CO$_2$ Demand Estimates for Major Oil Fields in Wyoming Basins

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Wyoming Oil & Gas Fields
Wyoming Oil Producing Fields

- By the end of 2006, 7024 million barrels of oil (MMBO) have been produced from 1237 oil producing fields.
- Top 400 fields with cumulative production of one MMBO or more.
- Top 400 fields have produced 6865 MMBO, account for 97.7% of the total produced oil.
- Only top 400 fields were evaluated in this study.
Outline

- Screening of Wyoming reservoirs suitable for CO₂ EOR
- CO₂ flood performance in Lost Soldier Tensleep reservoir
- Dimensionless curves of WAG (CO₂-water) flood and gravity stable CO₂ flood
- Estimations of initial and total CO₂ demand based on hydrocarbon pore volume (HCPV)
Screening Criteria for CO$_2$ Miscible Flood

- Sandstone or carbonate reservoir
- Oil gravity $> 22$ °API
- Reservoir depth $> 2,500$ ft
- Oil viscosity $< 10$ cp, at reservoir condition
- Good waterflood response, usually requires porosity $> 7\%$ and permeability $> 10$md
- Reservoir cum. oil production $> 1$ MMBO
**CO$_2$ Minimum Miscibility Pressure (MMP) and Formation Fracture Pressure**

![Graph showing CO$_2$ MMP and Fracture Pressure in Permian Basin Reservoirs](image)

Formulated from Heller and Taber, SPE15001
Wyoming Fields with Active CO2 Flood Projects

- Salt Creek
- Lost Soldier
- Wertz
- Monell Unit of Patrick Draw
Other Possible Candidates for Miscible or Immiscible CO$_2$ Flood

- For sandstone or carbonate reservoir
- If 13 °API < Oil gravity < 22 °API
- If 1,800 ft < reservoir depth < 2,500 ft
- If oil viscosity > 10 cp, at reservoir condition
- Reservoir cum. oil production > 1 MMBO
Lost Soldier Tensleep: Oil Recovery by Water & CO2 Floods

- OOIP: 240 MMBO (Brokmeyer, SPE 35191)
- Recovery by Water FL: 108.7 MMBO
- Recovery by Water & CO2 FL: 134.3 MMBO
- Incremental Oil by CO2 FL: 25.6 MMBO

- Water FL Rec.: 45.3% OOIP
- Water & CO2 FL Rec.: 56% OOIP
- Incremental Oil: 10.7% OOIP

Peripheral water flood only
Recovery = 87.7 MMBO
36.5% OOIP
Lost Soldier Tensleep: Cummulative CO2 Injection and Production (by Oct. 2004)

- Cumulative Oil Production
- Cumulative CO2 Injection
- Cumulative Gas Production (including CO2)

Cumulative CO2 Injected: 432 BCF
Cumulative Gas or CO2: 310 BCF (estimated)
Net CO2 Needed: 122 BCF (estimated)

Start of CO2 injection in Jan. 1989
Cum. incremental oil: 19 MMBO, by Oct. 2004
CO2 remained in reservoir: 122 BCF
Ratio of injected CO2/incremental oil: 22.7 Mcf/BO
Ratio of purchased/injected CO2: 0.282
Ratio of net CO2 purchased/incremental oil: 6.4 Mcf/BO
Dimensionless Curves from Lost Soldier Tensleep WAG Flood

1 HCPV = OOIP*Bo

- Oil Produced
- Water Produced
- CO2 Produced
- CO2 Injected
- Water Injected
Dimensionless Curves of Incremental Oil by WAG Flood

Cumulative Incremental Oil, HCPV vs. Cumulative WAG (CO2 + Water) Injection, HCPV

- San Andres Formation, West Texas
- Lost Soldier Tensleep
Gravity Stable CO$_2$ Injection

