Perspectives on EOR-Geologic Carbon Storage

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The Many Advantages of EOR- Storage:

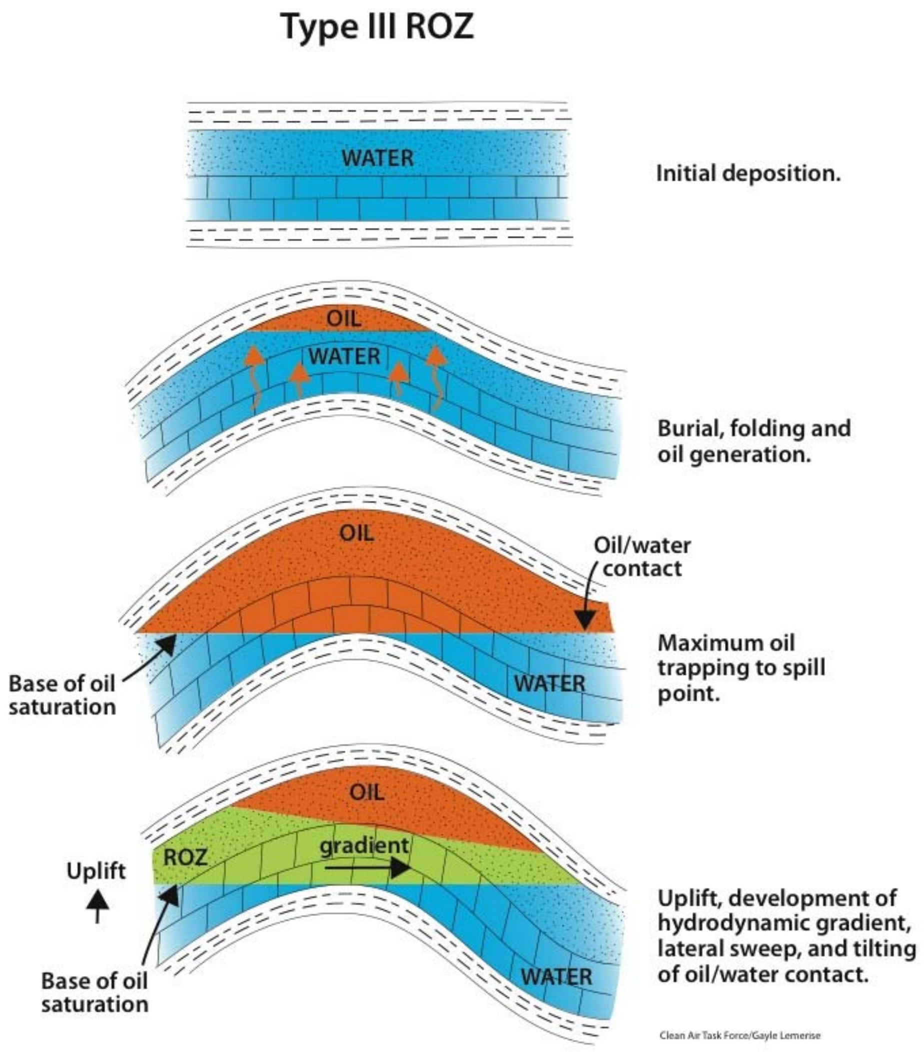
- Known trap, proven caprock, has stored hydrocarbons for millions of years.
- Known injectivity, vertical profile conformance.
- Pressure management; avoidance of seismicity.
- Existing reservoir model and data.
- CO_2 transportation infrastructure.
- CO_2 injection infrastructure.
- Inherent CO_2 plume management (via production).
- Efficiency of pore space contact through recycling.
- Undertaken in brownfield.
- Conducted in regions accustomed to injection (i.e., public acceptance).

Carbon Storage Opportunities Expand as EOR Storage Matures

- CO_2 EOR w/ incidental storage.
- Storage w/ incidental production.
- Residual oil zones.
- Stacked storage: large volume storage above or below fields.

