Pipelines – The Safest Way to Travel for CO$_2$
Whole Value Chain Carbon Capture, Utilization and Storage (CCUS)

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Ken Havens, Vice President of Operations and Engineering
Kinder Morgan CO$_2$ Company
## U.S. Energy Infrastructure

*Pipelines move most of the energy resources we depend on in our daily lives.*

<table>
<thead>
<tr>
<th>Natural Gas</th>
<th>Petroleum</th>
<th>NGL’s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nearly all natural gas is shipped via pipeline</strong></td>
<td><strong>Pipelines move 70% of petroleum products in the U.S.</strong></td>
<td><strong>Most NGL’s are shipped via pipeline</strong></td>
</tr>
<tr>
<td>Natural gas for consumer and industrial customers as well as power generation. 34% of all electricity in America is generated by natural gas.</td>
<td>Crude oil to refineries, gasoline and diesel fuel for consumers, jet fuel for airports and military bases.</td>
<td>NGL’s are used to make plastic, chemicals, fertilizer for agricultural uses, and propane.</td>
</tr>
</tbody>
</table>

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[NATURAL GAS IMAGE]

[NATURAL GAS IMAGE]

[NATURAL GAS IMAGE]

[PETROLEUM IMAGE]

[PETROLEUM IMAGE]

[NGL’S IMAGE]
**CO₂ Segment’s Asset Summary**

*Fully Integrated Asset Base in the Permian*

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**S&T Asset Summary**

<table>
<thead>
<tr>
<th>CO₂ Reserves</th>
<th>KMI Interest</th>
<th>NRI</th>
<th>Location</th>
<th>Remaining Deliverability</th>
<th>OGIP (tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McElmo Dome</td>
<td>45%</td>
<td>37%</td>
<td>SW Colorado</td>
<td>20+ years</td>
<td>22.0</td>
</tr>
<tr>
<td>Doe Canyon</td>
<td>87%</td>
<td>68%</td>
<td>SW Colorado</td>
<td>10+ years</td>
<td>3.0</td>
</tr>
<tr>
<td>Bravo Dome(^{(b)})</td>
<td>11%</td>
<td>8%</td>
<td>NE New Mexico</td>
<td>10+ years</td>
<td>12.0</td>
</tr>
</tbody>
</table>

**Pipelines**

<table>
<thead>
<tr>
<th>Pipelines</th>
<th>KMI Interest</th>
<th>Location</th>
<th>Capacity (mmcfpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortez</td>
<td>53%</td>
<td>McElmo Dome to Denver City</td>
<td>1,500</td>
</tr>
<tr>
<td>Bravo(^{(b)})</td>
<td>13%</td>
<td>Bravo Dome to Denver City</td>
<td>375</td>
</tr>
<tr>
<td>Central Basin (CB)</td>
<td>100%</td>
<td>Denver City to McCamey</td>
<td>700</td>
</tr>
<tr>
<td>Canyon Reef</td>
<td>98%</td>
<td>McCamey to Snyder</td>
<td>290</td>
</tr>
<tr>
<td>Centerline</td>
<td>100%</td>
<td>Denver City to Snyder</td>
<td>300</td>
</tr>
<tr>
<td>Pecos</td>
<td>95%</td>
<td>McCamey to Iraan</td>
<td>125</td>
</tr>
<tr>
<td>Eastern Shelf</td>
<td>100%</td>
<td>Snyder to Katz</td>
<td>110</td>
</tr>
<tr>
<td>Wink (crude)</td>
<td>100%</td>
<td>McCamey to Snyder to El Paso</td>
<td>145 mbbld</td>
</tr>
</tbody>
</table>

**Oil & Gas Production Asset Summary**

<table>
<thead>
<tr>
<th>Crude Reserves(^{(a)})</th>
<th>KMI Interest</th>
<th>NRI</th>
<th>Location</th>
<th>OOIP (billion bbls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SACROC</td>
<td>97%</td>
<td>83%</td>
<td>West Texas</td>
<td>2.8</td>
</tr>
<tr>
<td>Yates</td>
<td>50%</td>
<td>44%</td>
<td>West Texas</td>
<td>5.0</td>
</tr>
<tr>
<td>Katz</td>
<td>99%</td>
<td>83%</td>
<td>West Texas</td>
<td>0.2</td>
</tr>
<tr>
<td>Goldsmith</td>
<td>99%</td>
<td>86%</td>
<td>West Texas</td>
<td>0.5</td>
</tr>
<tr>
<td>Tall Cotton</td>
<td>100%</td>
<td>88%</td>
<td>West Texas</td>
<td>0.7</td>
</tr>
</tbody>
</table>

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Note: In addition to KMI’s interests above, KMI has a 22%, 51%, and 100% working interest in the Synder gasoline plant, Diamond M gas plant and North Synder plant, respectively.

\(^{(a)}\) Reserve life ~4 years based on current independent consultant reserve reserve report.

