Comments on the California Air Resource Board CCS Plans and Program

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As a long-time advocate of bridging carbon dioxide enhanced oil recovery (CO_2 EOR) with carbon capture and storage (CCS), I have been especially encouraged to see the work and breadth of understanding that ARB has accomplished. ARB's research into the areas of CCS has touched on the need for appropriate injection site selection, health, safety, and environmental monitoring in order to achieve a successful project. These attributes are core concepts to the CO_2 EOR community today. The CO_2 EOR group of companies is the only community currently qualified to address all these concerns surrounding CCS projects because of the over 40 years of experience gained in CO_2 gathering, handling, transportation and injection. The following paragraphs first outline why I recommend that ARB lean on CO_2 EOR for expertise and, secondly, contain suggestions for ARB's proposed program moving forward.

Preserving the CO_2 Injection Expertise

The experience gained by EOR operators is vital in developing dedicated CCS projects. Since carbon dioxide is different than other gases in many ways, it is imperative that the practical expertise be preserved and developed. One of those many differences is in its transition to and from its critical state. At approximately 1200 psi, compression of relatively pure CO_2 (>95%) quickly transitions into its dense, aka "critical" state. While in this state the CO_2 offers the advantages of the density of a liquid and the viscosity of a gas. This means easier movement through porous media yet efficient storage of liquid-like mass volumes. It also means that deep reservoir storage is efficient and is more assured and permanent than gas-like substances. The experience of the CO_2 EOR industry has shown that recycle of retained CO_2 is extremely difficult and the conversion from a stored dense state to a liberated gas state is a very slow and limited process[3]. This also means unless retained CO_2 is pressure-driven through active recovery methods it is unlikely to migrate. Even when pressure-driven, the volumes able to be recovered are only a small percentage of those injected. The industry has called that retention and is a diagnostic watched closely.

A quick look at CO_2 EOR history find that over 150 projects have been implemented by professionals representing over 40 differing companies in seven countries. Approximately half of those projects have been implemented in West Texas where reservoirs are appropriate and availability of CO_2 is widespread. Some of that CO_2 has been anthropogenic in the form of by-product of natural gas processing but most has come from nearly pure underground sources of CO_2 transported from as far away as 500 miles. This means that a vast network of CO_2 transportation pipelines is currently operating in the area with the capacity to move large quantities of anthropogenic CO_2 into reservoirs for utilization and subsequent storage. Figure 1 illustrates the existing scale of the CO_2 marketplace and transportation operations in West Texas. The opportunity to displace natural source CO_2 with anthropogenic CO_2 is immense given the proper economics. A program such as ARB's could be the catalyst needed to incentivize considerable CO_2 storage and thereby represent a large scale percentage shift from natural source CO_2 to anthropogenic.

In this current oil pricing environment much of the expertise is being lost. Intense competition from unconventional horizontal drilling has caused professionals with experience in EOR to be recruited away and the crises for continuing EOR is becoming a real issue. ARB's proposed program could move industry focus from a pure oil driven model to that of one of oil productions with a focus on sequestration or as ARB has coined it, "innovative crude".