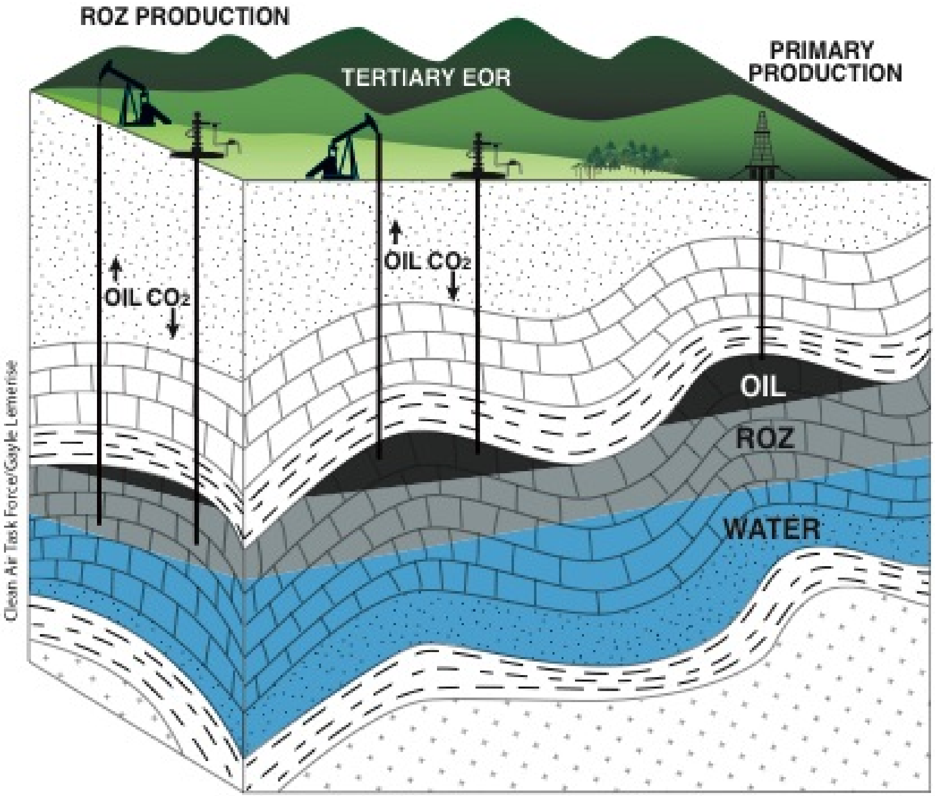
Residual Oil Zones Schematic: San Andres – Type 3

ROZ produced with same methods as CO2 EOR.



Estimated ROZ CO_2 Demand = 13 BT

(ARI, 2012)



-Examples include: TX: Seminole, Wasson, Means, Goldsmith. George Allen, Vacuum, Hanford, WY: Bighorn Basin.

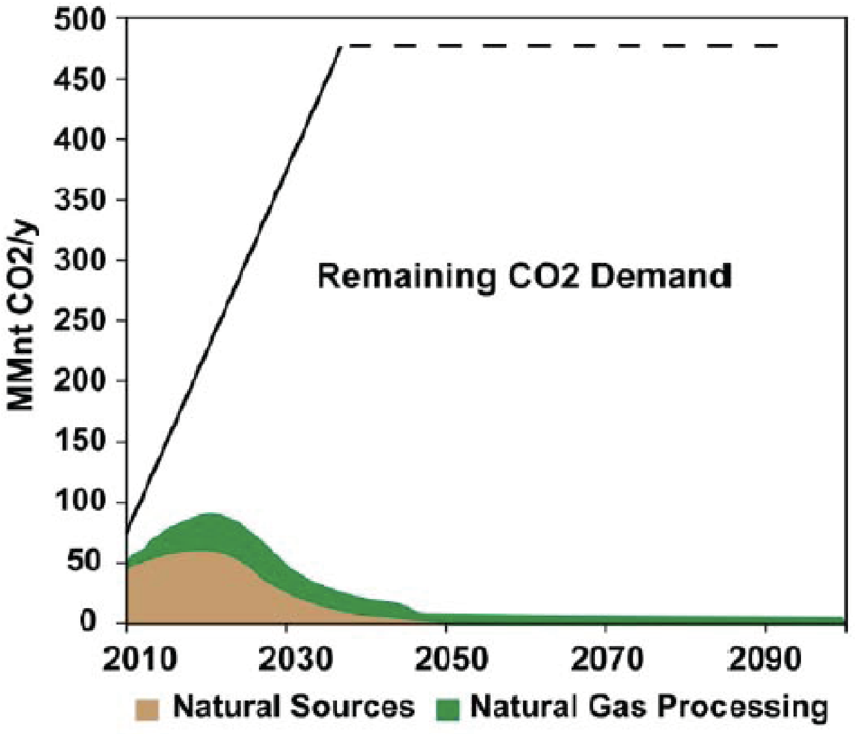
-Note "Greenfields" may allow production where no MPZ.

