNG facilities supported by world largest fleet of carriers supplies 21% of global LNG demand

3rd largest LNG producer supported by world’s largest fleet of LNG carriers ensuring credible and reliable supply for ASEAN and North Asia markets

For the purpose of this workshop: we will discuss two major scenarios on natural gas development in Malaysia

Natural Gas Development in Malaysia

High CO2 stranded gas development

Low permeability gas development
Over 13 Tscf of hydrocarbon gas remains undeveloped in high CO2 fields

The individual field CO2 content ranges from 28% to 87%
### Summary of High CO₂ Gas Fields

<table>
<thead>
<tr>
<th>Holder</th>
<th>Field</th>
<th>Total EUR (TSCF)</th>
<th>EUR Net of CO₂ (TSCF)</th>
<th>CO₂ Content</th>
<th>CO₂ Volume (TSCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETRONAS</td>
<td>Bujang</td>
<td>1.47</td>
<td>0.5</td>
<td>66%</td>
<td>0.97</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>Sepat</td>
<td>1.20</td>
<td>0.48</td>
<td>60%</td>
<td>0.72</td>
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<tr>
<td>PETRONAS</td>
<td>Noring</td>
<td>0.58</td>
<td>0.23</td>
<td>60%</td>
<td>0.35</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>Inas</td>
<td>1.04</td>
<td>0.42</td>
<td>60%</td>
<td>0.62</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>Tangga Barat</td>
<td>0.33</td>
<td>0.22</td>
<td>32%</td>
<td>0.11</td>
</tr>
<tr>
<td>PCSB</td>
<td>Ular</td>
<td>0.14</td>
<td>0.07</td>
<td>50%</td>
<td>0.07</td>
</tr>
<tr>
<td>PCSB</td>
<td>Gajah</td>
<td>0.12</td>
<td>0.06</td>
<td>50%</td>
<td>0.06</td>
</tr>
<tr>
<td>PCSB</td>
<td>Bergading</td>
<td>1.36</td>
<td>0.82</td>
<td>40%</td>
<td>0.54</td>
</tr>
<tr>
<td>PCSB</td>
<td>Beranang</td>
<td>0.08</td>
<td>0.06</td>
<td>28%</td>
<td>0.02</td>
</tr>
<tr>
<td>EMEPMI</td>
<td>Palas NAG</td>
<td>0.38</td>
<td>0.2</td>
<td>46%</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>6.70</strong></td>
<td><strong>3.06</strong></td>
<td></td>
<td><strong>3.64</strong></td>
</tr>
</tbody>
</table>

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<th>CO₂ Volume (TSCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETRONAS</td>
<td>K5</td>
<td>25.65</td>
<td>7.70</td>
<td>70%</td>
<td>17.95</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>J5</td>
<td>5.37</td>
<td>0.70</td>
<td>87%</td>
<td>4.67</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>J1</td>
<td>1.43</td>
<td>0.59</td>
<td>59%</td>
<td>0.84</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>T3</td>
<td>1.04</td>
<td>0.39</td>
<td>62%</td>
<td>0.65</td>
</tr>
<tr>
<td>PETRONAS</td>
<td>Tenggiri Mm.</td>
<td>0.33</td>
<td>0.18</td>
<td>47%</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>33.82</strong></td>
<td><strong>9.56</strong></td>
<td></td>
<td><strong>24.26</strong></td>
</tr>
</tbody>
</table>

High CO₂ Gas Fields in PM313 cluster identified as potential contributor for the CO₂ requirement in Peninsular Malaysia.
High CO₂ Gas Fields in South West Luconia cluster identified as potential contributor for the CO₂ requirement in Sarawak.

**South West Luconia Fields**

<table>
<thead>
<tr>
<th>Field</th>
<th>CO₂ Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK301</td>
<td>85%</td>
</tr>
<tr>
<td>SK302</td>
<td>90%</td>
</tr>
<tr>
<td>SK303</td>
<td>80%</td>
</tr>
</tbody>
</table>

### South West Luconia Fields

<table>
<thead>
<tr>
<th>Field</th>
<th>CO₂ Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK304</td>
<td>75%</td>
</tr>
<tr>
<td>SK305</td>
<td>85%</td>
</tr>
<tr>
<td>SK306</td>
<td>90%</td>
</tr>
</tbody>
</table>

There are multiple issues and challenges facing the development of high CO₂ gas fields:

- **High CO₂ content. Up to 85%**
- **Technology not fully ready to deal with very high CO₂ content coupled with very high flow rate**
- **Large footprint and exotic materials leads to astronomical capital expenses**
- **High pipeline cost due to tolerance for CO₂**
- **Users and/or disposal locations scattered and far from production area**

- **Kyoto protocol becoming legally binding**
- **Massive CO₂ by products from field production**
- **Meeting EOR requirement**

- **Economic outlook for field development alone may not be favorable hence the need for holistic approach**
- **Optimal development solution need to balance between time to meet gas demand and most economic development option**
Key challenges of developing high CO\textsubscript{2} fields and synergies development with EOR (1)

- Supply and Demand synergies
  - Demand from EOR is rather limited in volume and timescale
  - Supply from high CO\textsubscript{2} fields is highly dependent on downstream requirement. For example, for PGU – the requirement is more for C\textsubscript{2} (ethane) rich hydrocarbon, therefore the development priority of high CO\textsubscript{2} fields with low C\textsubscript{2} is lower in gas planning
  - In certain cases, the amount of CO\textsubscript{2} to be produce is more than what EOR is required therefore geological sequestration might be required
  - During production, the production of hydrocarbon take the highest priority than CO\textsubscript{2}, therefore blending option is more favourable than separation

