

Symposium on the Role of EOR in Accelerating the Deployment of CCS

CO₂ EOR: A MODEL FOR SIGNIFICANT CARBON REDUCTIONS

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The Oilfield Opportunity

One of the multiple future technology options required to mitigate carbon emissions from traditional fossil fuel power generation and other industrial processes is to capture and sequester (CCS) those emissions. Yet, at present, CCS at any meaningful scale relative to the extraordinary volumes of CO₂ emissions being produced is still years and possibly decades away. Capture costs appear to be unacceptably high, the “energy penalty” for capture on conventional existing coal fired power is far too high, the distribution network to move the CO₂ to repositories is mostly not in place, and the determination of safe and acceptable permanent repositories is not ready for accepting CO₂ for a multitude of reasons. Yet at the same time there is actually high demand and higher potential for CO₂ in existing oilfield tertiary enhanced oil recovery (EOR) operations where there exists both amenable pore volume and established CO₂ related infrastructure and expertise.

This paper will present two themes. The first theme is that hydrocarbon pore volume in current or potential EOR operations is readily available, accessible and more relevant than has been recognized, but also that new research and field trials of a new class of hydrocarbon pore volume is expanding known usable hydrocarbon pore volume by orders of magnitude. The second theme is that transforming EOR operations from merely commercial oil production operations to carbon storage operations requires a strategically planned and commercially incentivized research program. This program will necessarily be at large scale on both sources and sinks (critically enabled by a yet to be completed distribution system) to provide the necessary framework and risk mitigation to certify the EOR operations as acceptable permanent storage volumes. Without adequate research today at large scale, this paper will present why existing EOR operations are the logical place to begin if CCS is to be proven viable and developed as a mitigation option more broadly.

Too Much or Too Little CO₂?

There is an abundance of combustion-derived anthropogenic CO₂ yet there is virtually no mechanism to utilize it to meet existing or potential EOR demand. What policies, technologies, and science are required to address this mismatch? And with the greenhouse gas effect “cumulative present value” of an emitted molecule today being much higher than that of an equal molecule emitted 10 or 20 years away, there is urgency to both reduce CO₂ emissions short term and accelerate the development of the CCS option to keep the molecule out of the atmosphere in the first place. Perfecting this CCS option for full-scale implementation in 10 or 20 years, while a prudent and necessary component to have in a toolkit where not all the requirements have yet to be defined, is not an acceptable timeframe. And since the CCS option may not be as relevant or applicable to an unknown future energy portfolio in 10 or 20 years, it is imperative to develop and enable some components of the CCS option in a time frame of years, not tens of years.

A Paradigm Shift in Thinking

In order to foster this accelerated CCS development, there are several key attributes that must be acknowledged to meet the desired timing and scale objectives. These are:

1. The critical importance of a commercial driver to create wealth and incentivize the “all-in” participation of the private sector
2. The relevancy and potential of hydrocarbon pore volumes, depleted or not
3. The necessity of an extensive pipeline distribution network
4. A program designed for near term scale
5. A program designed to address the “chicken and egg” problem of science and research to lower capture technology costs multifold versus establishing the repositories for the CO₂ if it can be captured economically
6. The program must be more than a “clean coal” program

Creating Wealth

Acknowledging these attributes can move the needle off of near zero to begin putting meaningful amounts of CO₂ in the ground, and also moves the issue from merely a conference conversation to a reality. In addition the model proposed by this paper meets important parallel goals of creating jobs, minimizing costs to the public, and enhancing national security through the creation of a real and viable industry that can attract market capital and increase domestic oil production. Increasing domestic oil production not only creates wealth and royalties, and improves the balance of trade, but also provides important supply diversity to mitigate the risk of geopolitical oil supply disruptions caused by the combination of an overreliance on imported oil, especially in the vulnerable transportation sector which is virtually totally dependent on petroleum.

