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$^{	ext{TH}}$, 2012
Disclaimer and Acknowledgements

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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

CO₂ EOR PRODUCTION - kbopd

YEAR

* 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

<table>
<thead>
<tr>
<th>Sink Location</th>
<th>Project Description</th>
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<th>Incremental CO2 Rate (MMcfpd)</th>
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Total Incremental CO2 = 3420-4255
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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

CO2 EOR Supply in 2012

Key:
- Green: Potential Natural CO2 Source
- Green: Natural CO2 Source
- Blue: NG Processing Source
- Orange: Conversion Source
- Black: CO2 Pipeline
- Dotted: CO2 Pipeline planned

CO2 EOR Supply in 2012

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<th>Supply Capacity (MMcfpd)</th>
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<td>McElmo Dome</td>
<td>Kinder Morgan, ExxonMobil</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>
<td>Occidental</td>
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<td>Doe Canyon Deep</td>
<td>Kinder Morgan</td>
<td>CO</td>
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<td>LaBarge</td>
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<td>WY</td>
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CO2 EOR Supply in 2018?

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

CO2 EOR Supply in 2018?

~2900 MMcfpd

~1000 MMcfpd

~100 MMcfpd

~2500 MMcfpd

~2900 MMcfpd

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

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
Current Situation – 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
Since 1986 CO₂ EOR has produced 195 million barrels of oil in the Rockies
Wyoming CO$_2$ EOR (@ Dec, 2011)

CO$_2$ Oil 81' to present

Murrell, 2012 6th Annual Wyoming CO$_2$ Conference
Developments – Rockies

Key:
- Green circle: Potential Natural CO2 Source
- Orange circle: Natural CO2 Source
- Blue circle: NG Processing Source
- Red circle: Conversion Source
- Black line: CO2 Pipeline
- Dashed black line: CO2 Pipeline planned
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 CO$_2$ 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.
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.”
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

Note: Forecast based on internal management estimates. Actual results may vary.
Permian Basin
(see you tomorrow for Kinder Morgan’s presentation)
CO$_2$ 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)

(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

- 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)

- Range of nominal prices in Wyoming (Anecdotal)
- Range of price as % oil price in Wyoming (Anecdotal)

Modified from Melzer Consulting
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.
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.
Market Drivers – Target Growth

Total, Primary, Waterflood, Main Pay and ROZ CO\textsubscript{2} Performance (the Concept of "Brownfield" Quaternary Oil)

- Primary Production Peak
- Secondary Production Peak
- Tertiary CO\textsubscript{2} Production Peak
- Quaternary CO\textsubscript{2} ROZ Production Peak

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

Shape of 4\textsuperscript{th} Peak Dependent on Availability of Affordable CO\textsubscript{2}
Market Drivers – Target Growth

Bighorn Basin Tensleep Profiles

Non-commercial wells around existing reservoirs.

Yin, 2011, 5th Wyoming Annual CO2 Conf
Market Drivers – Target Growth

Yin, 2011, 5th Wyoming Annual CO2 Conf

Suspected ROZ presence in BHB, WY
Market Drivers – GHG Mitigation Policy

• Currently a supply-side influence. GHG policies seldom directly affect CO$_2$ 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$_2$/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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