CLEAN AIR TASK FORCE

CO_2 EOR Yields a 37% Reduction in CO_2 Emitted Per Barrel of Oil Produced

Utilization of captured CO_2 in Enhanced Oil Recovery (EOR) is a well-understood and verifiable process that can deliver CO_2 emission reductions. According to life cycle analysis done by the International Energy Agency (IEA), which includes impacts from potential increase in oil consumption, each tonne of CO_2 utilized in EOR nets a 0.63 tonne emission reduction. Said another way, EOR results in 37% reduction in CO_2 emissions per barrel compared to conventional oil production.

These values assume a scenario in which operators perform site characterization and risk assessments before selecting the site for EOR activities, measure CO_2 emissions from EOR processes, monitor for leakage of CO_2 and ensure long-term containment of CO_2 after injection has ceased.

Life Cycle Emissions: Per Barrel Basis

Figure 1 illustrates life cycle emissions on the basis of a barrel of oil produced through CO_2-EOR. For comparison, a barrel of oil produced using conventional means emits 0.51 tonnes of CO_2 on a "well-to-wheel" basis.[1]

CO_2 that is utilized for EOR eventually gets geologically trapped, permanently. Recovery of every barrel of oil produced through CO_2-EOR typically involves injecting and utilizing 0.3 tonnes of CO_2 into an oilfield. The injected CO_2 helps release crude oil trapped in the pores of the source rock and in the process the CO_2 becomes trapped permanently in those pores.

Hence, relative to conventional oil production, utilization of 0.3 tonnes of CO_2 for EOR lowers the well-to-wheel emissions from a barrel of EOR-produced oil to 0.21 tonnes of CO_2.

But, EOR operations at the project level have higher process emissions than conventional oil production. There is a 0.03 tonne increase in CO_2 emissions from processes such as separation and recycling of CO_2. Thus the benefit of CO_2 injection drops from 0.3 to a net reduction of 0.27 tonnes per barrel, hence the well-to-wheel emissions go up from 0.21 to 0.24 tonnes of CO_2.

If all EOR-supplied oil displaced existing supply of conventional oil, then the net reduction in emissions

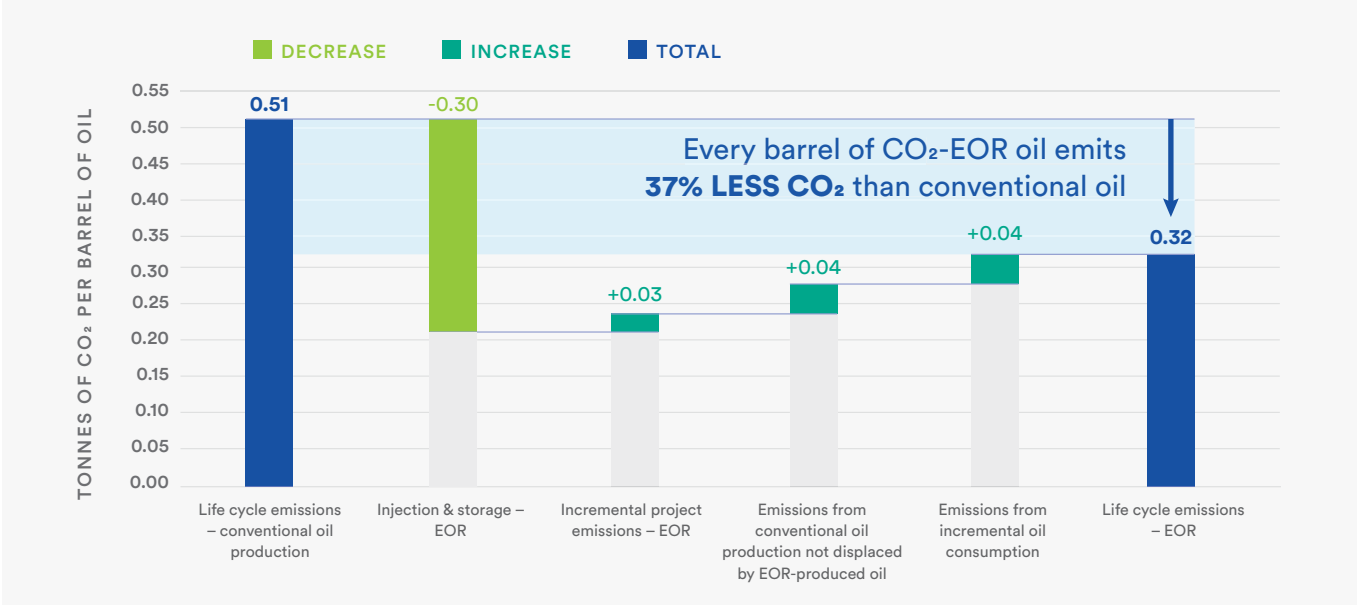

FIGURE 1: NET CO_2 EMISSION REDUCTIONS FROM ONE BARREL OF OIL RECOVERED THROUGH ANTHROPOGENIC CO_2-EOR

[1] Well-to-wheel emissions refers to life cycle emissions from of oil that includes all emissions downstream of the oil extraction process until when the oil is combusted, for instance, in a car. However, for EOR, calculating life cycle emissions will need to adjust well-to-wheel emissions to include global oil market impacts.

would be all of 0.27 tonnes of CO_2 per barrel. However, the operation of global oil markets does not allow for this one-for-one displacement. IEA's global oil market analysis estimates that when oil produced through CO_2-EOR hits the global market, 84% of EOR-supplied oil displaces existing supply and satisfies existing oil demand. The remaining 16% percent represents an increase in oil supply, which lowers the price of oil and results in increased oil consumption.