Why EOR Operators Should Care about CCS: Inadequate CO_2 Supply.

- 33 BMT CO_2 demand.
  (Kuuskraa/ARI, 2012).

- But only 2-3 BMT naturally-sourced CO_2.

- Captured sources of CO_2 are needed to fill large gap in supply.



EOR- Associated "Stacked" Brine Storage.

> High volume managed storage in saline brine formations associated with EOR. [Buffering Potential?]

> EOR facilities can provide existing transportation , injection and plume management--less environmental impact, lifecycle carbon from construction of new facilities.

2 Types:

- **LATERAL**: Downdip saline zones.

–Example: Denbury GCCC Cranfield Reservoir 4 MMT injected.

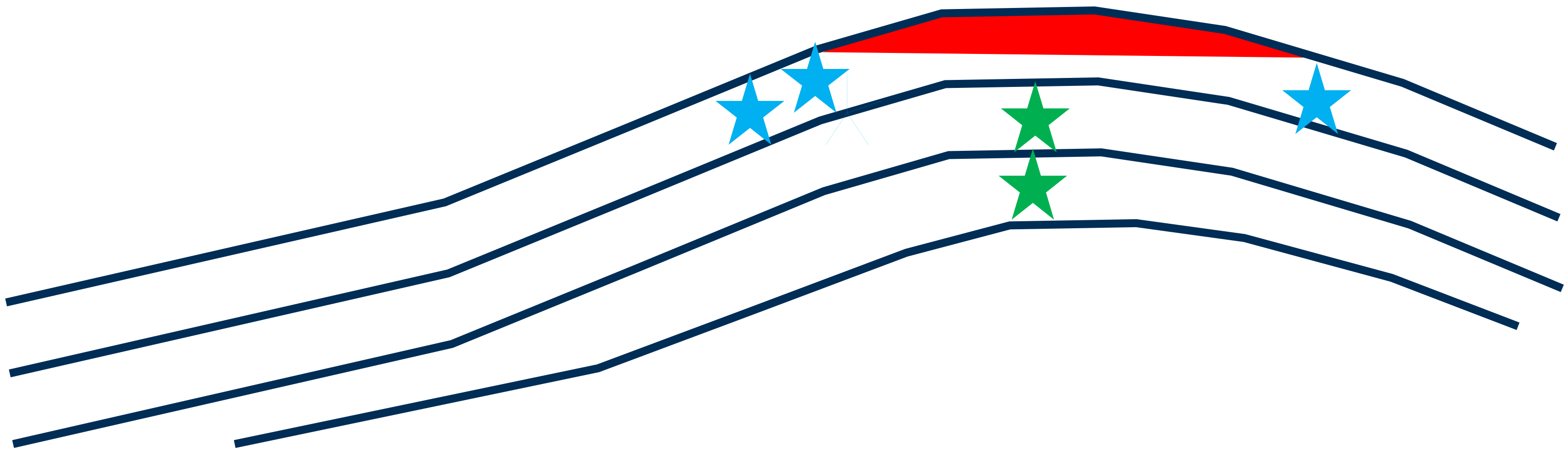
- **VERTICAL:** Saline aquifers associated with petroleum reservoirs.

–GCCC/Denbury Citronelle field (Plant Barry, AL).

–Saline zones in San Andres, Yates, Sprayberry, Wolfcamp, Queen, Bone Springs etc. Potential fields: Wasson, Seminole, etc.

