**ARB's Carbon Capture and Sequestration (CCS) Program**

**CCS Technical Discussion Series:**
**CO2 EOR**

## Background on ARB's CCS Technical Discussions

ARB is currently developing a program to allow for the use of carbon capture and sequestration (CCS) in its climate change programs, and to advance the use of CCS as a greenhouse gas (GHG) reduction strategy generally. As part of this effort, ARB's CCS program staff seeks to better understand the ability of CCS to contribute to California's climate goals, the limitations or advantages of the technology, and the innovation and incentives necessary for adoption. To support this work, ARB is developing a quantification methodology (QM) for CCS projects., The CCS QM may be adopted for use in the Cap-and-Trade and Low Carbon Fuel Standard programs as determined appropriate in rulemaking(s) specific to these programs. For more information on ARB's CCS program and development of the QM please visit our website at http://www.arb.ca.gov/cc/ccs/ccs.htm.

In order to ensure staff is using the best available information and understands stakeholder concerns, staff will be hosting a series of technical discussions. The CCS technical discussions will be topic focused stakeholder-led discussions. The intent is to allow interested parties to provide input that will inform development of the CCS QM, as well as the CCS program generally. ARB will identify subject areas and specific questions, with the expectation that stakeholders will provide presentations, or other materials, and participate in an open discussion.

The CCS technical discussions will be accessible via webinar, conference call, and in-person at ARB headquarters in Sacramento, California. At the discussion, staff will provide a short overview of the identified subject area, as well as other information pertinent to the discussion if applicable, but the primary focus will be on stakeholder presentations and discussions. ARB generally will not provide a presentation or formal meeting notes, but will post all stakeholder presentations or other submitted materials to ARB's CCS website at http://www.arb.ca.gov/cc/ccs/meetings/meetings.htm.

## $CO_2$ EOR Technical Discussion:

Carbon dioxide enhanced oil recovery ($CO_2$ EOR) is a tertiary method of oil production that injects compressed $CO_2$ into oil reservoirs and recovers additional crude oil beyond what is possible from the primary and secondary methods of crude production. In doing so, $CO_2$ EOR projects can store $CO_2$ in oil reservoirs. The use of oil reservoirs for geologic sequestration may be attractive as these reservoirs were known to have good seals that retained oil and gas for million years prior to initial oil production. However, these seals may have been compromised during oil extraction and may introduce potential for $CO_2$ leakage.

Revenues from additional production of crude oil can compensate for a portion of the cost of $CO_2$ capture, transport, and injection. As a result, current carbon capture projects may find it economically preferential to provide their $CO_2$ to oil field operators for use in $CO_2$ EOR projects, rather than using dedicated carbon sequestration wells and storage reservoirs where no such cost compensation is available. $CO_2$ EOR

projects where carbon sequestration is a specific goal of the project may increase in number and scale as public acceptance and regulatory oversight grow.[1]

ARB understands that current $CO_2$ EOR projects exist in order to extract oil, and generally do not place a particular focus on permanent storage of $CO_2$. In fact, in order to minimize $CO_2$ costs, $CO_2$ EOR operators may retrieve $CO_2$ from exhausted sites and transport that $CO_2$ for re-use in other sites. Some $CO_2$ is retained within injection sites and remains un-retrievable (sometimes called incidental sequestration). As a result, all $CO_2$ EOR projects may achieve some level of $CO_2$ sequestration. Where $CO_2$ EOR projects may differ from one another is the source of the $CO_2$ (natural[2] vs. anthropogenic), the amount of $CO_2$ injected that is sequestered, and the permanence of the sequestration. Therefore, throughout this document and our discussions we will tend not to distinguish between $CO_2$ EOR projects and operations based on whether their primary goal is $CO_2$ sequestration, but rather recognize, highlight, and design the CCS QM around the fact that $CO_2$ EOR projects can have a range of potential for $CO_2$ sequestration, and that, for permanent carbon sequestration to be recognized under California's climate programs, projects must meet CCS QM requirements.

As with other geologic $CO_2$ storage solutions, risks of $CO_2$ leakage either to the atmosphere or into unintended compartments in the subsurface may still exist. $CO_2$ leaks can pose a safety risk to human health, cause contamination of aquifers or other mineral resources in the subsurface, cause damage to plants and wildlife, or result in GHG emissions. These risks will be the specific focus of a separate technical discussion, but to the extent that there are risks that are more specifically relevant to $CO_2$ EOR they are applicable to the current technical discussion.

