FACT SHEET AND ANALYSIS

The Emission Reduction Benefits of Carbon Capture Utilization and Storage using CO_2 Enhanced Oil Recovery

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Enhanced Oil Recovery (EOR) using industrial CO_2 provides an important way to stimulate the development of the infrastructure needed to capture and store large amounts of CO_2 consistent with decarbonizing the energy system.

According to the International Energy Agency (IEA), utilizing industrial CO_2 Enhanced Oil Recovery for the purposes of Carbon Capture Utilization and Storage (CCUS) results in a net CO_2 emissions reduction.

Based on IEA's analysis CCUS-EOR using industrial CO_2 can result in a *63% net reduction in CO_2 emissions* for every barrel of oil produced.

If we do not take advantage of CO_2 EOR, the oil may be produced by other technologies that do not reduce emissions.

According to the IEA, there is a potential to store 140 billion tons of CO_2 in oil reservoirs around the world through CO_2 EOR[1] - resulting in a net emissions reduction by 88 billion tons of CO_2. This is more than 40 times the current U.S. power sector emissions. Thus, under the right economic conditions there would be a large market-based opportunity to reduce man-made CO_2 emissions. As a result, enhanced oil recovery activity using captured anthropogenic CO_2, could significantly drive the deployment of CCUS technology & infrastructure, and help lower technology costs around the globe.

Can CO_2 EOR provide a net reduction in CO_2 emissions?

Yes. CCUS combined with EOR involves the incidental geologic trapping or storage of CO_2 that occurs as part of the oil recovery process. CO_2 is injected into mature reservoirs, where it mixes with the remaining oil, enabling it to be more easily produced, and as a result of which a portion of the CO_2 (usually about one-third to a half) is geologically trapped, permanently. The CO_2 that is not trapped is produced with the oil, recaptured, and reinjected – and the process continues until all of the CO_2 is permanently sequestered.

Over the life of the project, almost all of the CO_2 delivered to the field is stored in the geologic formation. But because EOR produces oil, which when processed or used produces emissions, the stored volume of CO_2 cannot entirely be counted as an emissions reduction. When the volume of CO_2 stored underground is greater than those emitted by the excess emissions caused by EOR activity, then the difference must be counted as a net emissions reduction benefit.

The most recent and comprehensive assessment of net storage from CO_2 EOR was developed by the IEA in 2015.[2] The study indicates that for a given volume of CO_2 delivered to an oil field or storage site, EOR can provide a 63% net emissions reduction benefit, under the reasonable assumptions outlined below.