- Location
  - The requirement of CO\textsubscript{2} for EOR is scattered over various fields, and high CO\textsubscript{2} fields is located further away from these fields. For example, the location of BDO EOR fields is more than 200km away from CO\textsubscript{2} source in Sarawak

Key challenges of developing high CO\textsubscript{2} fields and synergies development with EOR (2)

- Economic Return (Value of CO\textsubscript{2} and Hydrocarbon)
  - Cost of developing high CO\textsubscript{2} field is much more higher than the normal gas field development
  - High power requirement and compression ratio will added more cost to already marginal economics of high CO\textsubscript{2} fields

- Separation Technology
  - Current separation technology is more suitable for onshore plant rather than offshore platform. These technology (Absorption, Adsorption, Cryogenic, Membrane) either required large amount of real estate or higher power requirement
  - Technology like membrane has shown positive development for offshore usage, however, the CAPEX and the OPEX of these technology is still high

- Uncertainty of CO\textsubscript{2} contents
  - Many of high CO\textsubscript{2} fields were drilled in the 70’s and 80’s, where emphasis for the CO\textsubscript{2} testing is low. These has resulted in unreliable data for CO\textsubscript{2} contents.
Holistic economic approach can be adopted, provided heavy EOR investment into these field development

- Current high CO₂ fields development planning is geared toward production of hydrocarbon gas to meet the downstream demand (PGU and MLNG)
- Due to very marginal economic or uneconomic field development of these fields, the CO₂ produce will be vented to the atmosphere. This is due to high cost to recover CO₂ (low CO₂ outlet pressure from the separation) and high transportation cost
- Unless if we could put value for CO₂ production, venting CO₂ will be the option to develop these fields.
- EOR need to invest in CAPEX and OPEX for the real estate required on the platform and all the facilities need to bring the CO₂ from the separation outlet to the EOR fields

Summary of the Way Forward and Solutions

To develop high CO₂ gas fields
- To find means of CO₂ usage
- To separate CO₂ from gas

To implement EOR (CO₂)
- To find large CO₂ supply
- To find high purity CO₂

Synergistic approach

Integrated area development plan

Add natural gas reserves
Add crude oil reserves
**Triple Plus – Tackling the Soft Issues**

- Both high CO2 field development and EOR are still new in Malaysia.
- Triple + is designed to address the 3 main soft issues.

**Deliver superior Business Results**

- **Build Institutional Capabilities**
  - Permanent EOR outfit
  - Add CO2 portfolio to Small Fields Dept.
  - Encourage & support calculated risk

- **Build Leaders**
  - Created specific technical positions
  - Conduct formal coaching system

- **Change Mindsets & Behaviors**
  - Positive mindset to high cost development
  - Conduct formal coaching system
  - Behave like a owner

**Summary and Conclusion**

**Summary**

- Over 13 Tcf of hydrocarbon gas locked in high CO2 fields
- There is a synergy between EOR and high CO2 fields

**Conclusion**

- Collaboration between EOR and CO2 fields development is needed to overcome the challenges
- Combining EOR and high CO2 fields development can improve economic feasibility
- An integrated approach is key to the success
For the purpose of this workshop: we will discuss two major scenarios on natural gas development in Malaysia

**Natural Gas Development in Malaysia**

- **High CO2 stranded gas development**
- **Low permeability gas development**

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**Angsi Field Location Map**

- 166 km offshore Terengganu (east coast of Peninsular Malaysia)
- Operated by PETRONAS CARIGALI SDN BHD
Angsi Field Overview

- 20 wells for hydraulic fracturing treatment
- Consist of K, L and I – formations
- Permeability ranges from 1 to 10 mD
- Porosity ranges from 15 – 20%

• Net thickness of 10 – 90 feet.
• Condensate gas ratio is about 25 to 100 stb / mmscf

Objectives of the initiatives

- Increase productivity of the wells
- Mitigate the detrimental effect of condensate drop out on gas recovery
The motivations.....

Production Tests:
- **M (Angsi-2 & 3):** Negligible flow, Perm ~ 0.02-0.005 md
- **L (Angsi-2):** Flowing < 0.5 MMSCFD, Perm ~ 0.02-0.006 md
- **K (Angsi-2):** Flowing < 4 MMSCFD, Perm ~ 0.7 md

**Angsi-4 Exploration Well (K-sst), hydraulically fractured/tested:**
- Pre-frac production yield 4-5 MMSCFD.
- Relatively short frac length, +/- 160 ft. maximum.
- Post-frac production: 4-5 Fold Of Increase (times), avg. 18 MMSCFD.

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The statistics.....

- 596 Days from First to Last Fracture Treatment (7-Dec-01 to 26-Jul-03) 85 Weeks or 20 Months
- 20 Different Wellbores
- 79 Fracture Treatments
  - 67 K-Sands
    - 18 K-28/30/35
    - 17 K-25L
    - 12 K-25U
    - 20 K-20/22
  - 8 L-Sands
  - 4 L-Sands
- 13,800,000 Pounds of Proppant (70 Boat Loads)
- 217,500 Barrels of Water (110 Boat Loads)

**Continuous effort to capture lesson learnt from early wells lead to significant improvement / optimization of subsequent treatment.**
• First time in Malaysia with full of lesson learnt and open up opportunity to develop other tight gas reservoir in Malaysia or other part of the world where PETRONAS operates.

• The treatment contributes to 50 to 60 percent of total gas production in the field, which initially sub-economic to be developed.

• Contributes to adding gas reserves of about 0.5 Tscf from K reservoirs of Angsi field alone.
Further readings:

- SPE 84395
- SPE 54335
- 4th Expert visit PPM Case Study, China (CCOP web page)

THANK YOU