CO$_2$ EOR Carbon Balance

Charles E. Fox
Kinder Morgan CO$_2$ Company, LP
Tip

Practice, arrive early and remember that the audience’s expectations are low.
EOR Carbon Balance

• Calculate carbon emissions for SACROC in 2007 using CA Registry methods (mostly)
• Compare various emission sources
• Comment on how you can make your calculations
• Look at short term and long term carbon balance calculations for the SACROC oil field
Oil Production (BOPD)

End of allowables and start of CO₂ flood
Occurred near the peak of waterflood

CO₂ Redevelopment
Basis - SACROC Complex 2007

- **Production**
  - 27,635 BOPD
  - 624,000 BWPD
  - 75,000 MCFD HC Gas
  - 637,000 MCFD CO2

- **Injection**
  - 582,000 BWPD into reservoir
  - 892,000 MCFD (CO2 + HC)
  - 212,000 MCFD Purch

- **835 Wells**
- **57 Compressors & Pumps >1000 HP**
- **225,500 HP in 2007**
  - Added five 5000 hp compressors later
- **Handles 120 MMCFD for 3rd Parties (16 MW)**
- **Snyder Gas Plant**
  - 15,000 BBL NGL/Day
  - 20 MMCFD HC gas
2007 Emissions

- Approximately 1 million tonnes CO$_2$e
- Primarily energy use – metered
  - Direct
  - Indirect
- Calculations based on
  - Metered volumes
  - Estimated factors
- California Registry Methodology
  - Except for indirect emissions
Gas Fired Power Plant

- 103 MW (net) Combined Cycle Plant
- Two LM6000 turbines
  - 45 MW each
- One HRSG
  - Heat Recovery Steam Generator
  - 18 MW
- Burns 19.8 MMCFD (20,300 MMBTU/day)
- Heat Rate – 8000 kW/MBTU
- 0.44 tonnes/MW-hr

397,500 tonnes in 2007
Purchased Power (Indirect)

- Purchase 107 MW
- Total power needs = 210 MW
  - 30% Wells/ESP
  - 20% Water General
  - 14% Inlet Compression
  - 34% Recompression
  - 1% CO₂ Recovery
  - 1% CO₂ Pumps

409,600 tonnes in 2007
336,900 tonnes in 2007*
*No 3rd party gas processing
Reciprocating Engines

- Cooper Bessemer
- Caterpillar
- White Superior
- Dresser Rand

- 2 stroke, lean burn
- 4 stroke lean burn

- Purpose
  - Sales
  - Gas gathering
  - Third party gas return

89,000 tonnes in 2007

- Metered
Flares

- CO$_2$ Membrane Facility
- CO$_2$ Membrane Topping Unit
- Snyder Gas Plant
- Two metered sources:
  - “Flared” CO$_2$
  - Gas burned

61,400 tonnes in 2007
Heaters & Boilers

- NGL treating and gas conditioning for $\text{CO}_2$ separation
- MDEA
- MEA
- $\text{CO}_2$ Recovery
- Metered gas usage

54,100 tonnes in 2007
Vented Emissions

- Compressors
- Heaters
- Reciprocating Engines
- Turbines
- Based on maintenance factors

34,500 tonnes in 2007
Fugitive Emissions

- SGP (non refrigerant)  
  - 343 tonnes
- Compressor area  
  - 178 tonnes
- Process area  
  - 132 tonnes
- Refrigerants (vehicles/offices)  
  - 87 tonnes
- Power Plant  
  - 39 tonnes
- Misc.  
  - 390 tonnes

1200 tonnes in 2007
Mobile Emissions

- Heavy duty vehicles
- Light trucks
- Passenger cars
- Fork lifts
- Lawn mowers

500 tonnes in 2007

- Gasoline and diesel usage
How did we get those numbers?