\(^{(b)}\) Not KM-operated.
SOURCE FIELDS – McElmo Dome and Doe Canyon

**McElmo Dome**
- 22 TCF OGIP
- 203,000 acre unit in Montezuma County, CO
- Majority of the unit is located under the Canyon of the Ancients National Monument
- First Production May 1984
- Production to date – 9.8 TCF
- 2018 Average Daily Production – 1,087 MMCFD

**Doe Canyon**
- 3 TCF OGIP
- 53,000 acre unit in Dolores County, CO
- First Production January 2008
- Production to date – 503 BCF
- 2018 Average Daily Production – 105 MMCFD
EOR: Technical Overview

<table>
<thead>
<tr>
<th>General Performance Characteristics</th>
<th>Reservoir Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Recovery efficiency - 10-15% OOIP</td>
<td>▪ Reservoir depth - 3000 ft or greater</td>
</tr>
<tr>
<td>▪ Incremental oil prod. - 20-30% of cum. production (primary and secondary)</td>
<td>▪ Oil gravity (API°) - 25 or greater</td>
</tr>
<tr>
<td>▪ Net utilization factor – 6-12 mcf/bbl oil</td>
<td>▪ High residual oil saturations</td>
</tr>
<tr>
<td>▪ Gross utilization factor - 10-30 mcf/bbl oil</td>
<td>▪ Favorable water flood characteristics</td>
</tr>
<tr>
<td></td>
<td>• Homogeneous reservoir</td>
</tr>
<tr>
<td></td>
<td>• No fractures or thief zones</td>
</tr>
</tbody>
</table>

CO2 - EOR The Impact

▪ Over 300,000 bpd produced in the U.S. due to CO2-EOR.

▪ Seemingly small – BUT, equivalent to just over 110 shipments of crude per year from nearby markets. Saving energy in bunker costs and risk of spills as well as benefits of less shipping pollution.

▪ CO2-EOR has an important niche in U.S. energy production. However, it requires incremental, readily available CO2 supplies to grow.
CO₂ Pipeline - Design & Operations
CO₂ Pipelines in the US
CO₂ Pipelines – Natural Gas Pipelines

- Use same steel metallurgy as Natural Gas Pipelines
  - Keep CO₂ dry
- Higher operating pressures
  - Gas – 600 psig to 1200 psig
  - CO₂ – 2000 to 3000 psig
  - Why? Maintain CO₂ in dense phase (>1300 psig) to allow pumping rather than compression.
- Pumps rather than compression
  - Energy savings
- Natural Gas – PHMSA regulated under CFR Part 192, “Transportation of Natural and Other Gas by Pipeline”
# CO₂ Pipeline Specifications

<table>
<thead>
<tr>
<th>Quality specifications for CO₂ pipelines.</th>
<th>Why are these specifications important?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) <strong>Product.</strong> Contain at least 95 mole percentage of CO₂.</td>
<td>a) <strong>Product.</strong> Maintain dense phase</td>
</tr>
<tr>
<td>b) <strong>Water.</strong> Contain no free water, and not more than thirty (30) pounds of water per mmcf in the vapor phase.</td>
<td>b) <strong>Water.</strong> Free water causes corrosion and damages pump seals.</td>
</tr>
<tr>
<td>c) <strong>Hydrogen Sulfide.</strong> Contain no more than 20 ppm, by volume, of H₂S.</td>
<td>c) <strong>Hydrogen Sulfide.</strong> Dangerous to health and safety of the public. Special requirements if &gt; 99 ppm in Texas.</td>
</tr>
<tr>
<td>d) <strong>Total Sulfur.</strong> Contain no more than 35 ppm, by weight,</td>
<td>d) <strong>Total Sulfur.</strong> Foul odor in product</td>
</tr>
<tr>
<td>e) <strong>Temperature.</strong> Shall not exceed 120°F.</td>
<td>e) <strong>Temperature.</strong> Protect pipeline external coating</td>
</tr>
<tr>
<td>f) <strong>Nitrogen.</strong> Contain no more than 4 mole percent.</td>
<td>f) <strong>Nitrogen.</strong> Maintain dense phase of product.</td>
</tr>
<tr>
<td>g) <strong>Hydrocarbons.</strong> Contain no more than 5% mole percent and Dew point no more than -20°F.</td>
<td>g) <strong>Hydrocarbons.</strong> Maintain dense phase of product.</td>
</tr>
<tr>
<td>h) <strong>Oxygen.</strong> Contain no more than 10 ppm, by weight, of oxygen.</td>
<td>h) <strong>Oxygen.</strong> Catalyst for other internal corrosion components. H₂S and O₂ form elemental sulfur in EOR piping</td>
</tr>
<tr>
<td>i) <strong>Other.</strong> Contain no liquid glycol or no more than 0.3 gallons of glycol per MMcf.</td>
<td>i) <strong>Other.</strong> Glycol damages pump seals.</td>
</tr>
</tbody>
</table>
CO₂ Pipelines - Design

