Outline of Presentation

- Elk Petroleum’s role as a stakeholder in the CCS rule making process
- CCS in oil vs. saline reservoirs
- Underground Injection Control (UIC)
- Class II vs. Class VI wells
- Legacy wells as candidates for CO2-EOR
- Best practices for CO2-EOR well configuration
- Best practices for CO2-EOR well abandonment
- Managing long-term liabilities with risk pools
- Recommendations
CORN ETHANOL CO₂ FERMENTATION EMISSIONS PATHWAYS

Carbon Neutral

Atmospheric CO₂
Fermentation Emissions

Carbon Negative

Atmospheric CO₂
Captured CO₂ used in EOR

Corn Ethanol CO₂ emissions are returned to the atmosphere during fermentation
Corn Ethanol CO₂ emissions are captured and stored in oil formation

CORN ETHANOL CO-PRODUCT CARBON CONTENT

- Ethanol: 4.36kg C
- $\text{CO}_2$: 2.18kg C
- DDGS: 3.06kg C

Corn (one bushel): 9.6kg C

Source: Katherine Hornafius
13th Annual Carbon Capture, Utilization & Storage Conference - April 28-May 1, 2014 - Pittsburgh, PA
EOR with Corn Ethanol Fermentation CO2 is Carbon Negative: CO2 sequestered > CO2 emitted by combustion

Source: Katherine Hornafius 13th Annual Carbon Capture, Utilization & Storage Conference - April 28-May 1, 2014 - Pittsburgh, PA
CARBON VALUE CHAIN FOR BIO-CO2-EOR

Ethanol → EOR → LCFS

Carbon Capture → Storage → Utilization

Source: Katherine Hornafius 13th Annual Carbon Capture, Utilization & Storage Conference - April 28-May 1, 2014 - Pittsburgh, PA
Saline Reservoirs

- Saline reservoir is *unconfined*, so plume modeling and monitoring is required
- Integrity of the seal is *unknown*, so risk of geological confinement failure exists
- **Limited experience** with CO2 injection into saline reservoirs, so *no history* of potential problems to guide practices
- EPA requires **Class VI** well construction and monitoring for CO2 sequestration in saline reservoirs
- *No commercial benefit* to injecting into saline reservoirs without carbon credits or tax incentives

Source: Kuuskraa et al., Mississippi Saline Reservoir Test, CCS Conference, Pittsburgh, May 7-10, 2007
Oil Reservoirs

- Oil reservoir is confined, or hydrocarbon accumulation would not exist
- Integrity of the seal is proven, so low risk of geological seal failure
- 40 years of experience with CO2 injection into oil reservoirs, so there is extensive history with potential problems to guide best practices
- EPA endorses use of Class II wells for CO2 storage until oil field is abandoned
- Oil revenue from sequestration makes projects commercially possible, especially if no new wells are needed
Regulation of Underground Water Resources

Underground Injection Control (UIC)

- Regulations promulgated by the Safe Drinking Water Act (SDWA)
- EPA rules for UIC found in Title 40 (Part 144-148) of the Code of Federal Regulations
- Administered under UIC Programs in most states by that state’s Department of Environment Quality (DEQ), Department of Natural Resources (DNR), or Department of Conservation (DOC), which also regulate the oil and gas drilling and production activities in that state
- UIC Program in California is administered by DOGGR (Department of Oil, Gas & Geothermal Resources) in consultation with SWRCB (State Water Resources Control Board)
### Distinctions between Class II vs. Class VI Wells

<table>
<thead>
<tr>
<th>Class II Wells (CO2-EOR Projects)</th>
<th>Class VI Wells (Saline Reservoirs)</th>
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</thead>
<tbody>
<tr>
<td>Class II wells are for fluids for EOR (CO2, brine) and liquid hydrocarbon storage</td>
<td>Class VI wells are a new category instituted in 2010 for CO2 long-term storage but <strong>not</strong> CO2-EOR wells</td>
</tr>
<tr>
<td>Most states have primacy over UIC wells and use Class II well permits to regulate EOR</td>
<td>EPA currently regulates all Class VI wells, but is encouraging states to apply for primacy</td>
</tr>
<tr>
<td>Area of Review is minimum 1/4-mile radius around Class II injector or defined by limits of CO2-EOR project</td>
<td>Area of Review is undefined for Class VI wells since the reservoir is uncontained (need to model plume)</td>
</tr>
</tbody>
</table>