With regard to the quantification methodology, the inclusion or exclusion of sources in the system boundary[3] has the potential to impact the magnitude of GHG emissions reductions. For the Cap-and-Trade Program, system boundaries are well defined in the GHG Mandatory Reporting Regulation (MRR); thus, the CCS QM should be designed to align with the MRR system boundaries. The LCFS program is based on lifecycle assessment and therefore, in the context of the potential use of the CCS QM in the LCFS program, it will be important to understand and define the most appropriate system boundary for $CO_2$ EOR projects.

Additionally, as with any method of $CO_2$ storage, but perhaps particularly so when the storage takes place in an active oil field, ARB's QM for $CO_2$ EOR with carbon sequestration must ensure that emission reductions for $CO_2$ sequestration projects are real, permanent, quantifiable, and verifiable.

The main goal of this technical discussion is to understand and receive recommendations on how to deal with the risks and particulars of permanent $CO_2$

[1] Hovorka, S., and S. Tinker. "EOR as sequestration: Geoscience perspective." Proceedings of the MIT Symposium on Role of EOR in Accelerative Deployment of CCS, Cambridge, MA, USA. Vol. 23. 2010.
[2] $CO_2$ from natural geologic sources, such as natural $CO_2$ domes, that would not otherwise be released would not qualify for CCS benefits under California's climate programs.
[3] The system boundary defines which processes and activities are included in the scope of analysis; this term is frequently associated with lifecycle analysis.

storage in oil fields using $CO_2$ EOR. As such, we are looking to determine what considerations need to be taken into account to ensure that the CCS QM provisions for $CO_2$ EOR as a storage method are robust and defensible, reservoir mechanical integrity is maintained throughout the lifetime of $CO_2$ EOR projects, and $CO_2$ leaks are minimized. The technical discussion also seeks inputs on co-optimization of oil production and $CO_2$ storage.

*Participating in the $CO_2$ EOR Technical Discussion*

DATE: Tuesday, August 23, 2016
TIME: 9:30 a.m. to 3:30 p.m.

To attend in person:

LOCATION: Conference Room 550
ADDRESS: Cal/EPA Headquarters Building
1001 "I" Street
Sacramento, California 95814

To participate by webinar:
https://attendee.gotowebinar.com/register/2504832999508397057

To participate by teleconference:

United States: +1 (415) 655-0060
Access Code: 318-888-298
Please note that this is a toll call.

*Presenting at the $CO_2$ EOR Technical Discussion*

If you would like to present at the $CO_2$ EOR Technical Discussion, please contact Mr. Anil Baral at (916) 327-6913 or Anil.Baral@arb.ca.gov by August 15, 2016. ARB is requesting that presentations be limited to 20 minutes. Depending on interest, ARB may adjust presentation length and will communicate this to presenters ahead of time.

If you require special accommodation for the scheduled meeting or need this document in an alternate format (e.g., Braille, large print) or another language, please contact Ms. Regina Cornish at (916) 327-1493, as soon as possible. TTY/TDD/Speech to Speech users may dial 711 for the California Relay Service.

If you have questions about the $CO_2$ EOR Technical Discussion, please contact Mr. Anil Baral at (916) 327-6913 or Anil.Baral@arb.ca.gov.

*Questions to Guide the $CO_2$ EOR Technical Discussion*

The following section provides a list of questions that is intended to guide stakeholder presentations and the discussion generally. Please note that this list is not exhaustive either in topics or questions. Please keep in mind that the goal of the discussion is to explore both what current practices in $CO_2$ EOR projects are, and what changes are needed for $CO_2$ EOR projects to achieve permanent carbon sequestration.

## Overview of $CO_2$ EOR

1. How are $CO_2$ EOR projects designed and operated? Are they designed or operated differently when carbon sequestration is specifically considered?

2. What are the important features and operations of $CO_2$ EOR ($CO_2$ injection, gas separation, $CO_2$ recycling, injection wells, production wells, etc.) with respect to permanent carbon sequestration?

## Quantification Methodology Elements for $CO_2$ EOR with Carbon Sequestration

1. ARB is aware of a number of $CO_2$ EOR accounting protocols and has included these in our accounting protocol technical discussion and overview document[4]. Are there others we should be aware of? What are the findings of each? How does the choice of system boundary in these protocols affect calculated GHG emissions?