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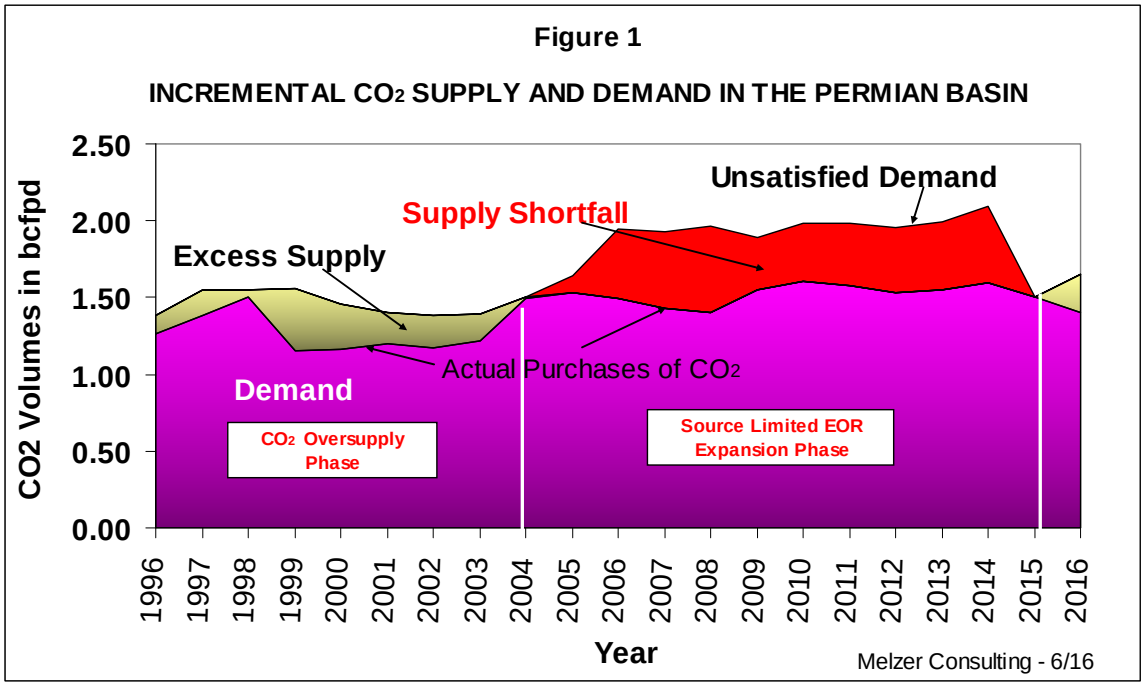
[1] www.Melzerconsulting.com

[2] www.CO2Conference.net

[3] Lin Zuo (2011), An Experimental Study of CO2 Exsolution and Relative Permeability Measurements During Saturated Water Depressurization, A Report Submitted to the Dept of Energy Resources Engineering, Stanford University in Fulfilment of Masters of Science, June 2011.



Permanence and Post Injection Access

The subject of documenting CO_2 storage permanence brings up a host of issues and several misconceptions. The Interstate Oil and Gas Compact Commission[4] has found that all States have separate mineral and storage rights. The pore space rights are controlled by the surface rights owner in most States and those can be severed from the mineral rights. Mineral rights have been deemed dominate in those States wherein the surface owner cannot refuse access to the mineral rights but has the right under the accommodation doctrine to receive compensation for damages to the surface.

CCS and CO_2 EOR bring both sets of rights into play. Some EOR companies have addressed this issue via storage leases but it could bring with it a possible conflict of mineral trespass when a strict definition of permanence is considered. The mineral leases are valid as long as mineral extraction is underway but upon closure (plugging of wells), the leases are to expire and access for proving permanence belongs to the surface owner or leases they have made with the permanence monitoring company. If compensation is received for the storage, the surface (i.e., pore space) owner will be entitled to some compensation. Monitoring wells outside of the mineral extraction area may be necessary as well. That will entail additional expense beyond the mineral extraction rights. The details of all of this will need to be settled if the economics merit negotiation between the involved parties. Incentives such as those being considered by ARB will likely be necessary for progress in establishing viable models for storage. The duration of required monitoring may play a huge role in those negotiations, and therefore ARB should be cautious of any proposed timeframe and consider economic impacts of its permanence protocols if it wants a successful program.