To account for market impacts, first, we must calculate net reduction only to the extent there is displacement. To illustrate in Figure 1, we "add back" the unrealized net reduction from oil that is not displaced, i.e.16% of 0.27 tonnes or 0.04 tonnes of CO_2. Next, we "add back" emissions from the increase in oil consumption that would not have occurred if not for the increase in oil supply from EOR i.e.16% of 0.24 tonnes (well-to-wheel) emissions or 0.04 tonnes of CO_2.

In the end, on a life cycle basis, CO_2 EOR still delivers significant net CO_2 reductions. On a life cycle basis, the IEA finds that every barrel of oil produced through CO_2-EOR results in a net emission reduction of 0.19 tonnes of CO_2. Compared to life cycle emissions of conventionally produced oil, EOR-produced oil emits 37% less CO_2 (0.19 = 37% of 0.51 tonnes). See Figure 1.

CO_2 EOR Results in a 63% Net Reduction per Tonne Stored

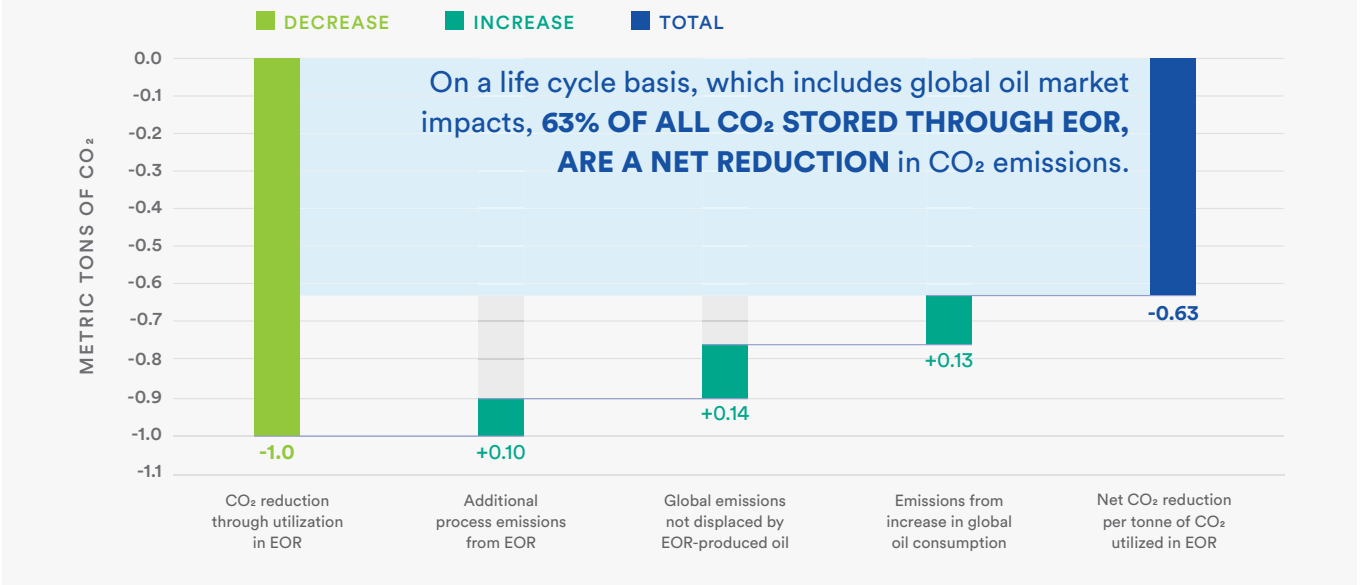

FIGURE 2: NET CO_2 EMISSIONS PER TONNE OF CO_2 STORED THROUGH EOR

Life Cycle Emissions: Per Tonne Basis

Figure 2 (above) illustrates life cycle emissions from EOR, but on the basis of a tonne utilized for CO_2-EOR.

Utilization of one tonne of CO_2 is accounted for as a reduction of one tonne of CO_2 that would have otherwise been emitted at the source.

Project level emissions from utilizing one tonne of CO_2 is approximately 0.1 tonnes of CO_2. Hence, the net CO_2 emission reduction per tonne utilized for EOR is reduced to 0.9 tonnes.

Since only 84% of the oil produced through CO_2 EOR displaces existing supply of oil, 16% of 0.9 or 0.14 tonnes of CO_2 emission reductions not achieved have to be "added back" to the calculation.

The IEA estimates that the well-to-wheels emissions of oil produced as a result of utilizing one tonne of CO_2 for EOR is 0.8 tonnes. Hence, 16% of 0.8 tonnes or 0.13 tonnes are additional emissions that need to be "added back" too.

As a result, on a life cycle basis, the net emission reduction per tonne utilized for EOR is 0.63 tonnes of CO_2. See Figure 1.

This is not necessarily true in all cases. Net CO_2 reductions vary depending on the type of oil assumed to be displaced and displacement values. In the scenario detailed here, IEA assumes 84% displacement of the existing supply of conventional oil. IEA's analysis estimates that a life cycle analysis would yield a net reduction in CO_2 emissions at displacement levels as low as 50%.

However, keeping market displacement values at 84%, if oil with the lowest carbon emissions intensity (as reported by Gordon et al., 2015) is displaced, then the emissions reduction benefit could be reduced to 0.47 tonnes of CO_2 per tonne of CO_2 utilized. Alternatively, if oil with the highest carbon emissions intensity is displaced, then the net reduction could be as high as to 1.50 tonnes of CO_2 per tonne of CO_2 utilized.