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THINK PIECE

From EOR to 'E^{2}R' Sequestering CO_2 while reducing dependence on imported oil

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Some men see things as they are and say why? I dream things that never were and say why not?

– R F Kennedy (based on G B Shaw)

The world today: EOR using geologically-occurring CO_2

CO_2-based enhanced oil recovery operations (CO_2-EOR) play an important role in re-establishing oil production from "depleted" fields. Begun in the early 1970s, by 2010 CO_2-EOR production accounted for about five to six per cent of total US domestic oil production – more than five times as much as in 1988. The technique works by injecting CO_2 into an old field where the CO_2 acts as a kind of solvent, allowing the oil to flow again to a production well. The process requires vast quantities of CO_2. Current EOR operations in the US require the injection of around 50 million metric tons of additional CO_2 each year,[1] using more than 7,000 CO_2 production and injection wells.[2]

During EOR operations, the CO_2 diffuses through the pores of the rock and mixes with the oil, causing the oil droplets to swell. This reduces surface tension and allows the oil to detach from the rock, much as hot water works better than cold water in detaching grease from dirty dishes. The CO_2 and water flow towards the zone of lower pressure that is created by a producing well and up the wellbore to the surface where the oil is separated from the CO_2 and transported to market. The CO_2 is dehydrated, re-compressed and then re-injected into the formation to repeat the cycle. In the right formations, CO_2-based EOR allows production of an additional 10 to 20 per cent or more of the original oil in place – but still leaves about one-third to one-half of the oil in the ground, together with injected CO_2.

The annual value of the CO_2 injected for EOR operations today appears to be in excess of US$1.25 billion and the value of the oil produced in the order of US$8.25 billion.[3] While producers endeavor to re-cycle as much of the valuable CO_2 as possible, the CO_2 gradually fills in the pore space previously occupied by the oil. Over time, the producing wells begin to produce more recycled CO_2 and less oil until eventually (after a productive period typically measured in decades), the field reaches an economic limit and is again deemed depleted. The wells are sealed, at which point the CO_2 is trapped in the same geologic formation that had contained the oil for millions of years. In effect, it has simply been moved from one geologic storage site to another, while liberating vast quantities of otherwise unrecoverable oil in the process.

About 90 per cent of the CO_2 used in EOR operations today comes from geological formations. Current geological resources of CO_2 in the US are in the order of nine billion metric tons (i.e. nine gigatons)[4] with annual deliveries for EOR of some 45 to 50 million metric tons.[5]

However, current CO_2 supplies are fully committed and cannot meet existing demand, much less future demand for increased oil production. The CO_2 supply shortfall to the Permian Basin as of mid-2010 has been estimated to be on the order of six million metric tons per year.[6]

Enhancing EOR with emission reduction benefits: moving from EOR to "E^{2}R"

Merely transferring CO_2 from one subsurface storage site to another does nothing to reduce atmospheric emissions of CO_2 from power plants or industrial facilities. But substituting *anthropogenic* CO_2 that is captured from emitting facilities – providing the "storage" component for "carbon capture and storage" – will reduce CO_2 emissions while it increases supplies of domestic oil. The economic benefit of enhanced oil recovery is thus further enhanced with the environmental benefit of reduced CO_2 emissions. The term "E^{2}R" captures this two-fold enhancement of producing oil from previously "depleted" fields by injecting captured, anthropogenic CO2 that is sequestered during the oil production. In short, in the world to come, EOR can become E^{2}R: *use of captured anthropogenic CO_2 in enhanced oil recovery operations in place of geologically-occurring CO_2.*

From the standpoint of ultimate storage during oil recovery operations, the origin of the CO_2 makes no difference (so long as any impurities introduced into the CO_2 stream during the capture process are removed). There are some key differences, however, between sequestering any CO_2 stream in non-oil producing operations (such as injections in a saline formation) as compared to E^{2}R sequestration. CO_2 injection during EOR or E^{2}R operations presents a lower and more-controlled subsurface pressure profile than injections into a non-oil producing formation. During oil production, oil, water and CO_2 are being *removed* from the reservoir through the production wells throughout the productive life of the field, precluding the pressure build-up that characterizes injections in a non-oil producing sequestration project. In addition, because the oil producing wells create a zone of lower pressure into which the mix of oil, water and CO_2 will flow, the movement of the CO_2 in the subsurface from injection to production well is far more predictable than where the CO_2 has to be injected into the rock formation at pressures sufficient to continuously push the CO_2 plume away from the injection well (because there is no zone of lower pressure into which it is drawn). And of course an oil-producing formation will almost by definition have structural or stratigraphic traps that held the oil in place for millions of years and similarly provide natural bounds for CO_2 storage.

