MHI’s Carbon Capture Technology

Wyoming/JCOAL Workshop 2017
Gillette, Wyoming

September 21
Background
KM CDR – Kansai Mitsubishi Carbon Dioxide Removal – Process®

- Similar to other amine-based technologies
- KS-1™ solvent with low degradation and negligible corrosion
- Proprietary features

KM CDR Process is a registered trademark of Mitsubishi Heavy Industries, Ltd., in Japan, the United States of America, European Union (CTM), Norway, Australia, and China.
**KM CDR Process® Development History**

From 1991 – 2 TPD Nanko Pilot Plant on Natural Gas Exhaust (Kansai Electric Power Co.)

From 2002 - 1 TPD Hiroshima Pilot Plant on Coal Exhaust (MHI R&D Center)

From 2006 – 10 TPD Matsushima Pilot Plant on Coal Exhaust (J-Power)

From 2008 - 400MWeq Absorber Flow Tests (MHI Mihara)

Engineering HQ (Yokohama)
MHI is the world’s leading large scale post-combustion CO₂ capture technology licensor.
MHI performed extensive testing to understand the impact of flue gas impurities and develop countermeasure technologies.

MHI performed liquid distribution tests for rectangular towers which simplify scale-up and modularization efforts. (Scaling technique is similar to that used on more than 200 commercial FGD systems.)
Plant Barry CO$_2$ Demo Plant – helped prove commercial viability of carbon capture on coal fired flue gas

- Funding for capture facility from Southern Company, MHI, and others.
- Designed to capture 500 metric tons per day of CO$_2$ at 90% capture efficiency.
- From 2011-14: over 12,000 hours, over 250,000 tons captured, over 125,000 tons injected.
- Tested multiple technology improvements.
Complete Petra Nova Project Overview

Oil revenues from CO₂ enhanced oil recovery can recover costs for the entire project without significant impact to the existing power plant.

- CO₂ Capture System (MHI technology)
- Cogeneration Plant
- CO₂ Transport / Pipeline
- Oil Field & Processing Facilities

NRG Energy and JX Oil and Gas formed the Joint Venture, Petra Nova Parish Holdings. They own the CCS facility and 50% of the CO$_2$ pipeline and oil field.
Petra Nova Carbon Capture Facility Project Overview

“NRG Energy, JX Nippon complete world’s largest post-combustion carbon capture facility on-budget and on-schedule”

- Takes a partial “slip” stream from host unit - NRG’s Parish Plant Unit 8
- Captures 5,200 tons of CO₂ per day
- Achieved COD on December 29, 2016.
- 2017 – Power Magazine “Plant of the Year”

Captured CO₂ is compressed by Mitsubishi’s compressor and transported 81 miles by pipeline to the West Ranch Oil field for EOR.

- 81 Miles (Parish to West Ranch)
- 12” diameter
- .1,900 psi at inlet

Reference: Petra Nova Parish Holdings
Petra Nova Oilfield Facilities – EOR Operation

CO₂ captured from Parish Unit 8 will boost oil production from 300 bbls/day to up to 15,000 bbls/day.

Reference: Petra Nova Parish Holdings
Economics & Opportunities
Economics for CCS

CCUS may provide a real value proposition to the owners. It worked in Texas!

**Costs**

<table>
<thead>
<tr>
<th></th>
<th>$ / ton-CO₂</th>
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<tbody>
<tr>
<td>Capture / Compression</td>
<td>$50 - $70</td>
</tr>
</tbody>
</table>

- Cost can vary depending on project and financing.

**Potential Drivers**

<table>
<thead>
<tr>
<th></th>
<th>$ / ton-CO₂</th>
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<tbody>
<tr>
<td>EOR (today’s value)</td>
<td>$20+</td>
</tr>
<tr>
<td>Tax Credit (12 years) ?</td>
<td>$35</td>
</tr>
<tr>
<td>Carbon Tax ??</td>
<td>$40</td>
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</tbody>
</table>

- CO₂ price for EOR will increase with higher oil prices and with motivated CO₂ purchasers.
- Revised 45Q could provide $35/ton tax credit for CO₂ used for EOR or $50/ton for CO₂ stored.
- Carbon Tax: industry support developing for $40/ton

*Pressure on climate change growing!*
Wyoming Opportunities for CCS

Wyoming may be a great candidate for the next large scale CO$_2$-EOR project based on its supply of CO$_2$ sources and EOR potential

- Wyoming’s coal fired power plants have required emissions controls and are located close by to oil and gas fields.

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Capacity (MW)</th>
<th>SO$_2$ Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jim Bridger</td>
<td>2,300</td>
<td>Yes</td>
</tr>
<tr>
<td>Laramie River</td>
<td>1,700</td>
<td>Yes</td>
</tr>
<tr>
<td>Dave Johnston</td>
<td>810</td>
<td>Some</td>
</tr>
<tr>
<td>Naughton</td>
<td>700</td>
<td>Yes</td>
</tr>
<tr>
<td>Dry Fork</td>
<td>390</td>
<td>Yes</td>
</tr>
<tr>
<td>Wyodak</td>
<td>360</td>
<td>Yes</td>
</tr>
<tr>
<td>Wygen</td>
<td>300</td>
<td>Yes</td>
</tr>
<tr>
<td>Neil Simpson</td>
<td>100</td>
<td>Some</td>
</tr>
</tbody>
</table>

Wyoming Opportunities for CCS

Wyoming oil fields could potentially support several large scale CO₂ Capture and EOR projects.

- Currently, Shute Creek Gas Processing Plant and Lost Cabin Gas Plant produce CO₂ for the nearby oilfields.
- In 2014, an ARI study assumed an additional 400 MMcfd (~20,000 mtpd) of CO₂ would be captured from new projects by 2020, mostly coal gasification.
- Oil produced from CO₂-EOR would have increased from 39,000 bbl/d in 2014 to 103,000 bbl/d in 2020.

MHI’s Technology Experience Summary

**Technology Development**

- **Tested** MHI proved viability at multiple R&D facilities.
- **Delivered** MHI delivered **eleven (11) operating commercial CO₂ capture plants** prior to the Petra Nova Project.
- **Scaled-up** MHI successfully scaled-up and demonstrated long-term operation at Alabama Power’s Plant Barry.

**Commercial Delivery – Petra Nova Project**

- **December 2016** – the world’s largest post-combustion CO₂ capture project on coal-fired flue gas (4,776 mtpd) – completes performance testing.

**Wyoming Opportunities**

- Wyoming’s abundance of CO₂ sources, EOR fields, and existing infrastructure provide a strong case for the next large-scale CO₂-EOR project.
MOVE THE WORLD FORWARD