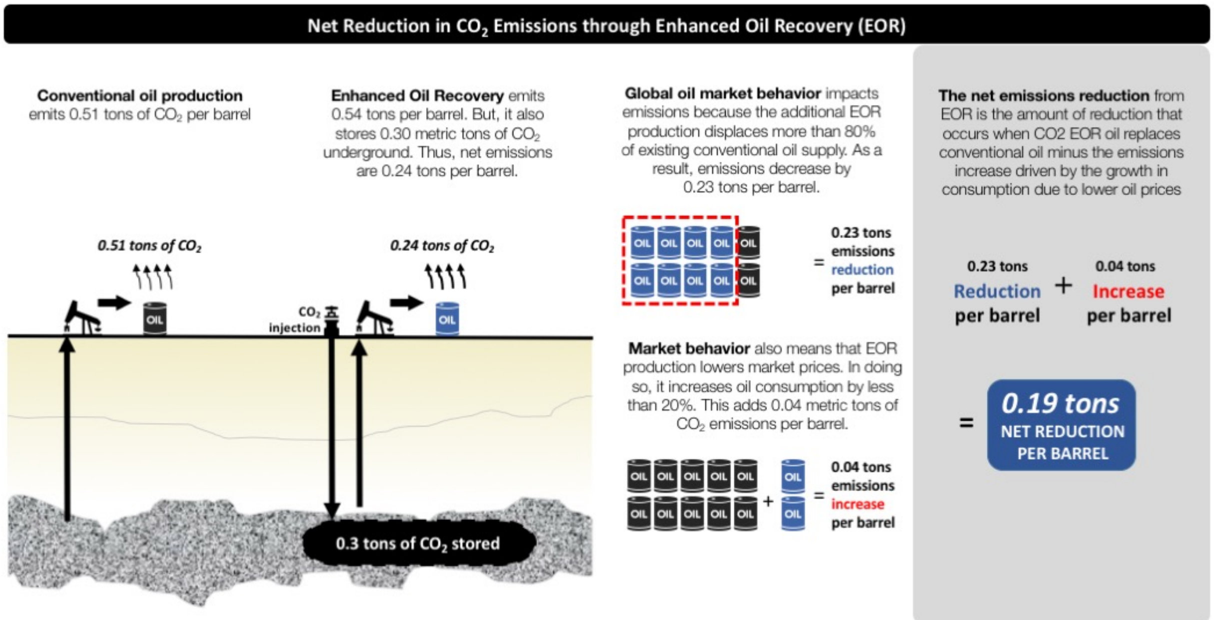

Figure 1: Net Reductions in CO_2 Emissions through Enhanced Oil Recovery (metric tons)

Figure 1 shows the benefits of CO_2 EOR in terms of CO_2 emissions reduction. The production and consumption of a typical barrel results in about half a metric ton of CO_2 being emitted to the atmosphere.

But, doesn't EOR result in greater overall CO_2 emissions due to oil production?

No. Producing a barrel of oil from CO_2 EOR is slightly more energy intensive than a conventional barrel of oil, with emissions of 0.54 metric tons and 0.51 metric tons of CO_2 respectively. But CO_2 EOR has the benefit of storing the 0.30 metric tons of CO_2 that was needed to produce 1 barrel of oil. After accounting for this benefit, the production and consumption of a barrel of oil from EOR contributes a net of 0.24 metric tons of CO_2 to the atmosphere.

If an EOR barrel replaced a barrel of conventionally produced oil in the market, then there would an emissions reduction of 0.27 metric tons of CO_2 per barrel (the difference between conventional oil emissions and EOR barrel emissions). In reality though, all else being equal, this 1 to 1 displacement does not occur. The new oil supply will lower the market price of oil and thus increase the demand for oil. The IEA estimates that for every 10 barrels of oil produced through CO_2 EOR, only 8 barrels of existing oil are displaced and 2 barrels are additional. The displacement of the 8 barrels (or 80% of existing supply) provides an emissions reduction benefit of 0.23 tons per EOR barrel.[3] But, the increase in consumption of the additional 2 EOR barrels (20% of existing supply) increases emissions by 0.04 tons per EOR barrel.[4] These market effects result in a net emissions reduction benefit to 0.19 metric tons of CO_2 per EOR barrel, on average.

Considering the CO_2 used for EOR is anthropogenic, i.e. captured from the power or industrial sectors and which would otherwise be released into the atmosphere, the net reduction of CO_2 is 63% per barrel of oil produced or per 0.3 tons injected (or, per any other volume of CO_2 injected).

The type of oil production that is assumed to be replaced by EOR is also a key factor in determining the net reduction in emissions. The IEA analysis found that net emission reductions could range from 47% to 150% depending on the carbon content of the oil that is assumed to be offset.[5] While a 20% increase in oil consumption driven by CO_2 EOR oil production delivers net emissions reduction, even if the consumption increased by 50% of a barrel, there would still be a net emissions reduction benefit.

Are there any other emissions that might affect EOR's benefit?

Yes, emissions upstream from the CO_2 EOR process can also affect the CO_2 emissions reduction benefits from using anthropogenic CO_2. But, it is important to note that the upstream emissions affect any sequestration method the same exact way. In other words, upstream emissions affect both EOR and storage in deep saline geologic reservoirs equally. Hence, it is only downstream emissions that provide the crucial "apples to apples" net emissions reductions benefit comparison.

Upstream emissions include those from coal and natural gas production, transportation of fuel, combustion and transportation of captured CO_2. But, the key emissions impact is driven by capture technology and configuration (new/retrofit/full or partial capture) used at the emitting source. For example, if we were to include in our upstream calculations a 90% capture from a retrofit on an existing coal plant using current conventional capture technology, then it would reduce the emissions reduction benefit from CO_2 EOR by 25%, due to process energy penalties and capture rates.[6] Alternatively, if we were to consider an advanced carbon capture technology such as one based on the Allam Cycle, which could reach 100% capture levels, bringing the energy penalty to minimal levels, then the reduction in the benefit from downstream CO_2 EOR would be minimal.[7]

Would the oil from depleted oil fields be produced anyway without CO_2 EOR?

