North American CO$_2$ Supply and Developments

Glen Murrell, EORI
w/ Steve Melzer, Melzer Consulting

PRESENTATION TO THE 18TH ANNUAL CO$_2$ FLOODING CONFERENCE, MIDLAND, TX
DECEMBER 6$^{th}$, 2012
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Agenda

• Status and Developments
• Market Drivers
Status and Developments
Current Situation – CO2 EOR

WW, U.S., & PB CO₂ EOR PRODUCTION
1986 - 2012

- Worldwide
- U.S.
- Permian Basin

* Ref: O&GJ Biennial EOR Editions & UTPB Petr Industry Alliance
Historic CO2 Sales

Average Daily CO2 Sales - Nth America

- Other
- Dakota Gasification
- MS/Gulf Coast
- Rockies
-Permian Basin
## Supply Developments

### CO₂ Source Prospects

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<th>Sink Location</th>
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<tbody>
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<td>Lost Cabin and GreenCore Pipeline (WY/MT)</td>
<td>Capture and PL under Construction</td>
<td>2013</td>
<td>50</td>
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<td>Ph 1 Complete, 2 under Construction</td>
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<td>&gt;1600-1855</td>
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Total Incremental CO₂ = 3420-4255
### Supply Developments

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**Total Incremental CO₂ = 3420-4255**
CO2 EOR Supply in 2000

Key
- Potential Natural CO2 Source
- Natural CO2 Source
- NG Processing Source
- Conversion Source
--- CO2 Pipeline
----- CO2 Pipeline planned
CO2 EOR Supply in 2000

- 230 MMcfpd
- 1250 MMcfpd
- 50 MMcfpd

Key:
- Potential Natural CO2 Source
- Natural CO2 Source
- NG Processing Source
- Conversion Source
- CO2 Pipeline
- CO2 Pipeline planned

CO2 EOR Supply in 2012

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<tr>
<th>Process</th>
<th>Project Name</th>
<th>Operator</th>
<th>Location</th>
<th>Supply Capacity (MMcfpd)</th>
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<td>Natural Resources</td>
<td>McElmo Dome</td>
<td>Kinder Morgan, ExxonMobil</td>
<td>CO</td>
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<td>Jackson Dome</td>
<td>Denbury</td>
<td>MS</td>
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<td>Bravo Dome</td>
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<td>Sheep Mountain</td>
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<td>Doe Canyon Deep</td>
<td>Kinder Morgan</td>
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<td>Natural Gas</td>
<td>Labarge</td>
<td>Exxon Mobil</td>
<td>WY</td>
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<td>Processing</td>
<td>Terrell, Grey Ranch, Mitchell, and Puckett</td>
<td>Sandridge Energy Inc.</td>
<td>Terrell and Pecos Counties, TX</td>
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<td>Turtle Lake</td>
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<td>Conversion</td>
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<td>Borger, TX</td>
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<td>Conestoga</td>
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CO2 EOR Supply in 2018?

Key
- Green Circle: Potential Natural CO2 Source
- Green Square: Natural CO2 Source
- Blue Circle: NG Processing Source
- Orange Circle: Conversion Source
- Solid Line: CO2 Pipeline
- Dashed Line: CO2 Pipeline planned

CO2 EOR Supply in 2018?

~2900 MMcfpd

~1000 MMcfpd

~100 MMcfpd

~2900 MMcfpd

~2500 MMcfpd

Supply Developments

• Rockies:
  • CO₂ Supply in the Rockies will increase by as much as 1 Bcfpd over next 5-10 years. Mostly by development of Riley Ridge but also through several conversion projects. Supply, and CO₂ EOR industry, could quadruple in 5-10 years. Implications for oil industry in the region in general and consequent state economics.

• Permian Basin:
  • Natural source supply will be lifted incrementally, but significant volume of additional supply will come from NG processing plants and conversion technologies.

• Midwest/Mississippi/Gulf Coast:
  • Natural source supply will be lifted incrementally, but supply will be supplemented massively by conversion project supply going forward. Ultimately, as Jackson Dome enters decline, majority of supply will be from anthropogenic sources.

• Mid-continent:
  • Possible tie-in to Permian Basin system. Additional supply provided by conversion projects.