Debunking Myths

In order to accept the commercially driven oilfield pore volume option, there are a number of “myths” that must be debunked, including for example the myth that oilfield pore volumes and EOR operations are insufficient in volume to make a difference. Not only are the depleted or partially depleted pore volumes extensive in existing “brown field” tertiary oil developments (Kuuskraa), but there also exist partially oil saturated intervals below the existing oil main pay zones (MPZ), which provide “quaternary” oil development opportunities. These relatively new quaternary opportunities are commonly referred to as residual oil zones (ROZ). These ROZs, which will be discussed in more detail later, are far more extensive in both thickness and areal extent than the significant MPZs which could alone, if effectively exploited, store significant volumes of CO₂. In addition, ROZs are believed to exist outside of the traditional oil provinces and can also provide an important scientific and technical proxy for the future development of pure saline aquifers for CCS.

Getting Started and Managing Risk

So what is the key to unlock this CCS option? Clearly effective policies to address and protect the public interest while incentivizing the private sector are required, and these policies must be science based. Funding a relevant monitoring overlay on existing CO₂ EOR operations at meaningful scale is a public interest and is a must. Also managing long term risk for an endeavor of this magnitude is critical in order to allow the private capital markets to function effectively. An incremental approach is an efficient and effective risk management tool as it allows the exploitation of existing system assets by first enabling the most promising opportunities then providing a build out option at the margin for smaller opportunities. As the cost of both capture and sequestration is reduced with time, the opportunities at the margin grow and the system continues to expand. The incremental approach allows the application of classic tranche based risk management.

Using History to Model a New Public Private Opportunity

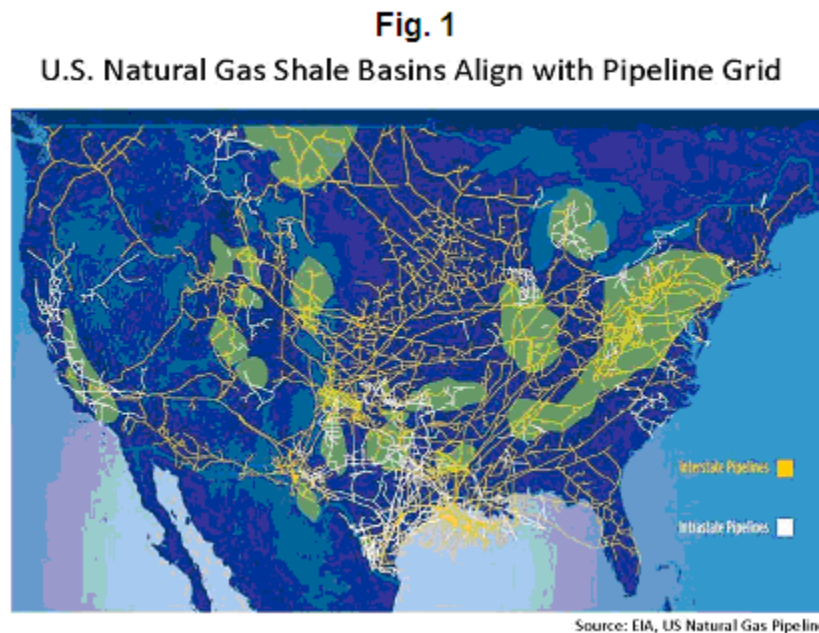
An intermediary “agent” between the requisite public R&D and the private sector application for both sources and sinks could be a pseudo public opportunity for the creation of the pipeline distribution network that connects the sources and sinks. Such endeavors have been successful in history including the example of the U.S. **transcontinental railroad** after the Civil War. Translating the need for a transcontinental railroad into reality required not only policy and capital but also more importantly leadership and vision. It has been said by some that the development of the transcontinental railroad was one of the most important events in American, if not global, history. It opened up economic development in North America and subsequently the entire world. In a period of less than a decade it reduced the transit time from New York to San Francisco from six months to six days, probably more important than the reduction over ensuing decades of six days to six hours from trains to airplanes.

