Considerations in Developing QM for EOR Storage.

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<table>
<thead>
<tr>
<th>Type</th>
<th>Storage Only-Saline</th>
<th>EOR with Incremental Storage</th>
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</thead>
<tbody>
<tr>
<td>Land</td>
<td>Greenfield</td>
<td>Brownfield-already impacted by oil industry operations</td>
</tr>
<tr>
<td>CO₂ Management</td>
<td>CO₂ injection</td>
<td>CO₂ injection, production, recycle</td>
</tr>
<tr>
<td>Pressure Build-up Risk</td>
<td>Potential for large areas of pressure increase; pressure management may be needed</td>
<td>Pressure management is goal of EOR</td>
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<tr>
<td>CO₂ Trapping</td>
<td>Inferred trapping mechanisms</td>
<td>Demonstrated trapping</td>
</tr>
<tr>
<td>Solubility of CO₂ in Formation Fluid</td>
<td>CO₂ weakly soluble formation brine</td>
<td>High solubility of CO₂ in oil</td>
</tr>
<tr>
<td>Subsurface Information density</td>
<td>Few wells: sparse information</td>
<td>Many wells: subsurface well known</td>
</tr>
<tr>
<td>Mechanical Integrity/ Risk of Well Failure</td>
<td>Few wells, carefully drilled, cased and cemented</td>
<td>Many existing wells, some in unacceptable condition. Expense to remedy: identify, and re-enter to plug/repair</td>
</tr>
<tr>
<td>Pore space access</td>
<td>Variable by state; evolving</td>
<td>Existing legal framework</td>
</tr>
<tr>
<td>Revenues to offset CO₂ capture cost</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Monitoring &amp; verification, accounting (MVA)</td>
<td>MVA must be based on comprehensive geologic study.</td>
<td>Existing reservoir production and surveillance knowledge contributes to development of MVA; integrity of existing wells in the field a principal leakage concern.</td>
</tr>
<tr>
<td>Public Acceptance</td>
<td>Unknown.</td>
<td>Likely to be good. Public familiar / comfortable with oil production</td>
</tr>
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- Application of a saline QM approach to EOR may not result in most effective use of resources and could inadvertently result in unnecessary barriers to commercial EOR storage development, and focus effort in wrong places to assure storage integrity.

Source: 1
Basis for EOR Storage

- 4 decades of CO2 know how.

- Known trap containing HCs for millions of years, known injectivity, production volumes.

- Plume and pressure control through patterned injection and withdrawal of oil and brine.

- Recycle means virtually all of the purchased/injected CO2 remains in system and not lost to atmosphere, with exception of small volumes of vented/ fugitives. Operators’ experience: Progressive CO2 trapped in the subsurface with recycle.

- “Incidental” or “associated” storage is the only acceptable carbon storage approach for today's production companies. Industry has no interest in "packing it to the brim."

- "Stacked" brine storage in associated saline intervals is a hypothetical, but could be useful in old fields taking advantage of the existing infrastructure.

- Production of Residual Oil Zones (e.g. K-M' TW. X Tall Cotton), including “greenfields” (no overlying main pay zone) can be treated like EOR-storage projects.
Focal points for risk reduction and CO2 containment from atmosphere

- Prevention--Site selection criteria should be adopted to screen out risky EOR projects for storage purposes - e.g. fields with fractured cap rock, fields with too many unknown legacy wells, or those fields with legacy wells which have been poorly plugged / old fields with casing pulled for steel reuse.

- Legacy well integrity -- All wells in projected CO2 management area should be investigated (robust p&a for abandoned wells; for repurposed wells, integrity of materials such as casing & cement) and remedied where needed.

- How to handle edge-of-field CO2 migration or "leakage" from the EOR complex (beyond a lease where CO2 can no longer be tracked); use of water curtains and their termination at end of a project. Accounting and CO2 containment and production sharing agreements between companies?

- Closure--No EOR projects have been closed yet. How is project closure defined? Production block by production block? One advantage in EOR is that while patterns may close, fields remain open, so some form of surveillance might easily continue.

- CO2 withdrawal / moving CO2 to another part of field, pipeline, or another project should be incorporated in accounting methodology.

- In the case of change of field ownership, how to handle accounting, transfer of MRV, reporting responsibilities, accounting for already-stored CO2.
Some Thoughts on Monitoring and Accounting

• Monitoring should be leak-hypothesis based, in conjunction with initial risk analysis.

• Data collected under an agreement with operators could provide a foundation for CO2 verification. E.g. Injection/ fluid production data & pattern balance. (NOTE** Avoid conflating oil production and total fluid production.)

• Overlaps in "next generation" EOR and monitoring methods (e.g. new patterns, more wells, instrumented observation wells, downhole sensors, zone-by-zone flow tests to manage and control the CO₂ flood) mean that sophisticated operators may employ reservoir surveillance methods that could double as verification.

• Possible approach--tracking “pattern balance” of injectors and producers (Ideal would be near 1:1 injection/recovery of all injected fluids (not oil)).

• Baseline monitoring in brownfields may be challenging. Katherine Romanak's method (see previous QM workshop) illustrates useful approach where leakage to aquifer or atmosphere is suspected.

• Simple methods such as routine surficial well observations will be very helpful in catching smaller well integrity failures and should be a part of all QM...But a regular "whack a mole" approach is not adequate and should raise questions about the viability of a field for CO2 containment.

• “Above zone monitoring interval” (AZMI) may useful for many projects—especially where there is an extensive, laterally communicative zone above a containment zone or cap rock.
Highlighting Key Points

• EOR storage has a different, although overlapping, set of considerations relative to saline storage.

• EOR can be advantageous for storage of CO2, but operators are currently only interested in incidental storage. Accounting for recycle may be difficult and most straightforward approach may be: purchased- losses.

• Well integrity is primary concern. Initial site screening should avoid fields with unacceptable remedial cost and leakage risk.

• The concept of closure may be different than saline. Approach should consider the long term nature of EOR. Storage projects will likely close block-by-block. Any closure monitoring requirements should be leak-hypothesis based.

• Mining of data should be considered a core component of proving up storage. The burden should be on the operator to help develop an approach that fits the field/ project.

• Hard to have all the answers. Geology is always unique to each project. No cookie cutters. Program should learn/adapt by doing.