Wyoming CO₂ Status and Developments
Glen Murrell
Agenda

• Industry Stakeholders
• Status
  • Supply
  • Projects
• Developments
  • Supply
  • Projects
• ROZ
Market Participants

Producers:


**ConocoPhillips** - Supplier, owner of Lost Cabin Gas Plant. Contracted to supply ~ 50 MMcf/d to Denbury.

**ExxonMobil** - Supplier, owner and operator of Shute Creek facility, with capacity of ~ 340 MMcf/d CO₂, supplying various clients. Pipeline operator.

Market Participants

Consumers:

Anadarko Petroleum Corporation - Operator of Salt Creek and Monell projects, taking ~ 125 MMcf/d from ExxonMobil. Distribution pipeline operator.

Chevron - Consumer, operator of Rangely field, taking ~ 35 MMcf/d from ExxonMobil. Distribution pipeline operator.

Devon Energy - Consumer, operator of Beaver Creek field, taking ~ 25 MMcf/d from ExxonMobil. Distribution pipeline operator.

Elk Petroleum - Consumer, JV partner in Grieve Field with Denbury Resources.

Merit Energy - Consumer, operator of Lost Soldier/Wertz fields, taking ~ 30 MMcf/d from ExxonMobil. Distribution pipeline operator.
Integrated Business Models:


### Process	| Project Name               | Operator                              | Location | Supply Capacity (MMcfpd)
---|---------------------------|---------------------------------------|----------|-----------------------
#### Natural Resources
- McElmo Dome               | Kinder Morgan, ExxonMobil             | CO       | 1,150
- Jackson Dome              | Denbury                               | MS       | 930
- Bravo Dome                | KM, Occidental, Amerada               | NM       | 290
- Sheep Mountain            | Occidental                            | CO       | 50
- Doe Canyon Deep           | Kinder Morgan                          | CO       | 110
#### Natural Gas Processing
- LaBarge                   | Exxon Mobil                           | WY       | 340
- Terrell, Grey Ranch, Mitchell, and Puckett | Sandridge Energy Inc. | Terrell and Pecos Counties, TX | 75
- Turtle Lake               | DTE Energy                            | Ostego, MI | 11
#### Conversion
- Agrium, Inc.              | Borger, TX                             |          | 26
- Koch Nitrogen             | Enid, Oklahoma                         |          | 35
- Conestoga                 | Liberal, KS                           |          | 4
Supply Developments

• Rockies:
  • CO₂ Supply in the Rockies will increase by almost 0.7 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.
Supply

- **Shute Creek***
  - Processes NG from LaBarge Field
  - First production (CH4, He, CO\(_2\)): September 1986
  - Supply capacity of ~340 MMcfpd.
  - Currently supplying about 210 MMcfpd to Rangely, Monell, Beaver Creek, Bairoil Complex and Salt Creek.
  - Excess capacity will be mostly subscribed to Grieve, Bell Creek, Hartzog Draw via Greencore Pipeline System (Denbury). Will require interconnect with Anadarko line somewhere near Hells Half Acre in Natrona County.

- **Lost Cabin**
  - Processes NG from Madden Field.
  - First production (CH4): April 1995
  - Supplies ~50 MMcfpd to Greencore Pipeline. No reported sales of CO\(_2\) @4/2013.

* From Condon and Parker, 2011: Shute Creek Treating Facility Project Updates. 5th Annual Wyoming CO\(_2\) Conference, July 13, 2011
Shute Creek CO2 Supply Capacity vs. Average Daily Sales

- Shute Creek CO2 Sales (Average MMcfd)
- Shute Creek CO2 Supply Capacity (MMcfd)
- Wyoming Crude Oil First Purchase Price (Dollars per Barrel) - 2012$
2012 Shute Creek CO₂ Sales (MMcf/d) by EOR Project

- Salt Creek: 95 MMcf/d
- Monell: 30 MMcf/d
- Rangely: 35 MMcf/d
- Beaver Creek: 25 MMcf/d
- Bairoil: 30 MMcf/d

Data from WOGCC website
$CO_2$ Purchases over time from Shute Creek

Data from WOGCC website
Since 1986 CO₂ EOR has produced an incremental **95.8 million** barrels of oil in Wyoming; **208 million** barrels in the Rockies system.
<table>
<thead>
<tr>
<th>Project</th>
<th>Field</th>
<th>Reservoir</th>
<th>Injection Start</th>
<th>Total CO₂ Purchased (Bscf)</th>
<th>Cum. Incr. Oil* (MMbbls)</th>
<th>RF* (% OOIP)</th>
<th>UR_NET* (Mscf/bbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bairoil</td>
<td>Lost Soldier/Wertz</td>
<td>Tensleep, Darwin/Madison, Flathead</td>
<td>1986</td>
<td>347 (331 @ 12/2011)</td>
<td>67.5 (65.8 @ 12/2011)</td>
<td>~10%</td>
<td>~5 (6 @ 12/2011)</td>
</tr>
<tr>
<td>Rangely Weber Sand Unit</td>
<td>Rangely</td>
<td>Weber Sst</td>
<td>1986</td>
<td>555</td>
<td>112</td>
<td>~6.0%</td>
<td>~5</td>
</tr>
<tr>
<td>Monell</td>
<td>Patrick Draw (Monell Unit)</td>
<td>Mesaverde Almond</td>
<td>2004</td>
<td>76 (65 @ 12/2011)</td>
<td>9.53 (7.49 @ 12/2011)</td>
<td>~8.3%</td>
<td>~8 (9 @ 12/2011)</td>
</tr>
<tr>
<td>Salt Creek</td>
<td>Salt Creek</td>
<td>WC 1&amp;2</td>
<td>2004</td>
<td>304 (269 @ 12/2011)</td>
<td>14.9 (10.7 @ 12/2011)</td>
<td>~1.3%</td>
<td>~20 (25 @ 12/2011)</td>
</tr>
<tr>
<td>Beaver Creek</td>
<td>Beaver Creek</td>
<td>Madison</td>
<td>2008</td>
<td>47 (38 @ 12/2011)</td>
<td>3.93 (2.46 @ 12/2011)</td>
<td>~3.6%</td>
<td>~12 (15 @ 12/2011)</td>
</tr>
</tbody>
</table>

