ARB CCS Technical Discussion Series: CO2 EOR

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August 23, 2016

CO2-EOR Production & CO2 Supply

- In 2012, CO2-EOR fields produced about 353,921 barrels of oil per day (bbl/d) in the U.S., which amounts to roughly 5.5% of domestic crude oil production. [1]
- Additional CO2-EOR production is limited by scarcity of CO2 supply
- ~ 80% of the CO2 used for EOR comes from naturally occurring, underground accumulations of CO2 [2]
- Remaining ~20% comes primarily from natural gas processing and fertilizer production plants [2]
- CO2 demand from natural sources will most likely continue to exceed supply, creating an incentive for CO2-EOR operators to pursue opportunities to capture man-made CO2 from large industrial facilities.

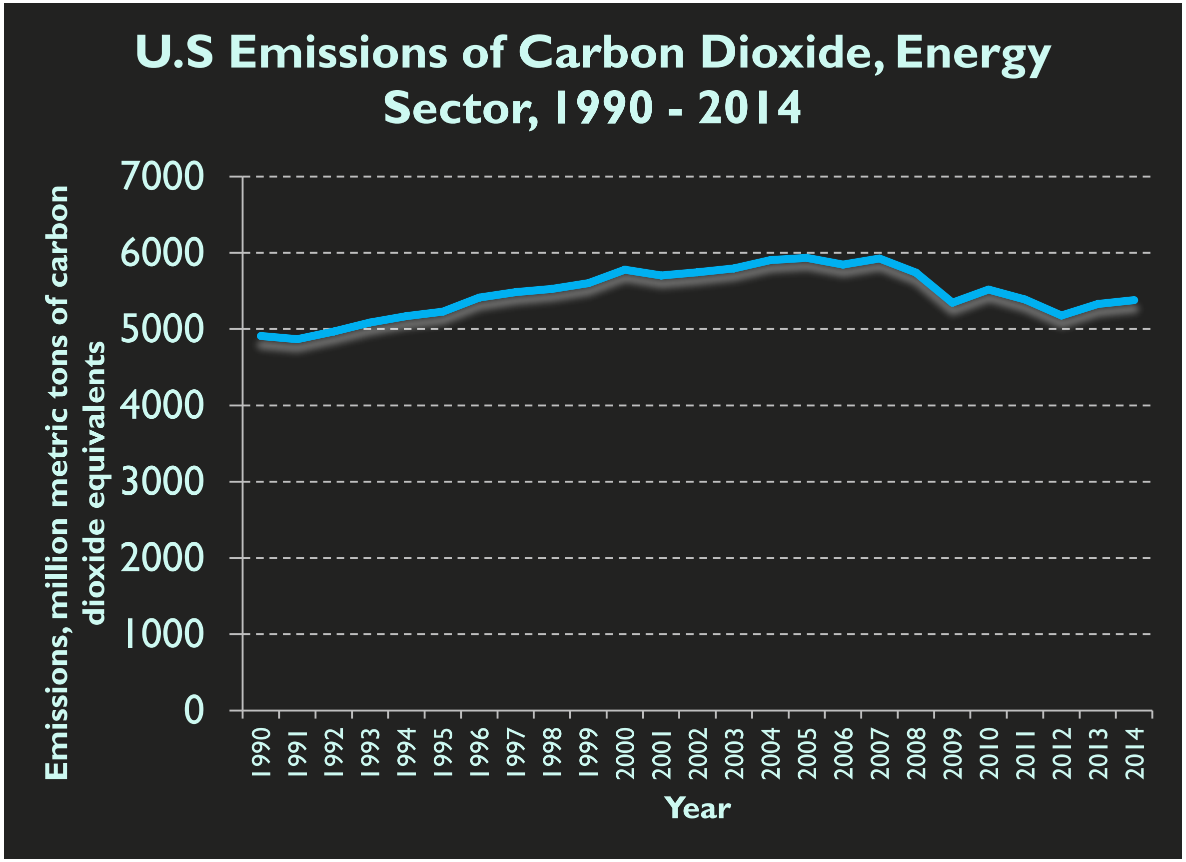
CO_2-EOR Potential

	Technically Recoverable Oil (Billion Barrels)		Economically Recoverable Oil (Billion Barrels)		Economic CO_2 Demand/Storage (Million Metric Tons)	
Oil price / CO_2 price	State of Art	Next Generation	State of Art	Next Generation	State of Art	Next Generation
$85/bbl / $40/tCO2	61.4	120.3	26.9	67.2	10,430	19,930
$45/bbl / $23.25/tCO2	61.4	120.3	13.9	49.3	4,800	13,400