Combustion Emissions from a Stationary Flare

<table>
<thead>
<tr>
<th>Specie</th>
<th>HC Gas Burned MMBTU</th>
<th>Emission t/MMBTU</th>
<th>Emission t</th>
<th>t CO2e/ t emitted specie</th>
<th>t CO2e</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>525.6</td>
<td>0.05306</td>
<td>27.88834</td>
<td>1</td>
<td>27.88834</td>
</tr>
<tr>
<td>N₂O</td>
<td>525.6</td>
<td>9 E-7</td>
<td>0.000473</td>
<td>310</td>
<td>0.14664</td>
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<tr>
<td>Methane</td>
<td>525.6</td>
<td>9 E-7</td>
<td>0.000473</td>
<td>21</td>
<td>0.00993</td>
</tr>
</tbody>
</table>

Based on fuel usage
Where can I go for more pain?
SACROC Complex GHG Emissions
2007 Estimate

1,046,000 Tonnes Total Complex
972,800 Tonnes CO₂ Flood
Figure 7. Contours of pH measured by BEG and TWDB in Scurry County between 1995 and 2008. Contour interval = 0.5 pH units.
Retention

- Federal Register/Vol 75/No 68/Apr 10, 2009/P. 16584:

  “There are several EOR operations in the Permian Basin of Texas. One study showed that retention rates (for CO₂) for 8 reservoirs ranged from 38% to 100% and averaged 71%, but many of these projects are not mature enough to predict final retention.”

- Implication: If it is not retained, it is emitted – NOT SO!

- Retention is a term of art
- From Practical Aspects of CO₂ Flooding (SPE Monograph 22)

  “Retention: the amount of CO₂ remaining in the reservoir at any given time, which equals the amount of CO₂ injected less the amount of CO₂ produced. This normally is expressed as a percentage.”

- Retention = Net Utilization/Gross Utilization
Carbon Balance 2007

- Purchased: 4.08 Mt
- Direct/Indirect Emissions: -0.97 Mt
- Total Sequestered: 3.11 Mt

- Oil Production: 10.1 MMBO
- CO2e Emitted/BO: 0.1 t/BO
- Mcf/BO: 1.8 Mcf/BO

Mt = million metric tons
Field Life Carbon Balance

- EOR Production* 185 million BO
- Purchased 260.0 Mt
- Direct/Indirect Emissions** -18.5 Mt
- Total Sequestered 241.5 Mt

*10% of 1.85 billion bbl OOIP
**CO2e emitted 0.1 t/BO

Sequestering 93% of purchased injection
Capital Carbon Emissions (Embedded Carbon)

- Emissions created by creating and installing the capital stock
  - Drilling and completing wells
  - Installing compression
  - Laying flowlines
- Hard to calculate
- 530 tonnes/$1 million GDP*
- SACROC CO$_2$ flood capital – approx $3.5 billion
- Approx 2 million tonnes

*2007 Data

WSJ 9/1/2009

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WSJ 9/1/2009
## Field Life Carbon Balance With “Capital Emissions”

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased</td>
<td>260.0 Mt</td>
</tr>
<tr>
<td>Direct/Indirect Emissions</td>
<td>- 18.5 Mt</td>
</tr>
<tr>
<td>Capital Emissions</td>
<td>- 2.0 Mt</td>
</tr>
<tr>
<td>Total Sequestered</td>
<td>239.5 Mt</td>
</tr>
</tbody>
</table>

Sequestering 92% of purchased injection
Additionality

• Some say one must include the emissions from the oil production. This only makes sense if you don’t assume that oil wouldn’t be produced elsewhere, nevertheless:

• 0.43 tonnes/BO – EPA
• 134 lb/mcf or 0.06 tonnes/mcf - EIA
Field Life Carbon Balance With “Capital Emissions” and Additionality

<table>
<thead>
<tr>
<th>Category</th>
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<tr>
<td>Purchased</td>
<td>260.0 Mt</td>
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<tr>
<td>Capital Emissions</td>
<td>- 2.0 Mt</td>
</tr>
<tr>
<td>Oil/Gas Product Emissions</td>
<td>- 97.0 Mt</td>
</tr>
<tr>
<td><strong>Total Sequestered</strong></td>
<td><strong>124.5 Mt</strong></td>
</tr>
</tbody>
</table>

Sequestering 48% of purchased injection
Conclusion

• GHG emissions at EOR fields are tied almost exclusively to energy consumption
  – electric power
  – gas fired reciprocating engines
  – heat
• GHG emission calculations are tedious
• EOR can sequester CO$_2$