2. Given the costs ($50-120/tonne)[5] [6] of $CO_2$ from post combustion capture, EOR operators may prefer to decompress the stored $CO_2$ and move some or most of the $CO_2$ to other fields for injection. There is also a possibility that EOR operators may choose to blowdown[7] their reservoirs after terminating injection in an attempt to extract a small amount of additional oil while also releasing some fraction of the $CO_2$ sequestered underground back to the surface. Hence, what is the best approach for addressing intentional $CO_2$ releases that may happen towards the end of $CO_2$ EOR projects? Alternatively, what would be the consequences to $CO_2$ operators if intentional $CO_2$ releases were not allowed for $CO_2$ EOR sequestration projects?

3. $CO_2$ EOR causes an increase in crude oil production capacity, which otherwise may not happen in its absence. What is the policy implication of increased crude

[4] ARB. "A Comparative Study of Existing Standards/Protocols for Carbon Capture and Sequestration to Inform Development of a Quantification Methodology. (2016).http://www.arb.ca.gov/cc/ccs/meetings/CCS_Protocols_Comparative_Study_4-4-16.pdf

[5] Kapteijn, Pieter Karel, Eric Kutscha, and Joshua Perron. "A Breakthrough Oxy-Fuel Technology For Cost-Effective CO2-Enhanced Oil Recovery." Abu Dhabi International Petroleum Conference and Exhibition. Society of Petroleum Engineers, 2012.

[6] Rubin, Edward S., John E. Davison, and Howard J. Herzog. "The cost of CO 2 capture and storage." International Journal of Greenhouse Gas Control 40 (2015): 378-400.

[7] A blowdown is the process in which, instead of simultaneously shutting in both injection and production wells at the time of termination, only the injection wells are shut in, initially causing the pressure to drop below the minimum miscible pressure. As a result, the $CO_2$ mixed with the remaining crude oil in the reservoir is released and makes its way to the production wells.

oil production and how do we incorporate this consideration in the quantification methodology under the LCFS?

## Reservoir Types

1. What types of oil reservoirs are suitable for $CO_2$ EOR?
2. What are the key reservoir characteristics that determine whether it is suitable for permanent sequestration?
3. Are there reservoirs that would be suitable for CO2 EOR but not suitable for permanent carbon sequestration?
4. Beyond conventional oil reservoirs, what other oil fields (e.g., tight oil formations, residual zones) do have potential to store $CO_2$ permanently? Are concerns or risks different?
5. What are the mechanisms of $CO_2$ trapping in $CO_2$ EOR reservoirs?

## Reservoir Integrity

1. How can the mechanical integrity of oil reservoirs undergoing $CO_2$ EOR be ensured?
2. What are the most likely leakage pathways from $CO_2$ EOR projects?
3. What do observations of current projects tell us about the magnitude of $CO_2$ leakage from operational $CO_2$ EOR fields? What does the historical monitoring say? What do observations in gas storage tell us?
4. Are the monitoring methods for detecting and quantifying leaks from $CO_2$ EOR projects different than from other reservoir or injection types? If so, what are they?
5. What unique steps must be taken to prevent $CO_2$ leakage from oil reservoirs undergoing $CO_2$ EOR? Should abandoned wells be subject to specific integrity or abandonment requirements?

## Injection Potential

1. Given the cost of $CO_2$, historically the goal has been to maximize crude oil production with the least amount of $CO_2$ use. With carbon pricing, $CO_2$ storage may be become an important source of revenue, which may incentivize $CO_2$ EOR operators to co-optimize both the amount of stored $CO_2$ and crude production. Can crude oil production and $CO_2$ storage be co-optimized, or are these goals at odds with each other?
2. Is co-optimization of crude oil production and $CO_2$ storage economically or otherwise necessary to make $CO_2$ EOR production feasible/attractive?
3. What are the potential sources of $CO_2$ for EOR and their supply potential?

4. What are the costs and constraints on $CO_2$ supply?

## Injection Wells

1. Are there specific mechanical integrity needs for $CO_2$ EOR injection wells?
2. How is pressure managed in $CO_2$ EOR injection? Is it different from other CCS reservoirs?
3. What are the different $CO_2$ injection methods (e.g., continuous, water alternating gas)?
4. Which $CO_2$ injection methods are preferable for maximizing $CO_2$ storage?
5. Which $CO_2$ injection methods are economically preferable?
6. Are there particular concerns or risks associated with each $CO_2$ injection method?

## Production wells

1. How do production wells operate in $CO_2$ EOR? Are they different from conventional oil production?
2. Are there specific mechanical integrity needs for $CO_2$ EOR production wells?