Source [3]

Sequestration Potential

- Total benefit from sequestering CO_2 through EOR equivalent to ~1-3.5 times annual U.S. energy-related CO_2 emissions, depending on oil & CO_2 price and technology used. [3]



Source [4]

CO2-EOR Challenges

- Fields with long operating histories and large numbers of wells
- Observed quality of construction and maintenance in the field varies considerably with location, operator and age
- May have multiple owners over time and well files and well histories may be missing or incomplete
- State and federal records may also be incomplete, given that oil exploration and production in the U.S. predated regulation by several decades in some cases
- Location and plugging status of all wells within the field may be unknown or imprecisely known
- Orphan wells are ubiquitous in regions that have undergone oil and gas exploration and are a potentially significant leakage risk for CO2-EOR projects
- Orphan wells may have been constructed and/or plugged using outdated methods, and may have not been maintained over time to ensure that the integrity of the construction and plugging materials has not degraded

CO2-EOR Challenges

- Maintaining mechanical integrity critical to preventing leakage; performance of existing projects generally not well documented/publicly available
- Numerous studies demonstrate that determining the precise number of violations, mechanical integrity and contamination incidents, and their variation with time or location is not possible with existing data [5]
- Information is incomplete, outdated, or nonexistent making it is difficult to infer exact mechanical integrity failure rates or the number, extent and frequency of contamination or leakage incidents
- Class II regulations leave significant discretion to operators
- 40 states have primacy for Class II, contain 94% of Class II wells and produced 99% of U.S. onshore oil in 2015
- Significant variation exists among state rules in terms of stringency and completeness, as well as in enforcement

CO2-EOR Challenges

- The commercial time horizon for a CO2-EOR flood (a few years to decades) is shorter than the time horizon of interest for achieving effective sequestration of CO2 from the atmosphere (centuries or longer)
- Migration of CO2 out of pattern, into authorized zones, or to the atmosphere is possible after injection and production cease due to lack of focus on post injection site closure
- Change in ownership may result in inconsistent stewardship of the stored CO2 and/or loss of critical knowledge of the field and its operating history
- Development of advanced EOR techniques could result in operators reentering CO2-EOR fields at a future date to recover additional reserves, which could necessitate "blowing down" the field

Leakage Pathways and Rates

- Largest documented release rate occurred at a blowout at the Sheep Mountain CO_2 Dome in Colorado.
  - Estimated 7,000 to 11,000 tons of CO_2 were released per day for 17 days, resulting in a total of approximately 200,000 tons of leaked CO_2. [6]
- Modeled CO_2 leakage rates from a completely unobstructed pipe found a maximum hypothetical CO_2 flow rate of approximately 20,000 metric tons/day (assuming a 7" inside diameter well and depth of ~5,000 feet)
  - Maximum exit gas velocity and flow rate is limited by the speed of sound
  - This theoretical maximum rate is approximately two times greater than Sheep Mountain [7]
- Maximum estimated leak rate from Aliso Canyon = 1,392 metric tons/day
- Leakage can occur through combination of well and geologic pathways, e.g. Leroy and Yaggy underground gas storage facilities [8][9]

Solutions

- Detailed site characterization to determine geologic suitability
- Site-specific Area of Review and Corrective Action plans that take into account field data and operating history
- Robust methods for identifying existing wells, including
    1. Historical Record Review
    2. Site Reconnaissance
    3. Aerial and Satellite Imagery Review, and;
    4. Geophysical and Air Emissions Surveys
- Ensuring MI of existing wells, including
    1. Well Record Review
    2. Field Inspection and Testing, and;
    3. Corrective Action
- Best practices for new well construction and conversion of existing wells
- Robust leak inspection, detection, reporting, and repair standards
- Comprehensive Mechanical Integrity Testing Plan, including post-closure

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