The US Environmental Protection Agency (EPA) has already recognized that sequestration of injected CO_2 occurs during EOR operation and has recognized the lower risk profile presented by EOR operations. EPA has also recognized, however, the absence of measurement, documentation, or verification of the specific quantities of CO_2 that remain geologically sequestered during EOR operations (as well as the importance of proper site characterization and the concern over potential CO_2 migration up through old well bores).[7]

Efforts are now underway in the US to remedy that documentary gap, however, by developing protocols for measuring, documenting and verifying the quantities of anthropogenic CO_2 that remain sequestered in geological formations during EOR operations, taking into account the fact that injected CO_2 is recycled and that some of the CO_2 may be moved from one geological formation to another as EOR operations evolve. Once these protocols are implemented, it will be possible to separately account for the quantities of anthropogenic CO_2 that are permanently sequestered even when those supplies are physically commingled with supplies of CO_2 that have been produced from geological formations.

Generally accepted protocols for accounting and verifying anthropogenic CO_2 sequestered during E^2R operations are an essential predicate for deploying CCS technology. They will be crucial to the success of early mover demonstration projects because the project developers will be required to show the long-term, secure sequestration of the captured CO_2. For example, about 75 per cent of the CO_2 that would be captured from the ten "first-mover" CCS demonstration projects selected by the US Department of Energy for federal support – over 12 million metric tons per year – is planned to be used in EOR projects.[8] At an assumed price of just US$14.30/metric ton, the output of these first mover projects could generate something on the order of US$4.3 billion in revenue over a twenty-five period.[9] This is US$4.3 billion more than would be available to emitters who develop a comparable set of otherwise identical projects to inject captured CO_2 into non-oil producing formations. The revenue from sale of the incremental barrels of domestic oil would amount to many times more. The non-E^2R project developers would presumably have to pay a disposal fee in comparison.

Conversely, failure to implement such accounting and verification protocols to properly account for sequestered CO_2 captured from these anthropogenic sources could eliminate many billions of dollars that would otherwise be devoted to reducing CO_2 emissions. and thus seriously delay deployment of CCS technology.

Similarly, any increased cost or uncertainty associated with using anthropogenic CO_2 in E^2R operations would make captured anthropogenic CO_2 less desirable to the oil producer than naturally-occurring CO_2 even though the two supply streams are physically interchangeable. In that case, EOR operators may avoid using captured CO_2 for enhanced oil recovery operations at all. Indeed, there might be an actual incentive to prevent *any* CO_2 supplier from introducing anthropogenic CO_2 into the supply mix if the result were higher costs or increased regulatory uncertainty for the rest of the operation. Such a result would be counterproductive from the standpoint of encouraging geologic sequestration of captured CO_2 to reduce atmosphere emissions.

In the United States, where there is significant demand for more CO_2 for oil production, the future of CCS is plainly E^2R. Failure to put the necessary steps in place for transitioning from EOR to E^2R will seriously stunt the deployment of CCS technology, regardless of federal research, development and deployment initiatives.

[1] *Final rule: Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells, 75 Fed. Reg. 77230, at 77244. (10 December 2010) (the "EPA Class VI rule").*

[2] *Oil and Gas Journal, Vol 108 (19 April 2010), "Special Report: EOR/Heavy Oil Survey: 2010 worldwide EOR survey" (Table "C" showing 10,121 CO_2 producing wells and 6,955 CO_2 injection wells in US) (http://www.ogj.com/index/article-display/2122881039/articles/oil-gas-journal/volume-108/issue-14/technology/special-report__eor.html) (subscription required). See also Markus G. Puder & John A. Veil, Argonne Nat'l Lab., Evaluation of State and Regional Resource needs to Manage Carbon Sequestration Through Injection (2007) (http://www.gwpc.org/e-library/documents/co2/Argonne%20Report%20CO2%20Resources.pdf).*

[3] *Estimates for value of CO_2 based on price estimates in A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide, (31 December 2010) (report prepared for the Interstate Oil and Gas Compact Commission and the Southern States Energy Board and funded in part by the US Department of Energy). Estimate for value of oil production based on price of $80/bbl and oil production from CO_2-EOR of 283,000 bbl/d per the 2010 O&GJ Survey).*

[4] *CO_2 reserve estimate based on R. Allis, T. Chidsey W. Gwynn, C. Morgan, S. White M. Adams, & J. Moore, Natural CO_2 Reservoirs on the Colorado Plateau and Southern Rocky Mountains: Candidates for CO_2 Sequestration, paper presented at the First National Conference on Carbon Sequestration (2001) (available at http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/6a2.pdf.) and Denbury Resources Inc., 2010 Form 10-K.*

[5] *Advanced Resources International, Inc. and Melzer Consulting, Optimization of CO_2 Storage in CO_2 Enhanced Oil Recovery Projects (30 November 2010), report prepared for the UK Department of Energy and Climage Change (DECC) (Office of Carbon Capture & Storage), at 6 (Table 1).*

[6] *Id., at 11. See also at 10, Figure 5, "CO_2 Supply and Demand in the Permian Basin").*

[7] *EPA Class VI Rule, 75 Fed. Reg. 77230, at 77244.*

[8] *See Table V-2: Planned DOE CCS Demonstration Projects, Report of the Interagency Task Force on Carbon Capture and Storage (August 2010), at 88-89 (Obama Administration task force on barriers to deployment of CCS).*

[9] *12 million tonnes per year times $14.30/tonne times 25 years equals $4.29 billion.*