Source: “Well Integrity in CCS/CCUS Projects, DOE Presentation”
Class II wells authorized for long-term CO2 storage

- Geologic storage of CO2 can continue to be permitted under the UIC Class II program

- CO2 can be safely stored where injected through Class II-permitted wells

- Class VI site closure requirements are not required for Class II CO2 injection operations

- EPA encourages states to apply for primacy for all well classes, including Class VI. States approved for primacy are expected to administer the program through their oil and gas program.

Source: EPA Memorandum from Peter Grevatt, Director of Ground Water and Drinking Water, April, 2015
Criteria for Conversion from Oil Well to CO2 - EOR Well

- Surface casing set & cemented 50 feet below lowest Useable Source of Drinking Water (USDW)
  - This will protect all known fresh water aquifers
- Production casing should be cemented from TD to above any hydrocarbon zone or potential water source
  - This will protect other reservoirs from EOR processes

Mechanical Integrity Test (MIT)

- Required to demonstrate mechanical integrity of Legacy Wells
Best Practices for CO2-EOR Well Configuration & Monitoring

**Configuration**

- New non-corrosive tubing and packer for primary pressure barrier
- New well head with corrosion resistant materials

**Monitoring**

- Monitor pressure of the injection tubing (primary barrier), casing (secondary barrier), and annulus
- Provides identification of any potential leaks from the primary barrier to the secondary barrier
- Monitoring should continue for the life of the CO2-EOR project
Plugging and Abandonment

1. Squeeze perforations with acid resistant cement under pressure from the Cement Retainer.
2. Cover the Cement Retainer with 50’ of additional acid resistant cement.
3. Cut and pull production casing above perforations.
4. Cap the production casing with acid resistant cement for internal and external hydraulic isolation.
5. Fill the lower 50’ of surface casing with acid resistant cement as well as the next 50’ below the surface casing to provide internal and external hydraulic isolation.
6. Fill the upper 50’ of surface casing with acid resistant cement to provide hydraulic isolation.

Abandoned Well Bore Diagram:
- 50' Surface Plug Set 5' below surface
- USDW Useable Source of Drinking Water
- Fresh Water
- Surface Casing Cement
- Production Casing Cement
- Cap production casing with cement inside and outside casing to provide hydraulic isolation.
- Cement Retainer set above perforated zone
- Hydrocarbon Zone
Ownership, Management, and Liability for Sequestered CO2

- The fundamental challenge is that CO2 will remain sequestered infinitely, while corporate lifetimes are getting much shorter.
- This has led to various proposed solutions to the problem of long-term stewardship for sequestered CO2.

<table>
<thead>
<tr>
<th>Issue</th>
<th>During CO2 Injection and Oil Production</th>
<th>After Oil Production Ceases</th>
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<tbody>
<tr>
<td>Ownership of CO2</td>
<td>EOR Company</td>
<td>Transfer to State, after 10 or more years (e.g., Texas, Montana, Louisiana)</td>
</tr>
<tr>
<td>Monitoring and Management of Sequestered CO2</td>
<td>EOR Company</td>
<td>Transfer to state or federal agency, after some period, paid for by Trust Fund created by sequestration operators</td>
</tr>
<tr>
<td>Liability for Sequestered CO2</td>
<td>EOR Company, covered by traditional insurance products</td>
<td>Lack of insurance market solutions leads to two tier solution, with industry Trust Fund taking first loss, and government taking residual loss</td>
</tr>
</tbody>
</table>
In order to encourage the implementation of CCS the ARB should consider:

- Establishing a set of criteria under which CO2-EOR projects would qualify for CCS credits under AB32 before project start-up, so that the pathway to obtaining carbon credits is clear.

- Allowing Class II wells to qualify for CCS credits in CO2-EOR projects until project abandonment (following the EPA ruling).

- Organizing an insurance pool to handle long-term CO2 leakage risk so that cost is spread over many projects and potential leakage of CO2 is accounted for in the carbon credit allocation methodology.