Likely. The same oil that is targeted for CO_2 EOR, can be produced by other technologies and will only result in increased emissions. Oil from depleted wells will be recovered using the best available method, even if it is not CO_2 injection, if the oil prices so dictate. CO_2 EOR is effectively in competition with other EOR options outlined below. These options do not provide any climate benefit, but instead only permit and lead to increased CO_2 emissions.

Geologically-sourced CO_2 has been in use for several decades for CO_2 EOR. 75% of the CO_2 currently used for EOR is produced from natural geologic deposits. National Energy Technology Laboratory (NETL) estimates that there are an additional 3.9 billion metric tons of geologically-sourced CO_2 in the US that could be produced economically for use in EOR.[8] Because the natural-sourced CO_2 was already geologically trapped, it does not deliver a climate benefit when used for CO_2 EOR, unlike industrial-sourced CO_2.

The use of surfactants, polymers, and detergents for chemical flooding in reservoirs is another form of enhanced oil recovery. Advances in drilling such as infield drilling, horizontal drilling and fracking could also be used to extract the oil from reservoirs, which would otherwise be targets for CO_2 injection.

Methane reacts in oil fields in a manner similar to CO_2. The Norwegian oil company Statoil has been injecting methane into the North Sea for oil recovery (64 million metric tons /year) in amounts that are similar to those of CO_2 injected into the Permian Basin in Texas for EOR.[9] Methane is also regularly injected into the North Slope formation also for EOR. Although EOR is typically not the way to extract the most economic value out of methane, it is still used in some regions where either CO_2 is not available or oil-gas price arbitrage drives a preference for methane injection to produce additional oil.

Conclusion

Enhanced Oil Recovery using captured industrial CO_2 can provide a net CO_2 emissions reduction of 63% relative to the CO_2 stored, taking into account emissions from oil consumption. The combination of the existing and projected demand for EOR and the availability of industrial CO_2 offers the potential for developing the needed infrastructure to more widely deploy CCUS technology at a significant scale and to store large amounts of CO_2. Without CO_2 EOR using captured industrial (anthropogenic) CO_2, the oil will likely be produced anyway, using other methods of extraction that do not provide emissions reduction benefits.

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1 IEA Greenhouse Gas R&D Programme (IEA, GHG), "CO_2 Storage in Depleted Oilfields: Global Application Criteria for Carbon Dioxide Enhanced Oil Recovery, 2009/12, December 2009."

2 International Energy Agency, "Storing CO_2 through Enhanced Oil Recovery, combining EOR with CO_2 storage (EOR+) for profit," 2015.

3 The more precise IEA displacement estimate is 84%. Multiplying that with the difference between conventional oil and EOR oil (0.27 metric tons per bbl) results in a net benefit of 0.23 metric tons per bbl.

4 The more precise IEA displacement estimate is 16%. Multiplying that with the emissions from one barrel of EOR oil (0.24 metric tons per bbl) results in a net increase of 0.04 metric tons per bbl.

5 International Energy Agency, "Storing CO_2 through Enhanced Oil Recovery, combining EOR with CO_2 storage (EOR+) for profit," 2015.

6 Calculated from spreadsheet model developed for Azzolina, et al., "How green is my oil? A detailed look at greenhouse gas accounting for CO_2-enhanced oil recovery (CO_2-EOR) sites." International Journal of Greenhouse Gas Control 51 (2016) pp. 369-379. Considering coal plant retrofit with 90% capture level, 30% energy penalty and make up power from NGCC without carbon capture (no displacement of electricity grid mix).

7 NETPower briefing to USEA, May 25, 2016.

8 National Energy Technology Laboratory, "Subsurface Sources of CO_2 in the Contiguous United States Volume 1: Discovered Reservoirs," March 4, 2015, DOE/NETL-2014/1637.

9 Cavanagh, Ringrose, Statoil, ASA "Improving oil recovery and enabling CCS: a comparison of offshore gas-recycling in Europe to CCUS in North America", GHGT-12, Energy Procedia 63 (2014) 7677 – 7684.