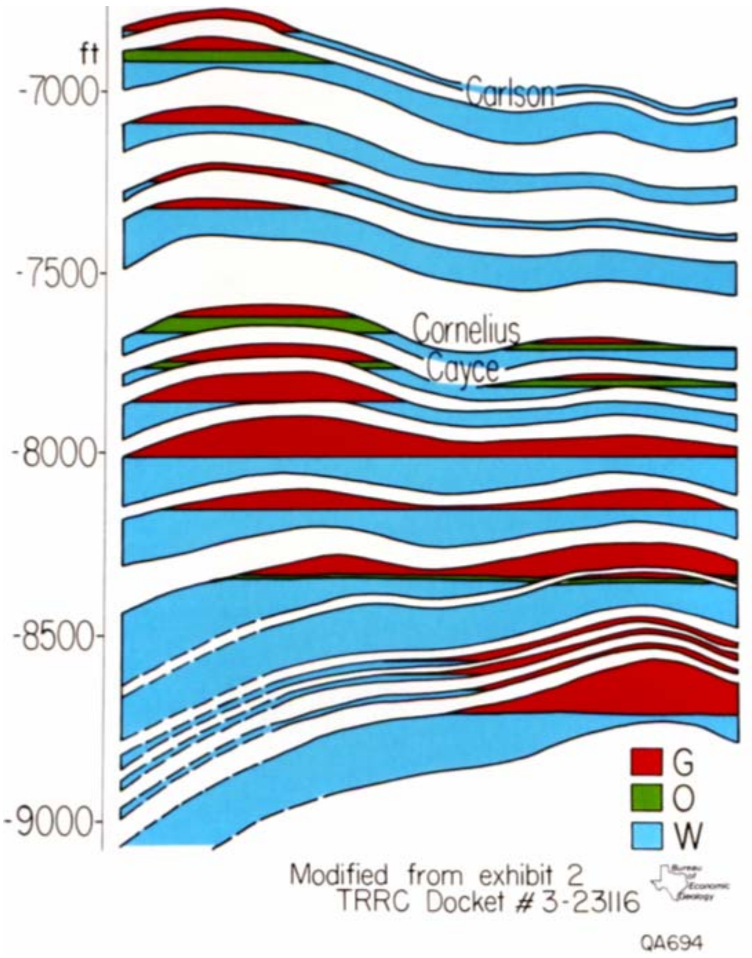
Geometries of Stacked Storage

- Vertical stacking ★
- Laterally offset ★



After Sue Hovorka, Gulf Coast Carbon Center/ TX BEG

Stacked Reservoirs, Frio Project, TX

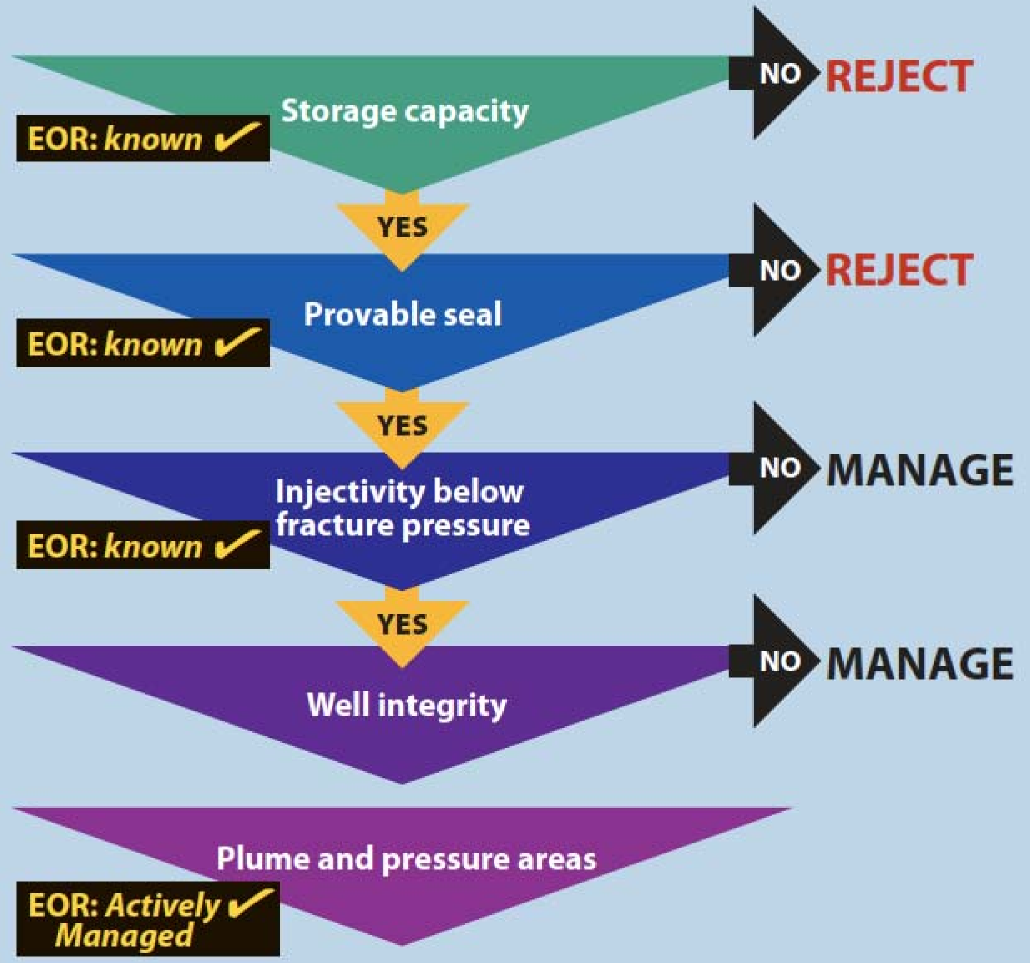


Courtesy Sue Hovorka / after Bill Ambrose, TX BEG/Gulf Coast Carbon Center

MVA: Security of CO_2 Ensured by Planning Activities & Plume Management.