• Canada:
  • Initiation of CO₂ Transport and Utilization system. CO₂ supply from upgrading processes.
Rockies
Bell Creek: Injection to commence 3/2013 @ 50 MMcfd
Supply – Rockies

- Shute Creek Gas Plant
  - 1981: Exxon drilled exploration wells
  - 1984: Shute Creek Construction
  - 1986: First Production (of CO₂)

- LaBarge Field – Madison Formation
  - CO₂ Reserves: est. 100 Tcf (CO₂ EOR in Wyoming needs ~40Tcf*)
  - Average well produces 45 MMcfd

Currently, only active supplier of CO₂ in Rockies Region. Can supply up to 340 MMcfpd. Supplies Rangely, Monell Unit, Beaver Creek, Bairoil Complex and Salt Creek.

* Miscible main-pay WAG CO₂ EOR; Wo et al., 2009: SPE 122921
Shute Creek CO₂ Supply Capacity vs. Average Daily Sales

- **Salt Creek** and **Monell** online
- **Beaver Creek** online
- **Oil price crunch**

**Figure Details:**
- **2011 Shute Creek CO₂ Sales (MMcfd) by EOR Project**
- **Shute Creek CO₂ Sales (Average MMcfd)**
- **Shute Creek CO₂ Supply Capacity (MMcfd)**
- **Wyoming Crude Oil First Purchase Price (Dollars per Barrel) - 2011$**

**Years:**
- 1987 to 2011

**Sources:**
- Parker et al., 2009 IPTC 13258
- DiPietro et al., 2012 SPE Economics & Management
- WOGCC Website
Since 1986 CO₂ EOR has produced 195 million barrels of oil in the Rockies
Developments – Rockies
Supply Expansion – Rockies

2013

• **Lost Cabin Gas Plant**: 50 MMcfd, supplying Denbury’s Greencore Pipeline.

~2016

• **Riley Ridge Gas Plant**: Initially 130 MMcfd, ramping up to ~600 MMcfd over 5 years. Will require pipeline for transportation. 2.4 Tcf CO₂ reserves.
• **DKRW Medicine Bow F&P**: Phase I 100 MMcfd, Phase II additional 100 MMcfd. Timing of Phase II ~2022.
• **Linc Energy UCG**: 115 MMcfd (Reported by Gas Tech). Timing unknown.
• **Carbon Energy UCG**: Volume and timing unknown.
Rockies CO₂ Supply Capacity

- DKRW (Phase II)
- Carbon Energy
- Linc Energy
- DKRW (Phase I)
- Riley Ridge
- Lost Cabin
- Shute Creek

~1 Bcfd increase

Denbury - ExxonMobil Deal

Denbury gets:
• Hartzog Draw (WY) and Webster Field (TX)
• $1.6 Billion cash

ExxonMobil gets:
• 196,000 net acres Bakken assets (all of Denbury’s Bakken holdings).

Devil in the detail:
“Denbury has agreed in principle to either purchase an interest in the CO2 reserves in ExxonMobil's LaBarge Field in southwestern Wyoming or purchase incremental CO2 from that field, on terms and conditions to be mutually agreed upon by the parties.”
Gulf Coast
Jackson Dome Area

- 6.1 TCF Proved Reserves estimated at 9/30/12
- 3Q 2012 Average Daily Production – 1,036 MMcf/d
- 4 wells drilled in 2012
Gulf Coast Supply

**Additional CO₂ Potential**
- Probable & Possible Reserves: ~3 TCF
- Improved Recovery of Proved Reserves: ~0.8 TCF

**JACKSON DOME**
- **PROVED RESERVES**
  - ~6.1 TCF
  - Estimated as of 9/30/2012

**Gulf Coast CO₂ Demand**

**ANTHROPOGENIC SUPPLY**
- Executed Agreements with Future Construction

**RISKED DRILLING PROGRAM**
- Executed Agreements with Construction Commenced

Note: Forecast based on internal management estimates. Actual results may vary.
Permian Basin
(see you tomorrow for Kinder Morgan’s presentation)
CO₂ EOR: Market Drivers
Market Drivers

1. Oil Price (Demand Pull)
2. Conversion Projects (Supply Push)
   • In turn driven by 1, 4 and 5
3. Target Growth (ROZs)
4. GHG mitigation policy
5. Commodity Recognition
Market Drivers – Oil Price

WTI Breakeven Price for a 15% After-Tax Rate of Return ($ per Bbl)$^{(1)}

- CO2 EOR $^{(2)}$: $50
- OK Mississippian: $50
- Wattenburg: $51
- DJ Niobrara: $58
- Wolfberry Vertical: $59
- Avalon Shale: $61
- Spraberry Vertical: $64
- Eagleford Oil: $65
- Activity Weighted Avg: $75
- ND Bakken: $76
- MT Bakken: $79
- Delaware Wolfcamp: $83
- Pronghorn/Sanish: $86

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(1) Source: ISI Group report dated June 15, 2012. Defined as the threshold WTI oil price necessary to generate a 15% after-tax rate of return. Excludes acreage costs.