Natural CO_2 vs. Anthropogenic CO_2 and Future Opportunities for Storage

As stated, much of the approximately 800 million tons of CO_2 for EOR in the Permian Basin has been provided by natural underground sources of supply. Those volumes of CO_2 have reached 35 million tons/year of CO_2 in West Texas alone; demand for CO_2 in EOR activities remains strong. Despite these large CO_2 purchases, it has been stated by many that the CO_2 demand marketplace is limited. With the

[4] CO_2 Storage: A Legal and Regulatory Guide for States, Interstate Oil and Gas Compact Commission Report 2008; https://iogcc.myshopify.com/collections/frontpage/products/co2-storage-a-legal-and-regulatory-guide-for-states-2008

support and incentives of programs like ARB's LCFS and Cap-and-Trade, much of these volumes could be supplied by anthropogenic sources; thereby insuring greenhouse gas reductions while at the same time providing for domestic energy needs and building further CCS expertise. Recent work in the Permian Basin region is showing that a limited CO_2 marketplace is a gross mischaracterization and the CO_2 purchase market may be poised to grow significantly. In addition to CO_2 EOR at mature oil fields, there is new excitement present from residual oil zones (ROZ) and their vast presence both beneath oil fields and even aside existing production ("greenfields"). These ROZs can be considered deep saline formations but with immobile oil present in the pore space often occupying as much as 30%-40% of the pore space. Pilot projects are underway demonstrating successful economics even at $50-$60/barrel of oil.

Perhaps the best way to view the scope and scale of these newly recognized hybrid saline/ROZ reservoirs is to look at the recent assessment of the in-place ROZ resource. A recent 12-county resource conducted in West Texas[5] found 180 billion barrels of oil in place in the ROZs in reservoirs with a CO_2 storage capability of twice that amount of reservoir pore space. To put that in perspective, the CO_2 EOR industry in the Permian Basin alone has incidentally stored an estimated 700+ million tons of CO_2 while producing to date approximately 2 billion barrels of oil. Using a recovery factor of 20-25% of the identified ROZ resource above, another 36-45 billion barrels could be produced if the CO_2 were available. Utilizing a 10 mcf of CO_2 per barrel of oil utilization factor, those figures would equate to an ability to store 20-30 billion tons of captured CO_2. To emphasize, this additional need demonstrates the immense opportunity for utilization and ultimate sequestration of anthropogenic CO_2. This would be accomplished with the required reservoir pressure control as a necessary by-product of the EOR process.

Quantification Method

ARB has asserted that it will treat CO_2 transferred from one field to another as being emitted. The first point I would make is that transference field-to-field has not occurred to date. I contend that the recycle volumes decline as a project winds down and the recycle goes into the least mature parts of the same field and not another field. Eventually, the volumes decline to a point that the project economics are no longer viable and wells are plugged. But even with that as the standard practice, I believe the venting model is an overly conservative accounting of the CO_2 given that any recycle volume is a valuable commodity so it would remain within the capture and transportation system during the transfer and would be utilized in injection efforts in the new field. Furthermore, like all EOR projects, this "other" field will have been carefully selected for injection with proper monitoring and design to insure the success of the project economically and physically in order to preserve the resources in-place. I would suggest that ARB continue to view any transfers to other EOR fields as captured since the CO_2 remains captured and unvented to the atmosphere.

Summary

All the above figures for oil production and CO_2 storage capacity are obviously driven by the economics of CO_2 and oil prices plus any incentives that might be present. New EOR project opportunities are numerous especially with the ROZ EOR demonstration projects underway. However, new projects will only move forward if the incentive for capture and monitoring are sufficient. ARB should look at EOR opportunities as a way to achieve CO_2 sequestration economically; since much of the economic burden will be covered by production activities of these fields. Again, I salute the thoroughness of your work and I welcome the initiative of the Air Resource Board to investigate this exciting opportunity.

[5] Identifying and Developing Technology for Enabling Small Producers to Pursue the Residual Oil Zone (ROZ) Fairways in the Permian Basin San Andres Formation, Trentham, R.C., Melzer, L.S., Vance. D. and Kuuskraa, V., (2016) Research Partnership to Secure Energy for America and U.S. Dept of Energy Final Report, www.netl.doe.gov/file%20library/research/oil-gas/10123-17-final-report.pdf