Goals of MVA:

- Ensure CO_2 remains out of the atmosphere.
- Protect USDWs.
- Surveillance could result in more effective CO_2 flood.



After Hill, Hovorka, Melzer (2012); Original chart: Sue Hovorka.

Four Critical Components of Secure EOR–Storage.

Characterize Field for storage (e.g. capacity, integrity of seal following waterflooding); pre-injection (baseline") measurements.

Ensure Mechanical Integrity.

Unknown mechanical integrity presents greatest leakage risk.

- For new wells, robust casing and cement job.
- Map/field survey for existing wells in predicted area of plume.
- Monitor suspect wells.
- Re-enter wells for "corrective action" where poor P&A

Monitor Above Zone (AZMI) to ensure no adverse migration of CO_2 (e.g. P,T,X) above seal.

Conformance/ Post-Flood CO_2 Plume Equilibrium. Injection & post-injection monitoring/surveillance demonstrating conformance with reservoir model & demonstrating final equilibrium of plume.

Summary.

- Next generation EOR and ROZ development could demand north of 30 BT CO_2. The existing CO_2 resource is 2-3 BT. Will require captured sources of CO_2.
- EOR can provide a revenue stream to close capture cost gap, in turn generating more CO_2 for future EOR.
- Advantages: existing pipeline & injection facilities, known capacity & injectivity, reduced risk.
- EOR, ROZ & stacked storage can manage & accommodate large CO_2 volumes in future w/ existing infrastructure.
- MVA should seek to mine existing field model, data & surveillance. Early movers will chart path forward.

Thanks.

For a copy of GHGT-11 paper

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Geologic carbon storage through enhanced oil recovery.

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Abstract

The advancement of carbon capture technology combined with carbon dioxide (CO_2) enhanced oil recovery (EOR) holds the promise of reducing the carbon footprint of coal-fired power plants and other industrial sources, while at the same time boosting production of oil. CO_2 injection in deep formations has a long track record. Tertiary EOR with CO_2 has its origins in West Texas in the 1970's, when CO_2 was first used at large scale at the SACROC field to produce stranded oil following primary and secondary production (water flooding). Because CO_2 mixes with oil and changes oil properties, CO_2 floods are effective at producing additional oil following water flooding. Carbon dioxide is a valuable commodity both because of its ability to stimulate oil production from depleted reservoirs, and because of the limited volumes of naturally-sourced CO_2 in the U.S. Therefore, during large-scale commercial floods, CO_2 that is produced with oil during EOR is separated, compressed and re-injected and recycled numerous times. Venting to the atmosphere is a rare event, quantifiable, and constitutes an insignificant fraction of the injected CO_2. The CO_2 purchased mass, net any venting during EOR activity is sequestered in the reservoir by a combination of capillary, solution and physical trapping mechanisms. Approximately 600 million metric tonnes of purchased CO_2 have been utilized in the southwest U.S. Permian Basin (PB) alone, the rough equivalent of 30 years worth of CO_2 from a half dozen medium-sized coal-fired power plants.

Although CO_2 EOR technology is mature in the U.S., many reservoir targets have not been flooded because of limited CO_2 supply. Moreover, very large newly discovered EOR resources, known as "residual oil zones" (ROZs) occur in naturally water-flooded intervals below the oil-water contact in reservoirs that possess pore space containing immobile oil. ROZs are also now being documented in geologic settings without overlying conventional oil and gas accumulations. ROZ exploration and production using CO_2 promises the supplemental capacity to accept very large volumes of CO_2 in order to access and produce the remaining immobilized oil.

Many existing EOR sites may be ideal for sequestration because they: 1) provide known traps that have held hydrocarbons over geologic time, 2) provide existing CO_2 transportation and injection infrastructure, 3) occur in areas where the general public widely accepts injection projects, 4) provide CO_2