(2) Internal estimate for indicative large CO2 EOR development project in the Gulf Coast Region.
Market Drivers – Oil Price

Average Daily CO2 Sales - Nth America

- Oil Price
- Market Drivers
- CO2 Sales (MMcfpd)
- Year

- Other
- Dakota Gasification
- MS/Gulf Coast
- Rockies
- Permian Basin
- WTI Price (2011$)

Market Drivers – Oil Price

Denver City CO₂ Price and Anecdotal Wyoming CO₂ price
($/Mcf and as % of price of oil)

- Denver City $/Mcf
- Denver City % W.Tx.Sour
- Range of nominal prices in Wyoming (Anecdotal)
- Range of price as % oil price in Wyoming (Anecdotal)
Market Drivers – Conversion Projects

- Include:
  - Underground Coal Gasification - Linc Energy (WY), Carbon Energy (WY)
  - IGCC & Coal to power - TX Clean Energy (PB), Indiana Gasification, Kemper County (AL), WA Parish (TX), Hydrogen Energy California...
  - Coal to Liquids (& by-products) – DKRW Medicine Bow F&P (WY)
  - NG to Liquids (& by-products) – Rentech (MS)
  - NG to Hydrogen - Air Products (TX)
  - Any other hydrocarbon conversion/refinement process – Oil sand upgrading (Shell Quest Project (AB,Ca)

- Tremendous interest in developing these projects with CO₂ off-take for EOR built in.
  - Examples in WY, TX, ND, OK, KS, MS, LA, IA and Canada

- Driven by need to add value to traditionally low-value (Coal), or recently low-value (NG) commodities, mitigate potential GHG liabilities, and exploit CO₂ commodity value.
WY. Crude Price and NG Wellhead price change since 7/1977

- Wy. Crude Price 2011$ - % Change since 7/1977
- NG Price 2011$ - % Change since 7/1977
Market Drivers – Target Growth

- Flooding of the ROZ has proven that CO2 EOR targets are much larger than initially thought, and that targets that were initially thought to be too small are actually highly viable when the ROZ is added.
- New work is showing that the Permian Basin San Andres appears to have in excess of 100 billion barrels in place in the ROZ.
- The ROZ in *producing* Bighorn Basin Tensleep reservoirs in Wyoming is calculated to be as large, in terms of oil in place, as the Main Pay zone. Massive opportunities for Green-field development exist.
Enhanced Oil Recovery Institute

Market Drivers

Total, Primary, Waterflood, Main Pay and ROZ CO₂ Performance
(the Concept of "Brownfield" Quaternary Oil)

- Target Growth

Annualized Oil Production in bopd

Year

Primary Production Peak

Secondary Production Peak

Tertiary CO₂ Production Peak

Quaternary CO₂ ROZ Production Peak

Primary Cum = 125 mm bbls
Secondary Cum = 325 mm bbls
Tertiary Cum = 200 mm bbls
Projected Quaternary Cum = 200 mm bbls

Melzer Consulting
Bighorn Basin Tensleep Profiles

Non-commercial wells around existing reservoirs.
Suspected ROZ presence in BHB, WY
Market Drivers – GHG Mitigation Policy

- Currently a supply-side influence. GHG policies seldom directly affect CO\textsubscript{2} EOR as they are designed with the emitter in mind.
- Still no actual comprehensive GHG reduction bill passed by congress (but the EPA has been busy).
- EPA Recognizes CCUS as a pollution control technology.
- Some GHG policies actually place barriers between CCS and CCUS e.g. Class VI rule.
- EPA Carbon Pollution Standard (1,000 lb CO\textsubscript{2}/MWh gross)
  - NGCC plants should be OK.
  - Hugely influential for other power generation systems, especially coal.
Market Drivers – Commodity recognition

- Change in characterization of CO₂ from a waste product to a commodity e.g. Indiana Gasification
  - The Indiana Department of Environmental Management (IDEM) takes position that, in this case, CO₂ is not a captured pollutant, but rather a commodity that the plant produces and sells. Consequently, not a pollutant under the CAA. Only CO₂ that is vented by the plant needs permitting.
  - Downstream controls on storage were not relevant to this permitting action.

- Implications:
  - Permitting
  - Capture and Avoidance
  - Class VI rules
  - Sales contracts
Questions?

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