Engineering/Design

- Hydraulics
- CO₂ Quality
- H₂S
- Outside Diameter
- Wall Thickness
  - Barlow’s Formula
  - Standard/Heavy Wall
- Ductile Fracture Analysis
  - Theoretical Charpy Numbers
  - Crack Arrestors
    - Operating Company risk tolerance
    - Design pipeline system in order to not add fracture arrestors
    - Wall thickness changes (crossings) to act like fracture arrestors

Lot Purchases from Vendor

- Review MTR’s in detail before purchase
  - High Grade/High Strength
  - Approved Vendors/mills
Pipe Manufacturing Process and Grade:

CO₂ Pipelines-Pipe

Engineering/Design/Specification

Reference


Pipe Manufacturing Process and Grade:

- Pipe Manufacturing Process and Grade:
  - High Frequency Electric Welded (HFW)
  - Electric Resistance Welding (ERW)
  - Double Submerged Arc Welding (DSAW) / Longitudinally submerged arc-welded pipes (LSAW)
  - NO HSAW
  - Preferred Grade: X65 or X70

CO₂ Pipelines-Coating

- Fusion Bonded Epoxy (FBE):
  - Standard Pipe

- FBE+ Abrasive Resistant Overlay (ARO)
  - Crossings (heavy Wall)
  - HDD/RRC/Highways/Roads/Water

- Powder Manufactures:
  - Valspar
  - Dupont
  - 3M

(a)Reference
Pipeline Construction Sequence

A - Surveying and Clearing of Site
B - Laying Out Pipe Sections
C - Welding Pipe Sections Together
D - Digging Pipeline Trench

E - Construction Inspections
F - Lowering Pipe Into Trench
G - Backfilling Trench and Pipeline
H - Hydrotesting Pipeline
I - Site Restoration
CO₂ Pipelines - Regulations

- Regulated by Department of Transportation, Pipeline Hazardous Materials Safety Administration
- CO₂ Pipelines are regulated under 49 CFR Part 195 - Transportation of Hazardous Liquids by Pipeline
- Governs materials, design, construction, operations, and maintenance
- State Agencies may have additional regulations
- Regulations are specific/prescriptive or performance based
- Operations and Maintenance Manual
  - Operator interpretation and implementation of code
  - Provides uniform standard
  - Auditable procedures
  - Must follow plans and procedures as outlined in O&M Manual
  - Operators must comply with minimum standards from code or state
- Records prove compliance – types of records
  - Life of facility (includes construction, materials, repairs, testing, and MOP information)
  - Transient (includes tests, inspections, patrols, and surveys)
  - No records = did not do the work
- Pipeline Safety Management System – API RP 1173
CO₂ Pipelines-Operations

Operations:

- ANSI 900/1,500 Pipeline System
- Minimum CO₂ Pressure: 1,300 psig
- Maximum Operating Pressure (MOP) varies per hydraulics/terrain
  - Typical: 2,160 psig / 2,220 psi
  - As high as 3,000+ psig
- Measurement – Orifice Measurement
- Cathodic Protection
  - Typical: Impressed Current System
- Remote Controlled by SCADA
- Pipeline Integrity Program
  - “Piggable”-Pigging program per CFR 195 and Kinder Morgan O&M
  - Anomaly Digs Per CFR 195 & O&M
- One Call Program
  - 811 Call Before You Dig Program
CO₂ Pipelines – Operations
SCADA: Operational Control

Cortez, Colorado Control Center

System Control

- 24 hour monitoring and control of Pipeline Facilities
- Monitor pressures and flow at key points on the system
- Receive key alarms from field locations and callout employees in response
- Provides full remote control to:
  - Start/stop Pump Stations
  - Flow control of meter facilities to customers
  - Shut-down and closure of valves during normal operations and in an emergency
**Kinder Morgan CO₂ Pipeline System**

### CO₂ Pipeline System

![Map of CO₂ Pipeline System](image)

### Pipeline Details

<table>
<thead>
<tr>
<th>Name</th>
<th>Length (miles)</th>
<th>Diameter</th>
<th>Year Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRC PL</td>
<td>138</td>
<td>16”</td>
<td>1975</td>
</tr>
<tr>
<td>Cortez PL</td>
<td>502</td>
<td>30”</td>
<td>1984</td>
</tr>
<tr>
<td>Central Basin PL</td>
<td>143</td>
<td>26”, 24”, 20”, &amp; 16”</td>
<td>1985</td>
</tr>
<tr>
<td>Pecos PL</td>
<td>25</td>
<td>8”</td>
<td>1985</td>
</tr>
<tr>
<td>Centerline PL</td>
<td>112</td>
<td>16”</td>
<td>2002</td>
</tr>
<tr>
<td>Cogdell PL</td>
<td>4</td>
<td>10”</td>
<td>2003</td>
</tr>
<tr>
<td>Eastern Shelf PL</td>
<td>91</td>
<td>10”</td>
<td>2010</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,298</strong></td>
<td><strong>4” to 30”</strong></td>
<td></td>
</tr>
</tbody>
</table>
QUESTIONS?