* Incremental recovery, utilization ratio and recovery factors are highly sensitive to analytical assumptions. We have been as conservative as possible and our assumptions may not match those used internally by operators.
CO₂ EOR Incremental Production and % of Total WY Production

Wyoming CO₂ EOR Incremental Production

as % of Total Wyoming Production
Wyoming Oil Production by Type

- "Conventional" Oil
- Incremental CO₂ Oil
- Pindeale/Jonah Condensate

Year: 1981 to 2012

Annual Production (BOPY)
Wyoming Oil Production by Type

- Incremental CO\(_2\) Oil
- Pindeale/Jonah Condensate
- Stimulated Horizontal Plays
- "Conventional" Oil

Annual Production (BOPY)

Year:
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
Stimulated Horizontal Play Production

Oil Production (BOPY)

Year


FRONTIER

SUSSEX

NIOBRARA

TURNER

PARKMAN

MOWRY

TOTAL
Future Supply

• Riley Ridge Unit
  - Will produce from LaBarge Field. Gas Plant currently under-construction does not include CO2 capture. CO2 capture facility currently being designed will initially supply ~130 MMcf/d and is planned to double over the next decade. Initial supply expected ~2017.

• DKRW Medicine Bow F&P
  - Phase I CO2 supply ~100 MMcf/d, Phase II, if implemented, would double this amount. Contracted to Denbury. @ 3/2013 still seeking final financing piece. @ 6/20/2013 permit re-submitted, construction scheduled to start 7/2014, in operation mid-2018.

• UCG
  - Linc Energy
    - Powder River Basin based. Will provide CO2 to Linc projects
  - Carbon Energy
    - Green River Basin. Lease agreement with Anadarko includes CO2 off-take clause.

• At least 4 other entities considering some form of Hydrocarbon Conversion with CO2 supply for EOR built in.
Forecasting CO2 EOR Incremental production

- Collaboration with Phil DiPietro from NETL
- Normally need a dimensionless curve
  - Can be difficult, and at least very time consuming, to compile data.
- On a system and sub-system basis, we can use $UR_{Net}$
- Use sensitivity analysis on historic data to determine best model (nominal, cumulative, average, SLM) and forecast system of $UR_{Net}$ in each system (e.g. Rockies, Permian, GC/MS)
- Assume ‘perfect’ knowledge of supply capacity past and future.
- Use probabilistic methods to forecast actual sales.
- Use $UR_{Net}$ to calculate production from forecast sales.
- Not perfect but much better than resource based models currently used.
Future Projects

• Denbury/Elk - Grieve
  • First injection reported March 2013. First incremental production expected late-2014 or early-2015.

• Denbury - Hartzog Draw
  • Under development. First injection and first incremental production expected in 2016.

• Denbury - Bell Creek (MT)
  • Injection has commenced. First incremental production expected 2nd half of 2013.

• Linc Energy – Glenrock area fields
  • Under development

• Denbury - Cedar Creek Anticline (MT, ND, SD)

• Magellen Petroleum - Poplar Dome (MT)
  • Under development. Pilot project planned.

• Confidential
  • Two other projects being investigated in Wyoming
CO2 Supply

• Great target, no supply.
• No supply does not mean no CO2. There are vast volumes of CO2 in Wyoming, but there is limited deliverability.
• LaBarge and Lost Cabin sources are fully utilized (or will be soon).
• Denbury had plans to get in to the BHB, but, after divesting BHB assets, have stepped back to focus on CCA. Will they be back?
• Several hydrocarbon conversion prospects floating around.
• Some of which consider current source/transport system as competitive threat. Consequently they are looking at regions isolated from the system (BHB and WRB).
• Problems associated with cost and policy.
Conclusions

• Development of CO$_2$ EOR projects in Wyoming continues.
• Supply capacity, CO2 sales and incremental production are forecast to increase over next 5 years.
• In 2012, CO$_2$ EOR produced 7.15 million barrels of oil (12.4% of total oil production) in Wyoming, 10.25 million barrels in the Rockies system.
• CO$_2$ EOR has produced 95.8 million barrels of oil from Wyoming reservoirs, and 208 million barrels in the Rockies system.
• CO$_2$ EOR, Condensate production (and the increasing influence of stimulated horizontal drilling) has reversed the decline of oil production in Wyoming.
Questions?

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Wyoming CO₂ EOR (@ Dec, 2011)

Wyoming CO₂ Oil and State Tax Revenue per year

- Tax Revenue
- CO₂ Oil
Utilization Ratio*

\[ UR_{\text{net}} = \frac{CO_2 \text{ purchased}}{\text{Incremental oil}} \]

\[ UR_{\text{gross}} = \frac{CO_2 \text{ purchased} + CO_2 \text{ recycled}}{\text{Incremental oil}} \]

- A measure of economic efficiency.
- Dependent on flood design and maturity.
  - WAG vs GS, number of HCPVs injected
- Compare Salt Creek with Beaver Creek
  - SC: phased, WAG, pattern flood, 1099 MMBO OOIP.
  - BC: WAG-GS hybrid, Single development phase, 109 MMBO OOIP
- A measure of technical efficiency.
- Dependent on flood design and sweep efficiency.

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