- Reservoirs with large dip angles
- Reservoirs with high concentrations of vertical fractures
- Top-down continuous CO$_2$ injection
- Higher oil recovery (> 70% of OOIP)
- Larger volume of CO$_2$ injection
- Best for projects designed for CO$_2$ EOR and CO$_2$ storage
Gravity Stable CO2 Flood in Muddy Sandstone Reservoir
(calculation based on Wood & Lake' model, SPE 100021)

Calculated Case:
After 1.2 PV of CO2 injected
Reservoir dipping 15 degrees
CO$_2$ Flood (WAG) Injectivity

- Good: 10-15% HCPV per year
- Typical: 5-10% HCPV per year
- May not be economically viable if injectivity < 4% HCPV per year
Lost Soldier Tensleep: CO2 / Water Injection Ratio

Monthly CO2 / Water Injection Ratio

- In surface unit: MCF (CO2) / BW (water)
- In reservoir unit: rb (CO2) / rb (water)
Estimating Total CO$_2$ Demand for A Reservoir

- With assumptions of 1:1 WAG at reservoir condition; 2.5 HCPV of total WAG injection; 70% of injected CO2 being produced and re-injected

$$\text{Total CO}_2 \text{ Demand (MCF)} = \frac{1.25 \times 0.3 \times B_o \times OOIP}{B_{CO2}}$$
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<th>Basin</th>
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<th>current recovery 30% of OOIP Total CO2, BCF</th>
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Hanna Basin
Laramie Basin
Denver Basin
Shirley Basin
Powder River Basin

For Miscible CO2 Flood
For Possible Miscible and Immiscible CO2 Flood

Bighorn Basin
109 Reservoirs
3.3~4.9 TCF (52 Res.)
1.8~2.7 TCF (57 Res.)

Wind River Basin
52 Reservoirs
1.2~1.9 TCF (28 Res.)
0.1~0.2 TCF (24 Res.)

Greater Green River Basin
60 Reservoirs
0.8~1.2 TCF (23 Res.)
0.4~0.6 TCF (37 Res.)

(Excluding Salt Creek)

(Excluding Lost Soldier & Wertz)

291 Reservoirs
4.4~6.6 TCF (168 Res.)
0.8~1.3 TCF (123 Res.)

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Estimating Initial CO$_2$ Demand for a Reservoir

With assumptions of 1:1 WAG at reservoir condition; injection rate at 10% HCPV per year

$$CO_2 \text{ Injection Rate (Mcf/day)} = \frac{0.1 \times B_o \times OOIP}{2 \times 365 \times B_{CO2}}$$
Powder River Basin: Est. Initial CO2 Demand by Reservoirs
(Assuming Cum. Oil Production as 38% of OOIP)

- Hartzog Draw - Shannon: 264 MMCF/D
- Hilight - Muddy: 117 MMCF/D
- Lance Creek - Leo: 107 MMCF/D
Bighorn Basin: Est. Initial CO2 Demand by Reservoirs
(Assuming Cum. Oil Production as 38% of OOIP)

Reservoir ID Ranked by Initial CO2 Demand

CO2 Injection Rate, million cf/d

- Oregon Basin - Embar: 299 MMCF/D
- Elk Basin - Madison: 244 MMCF/D
- Elk Basin - Embar-Tensleep: 190 MMCF/D
- Byron - Tensleep: 115 MMCF/D
- Garland - Madison: 107 MMCF/D
Wind River Basin: Est. Initial CO2 Demand by Reservoirs (Assuming Cum. Oil Production as 38% of OOIP)

Steamboat Butte - Tensleep: 103 MMCF/D
Beaver Creek - Madison: 55 MMCF/D
Big Sand Draw - Tensleep: 54 MMCF/D
Greater Green River Basin: Est. Initial CO2 Demand by Reservoirs
(Assuming Cum. Oil Production as 38% of OOIP)

Arch - Almond: 79 MMCF/D
Brady - Weber: 73 MMCF/D
Brady - Nugget: 57 MMCF/D
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