Economic Analyses for Enhanced Oil Recovery

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Today’s presentation will describe ongoing and future economic work in the EORI. Projects include:

- Improving the Scoping of Possible EOR projects with CO$_2$.
- Evaluating risk in an EOR Project
- Forecasting the impact of CO$_2$ subsidies and taxes.
- Estimating Costs and Projecting Tariffs for a Pipeline Infrastructure.
- Scoping EOR with non-CO$_2$ Substances.
Improving the Scoping of Possible EOR-CO$_2$ Projects Entails

- Improving injectivity estimates for all Field Reservoir Combinations (FRCs)
- Collecting missing observations for FRCs that could not be scoped for lack of data.
- Scoping FRCs that have accumulated production that is less than 5 mm barrels.
Forecasts from scoping models depend on data, which are estimated values.

Selected observations have significant impact on scoping outcomes.

Think of these values as random variables with some probability distribution.
Critical Data Parameters and Uncertainty

How does profitability or an EOR project change as the following observations change?

- Original Oil in Place (OOIP)
- Injection Rate (Injectivity)
- Project Area in Acres
- CO₂ Prices
- Oil Prices
Treating our observation as the mean, we can define a probability distribution with a range of higher and lower values:

- OOIP: (-20%, +20%)
- Injection Rate: (-50%, +50%)
- Project Area: (-10%, +10%)
- CO₂ Prices: ($1.00 - $3.00)
- Oil Prices: ($40 - $100)
Treating our observation as the mean, we can define probability distributions with a range of higher and lower values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distribution</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>OOIP</td>
<td>Triangular</td>
<td>(-20%, +20%)</td>
</tr>
<tr>
<td>Injection Rate</td>
<td>Triangular</td>
<td>(-50%, +50%)</td>
</tr>
<tr>
<td>Project Area</td>
<td>Triangular</td>
<td>(-10%, +10%)</td>
</tr>
<tr>
<td>CO₂ Prices</td>
<td>Uniform</td>
<td>($1.00 - $3.00)</td>
</tr>
<tr>
<td>Oil Prices</td>
<td>Uniform</td>
<td>($40 - $100)</td>
</tr>
</tbody>
</table>
Consider a triangular (bounded) probability distribution for OOIP:
Randomly Choose Values for Each Parameter

- We now randomly sample a value from these distributions

- Repeating this process thousands of times (say 25,000) gives us a distribution of profits and other outcomes
Example: Lance Creek – Leo in Wyoming

- Initial scoping scenarios reveal that the Lance Creek /Leo is expected to be very profitable under selected assumptions...

<table>
<thead>
<tr>
<th>Label</th>
<th>Field</th>
<th>Reservoir</th>
<th>Cum. CO₂ Demand (Bcf)</th>
<th>Oper.- (1) ating Period (Years)</th>
<th>Avg. (2) CO₂ Demand (MMcf/d)</th>
<th>Avg. (3) CO₂ Demand (MMcf/d)</th>
<th>PV of Profits ($MM)</th>
<th>Incr. Oil Prod. (MMbo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>LANCE CREEK</td>
<td>LEO</td>
<td>36.2</td>
<td>19</td>
<td>10.9</td>
<td>3.8</td>
<td>129.8</td>
<td>9.4</td>
</tr>
<tr>
<td>70</td>
<td>RAVEN CREEK</td>
<td>MINNELUSA</td>
<td>34.6</td>
<td>12</td>
<td>12.6</td>
<td>5.2</td>
<td>80.3</td>
<td>5.7</td>
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<tr>
<td>35</td>
<td>GLENROCK SOUTH</td>
<td>DAKOTA</td>
<td>32.0</td>
<td>14</td>
<td>11.0</td>
<td>4.2</td>
<td>87.0</td>
<td>6.2</td>
</tr>
<tr>
<td>39</td>
<td>HAIYERSON</td>
<td>MINNELUSA A</td>
<td>25.4</td>
<td>13</td>
<td>9.9</td>
<td>3.6</td>
<td>30.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Example: Lance Creek – Leo in Wyoming

- **Estimation Error and Uncertainty for OOIP, Injection and Project Area:**
  - **OOIP** = 121,000,000 stbo (-20%,+20%)
  - **Injectivity** = 27,700 bwwm (-50%,+50%)
  - **Project Area** = 2,138 acres (-10%,+10%)
  - **CO₂ Price** = $1.00 - $3.00
  - **Oil Price** = $40 - $100
  - **Fixed Values** = 80 Acre Spacing 
    LSTP Analog
Example: Lance Creek – Leo in Wyoming

Distribution of Profits Measured in % IRR

Lance Creek - Leo in Wyoming

- Frequency
- Cumulative %

Median IRR: 119%
Median Project Life: 19 Years

% Internal Rate of Return on Net Quarterly Cash Flows from CO2 Enhanced Oil Recovery
Impact of CO₂ Subsidies and Taxes

- Suppose there is a tax on CO₂ emissions or subsidies in the form of tax credits are paid to use CO₂ in EOR.
- CO₂ sales are privately negotiated.
- The impact of the taxes and subsidies can be estimated with simulated markets.
Direction of Impact

- A tax or subsidy on CO$_2$ should motivate sellers.
- The direction of impact is a lower CO$_2$ price.
- The market simulations can estimate the percentage change.
Pipeline Costs and Tariffs
The Permian Basin
The Bigger Infrastructure Picture

**Time Path of CO₂ Pipeline Deliveries**

- **EOR-CO₂ Deliveries**
  - **Enhanced Coalbed Methane Recovery Deliveries**
  - **Continued EOR Deliveries**
    - **Other Sequestration Deliveries**
In principle EOR scoping can be done for any substance using the analog method, if we have data on the productivity of injections and the net quantities of the substance needed to do a sweep.

Possibilities include polymer flooding and gas displacement recovery with methane or nitrogen.
The End

Questions and Comments