The transcontinental railroad was created by the unique confluence of existing skills. First it required the leadership and endorsement by one of the greatest presidents in U.S. history, Abraham Lincoln. It also had to have the vision of those who understood its profound and immense potential. Due to its unprecedented logistical complexity it required the expertise that could only be provided by the experienced military leaders from the Civil War to actually pull it off. And it required the deal making, and risk taking, financiers to find the capital for it all, incentivized by a unique structure of bonds authorized based on miles of line actually laid. It required new routing, but it also incrementally built and expanded upon existing railroad routes from the Midwest. At its completion it may have been successful because it wasn't perfect, which in some odd ways probably mitigated some of its enormous risk. There were several “routes” that could have been taken, but multiple routes probably would not have garnered the necessary public traction, and certainly would have taxed the available resources, maybe even have killed the whole idea. The project was, in the end, effective although not exactly efficient, and was in fact actually very messy both in financial and human terms. But it happened, and in many respects was instrumental in the establishment of United States as the global superpower it is today. There was a vision, an urgent need, and the national will and perseverance to make it happen.

Leveraging Existing Policy/Infrastructure

While the transcontinental railroad, at least past its Midwestern origin, was built entirely from scratch across mostly uninhabited territory, another example of a game changing development in the U.S. has been the development of **unconventional natural gas resources**. In contrast to the transcontinental railroad, unconventional gas developed from anything but scratch. In fact unconventional gas was in many ways a serendipitous development resulting from the infrastructure put in place for the development of conventional oil and natural gas resources.

This existing infrastructure (Fig. 1) for conventional resources was quite convenient, if not coincidental for the development of unconventional resources, and turned out to be extremely efficient and effective to logically leverage and extend conventional oil and natural gas development for unconventional resource development.



Geologists had for decades searched for impermeable barriers that “trapped” hydrocarbons in permeable rocks that resulted from the migration of hydrocarbons (or leaks) from the original source rocks. The source rocks, although once thought to be unproduceable, were well documented and mapped. At some point geologists and engineers realized that with the right tools and technology the source rocks may actually be the ultimate prize due to their immense scale. With the infrastructure, regulatory, and legal framework all in place from years of conventional hydrocarbon development, the same framework could be easily utilized for the exploitation of unconventional natural gas resources even though the technical hurdles were formidable and required extraordinary research efforts, iterations, and perseverance to overcome. In hindsight unconventional gas might never have become a reality should it have required complete system development from scratch; that had already been provided by its predecessor - conventional oil and natural gas development. Full system development combined with the technical uncertainties of establishing economical production in meaningful quantities from basically impermeable rocks, rocks once thought only to be unproduceable geologic marker beds, may well have been more risk than the capital markets would be willing to finance.

In the course of developing conventional oil and natural gas reservoirs in a multitude of geologic basins, a service infrastructure and pipeline network developed incrementally, and markets

logically developed for this valuable and convenient natural gas energy source. Mineral ownership issues were resolved by legislation and within court rooms over time, and effective regulatory policies were developed to protect the public interest and the environment. All of this provided the requisite economic incentives for the capital markets to work efficiently, all protected by a judicial system, which although not perfect is transparent and effective in providing the requisite legal certainty for the capital markets to function confidently.

Creating a New Hybrid Model

So from the example of the transcontinental railroad developed from scratch to the example of unconventional gas development built on the back of a similar and existing resource, where does this leave the development of CCS? A national CCS implementation could easily be a hybrid of the two different models. Clearly there are components that must be developed either from scratch or pushed out of their infancy of development. Measurement, verification, and permanency are all processes that need refinement and emphasis. Long term stewardship issues have to be resolved, and pore volume usage and ownership must be established. New pipelines and distribution networks need to be financed and built, but could be done so with a pseudo public variation of the transcontinental railroad, for example climate change bonds sold to the public via a quasi governmental agency.

But there are also clearly many existing system components of the hydrocarbon pore volume model that provide a significant and indispensable jump start to accelerate CCS to meet an urgent need and provide the tools to promote the national will to accomplish it. The oil and natural gas industry is where the subsurface fluid flow and storage expertise resides, versus, for instance, the clean coal program which is driven by the surface capture side of the equation due to the volumetric challenges of the emissions from coal fired power generation. Existing tertiary EOR operations are also well along the learning curve of transporting, injecting, processing, and operating with CO₂. There is a well-established CO₂ industry that can be exploited and leveraged. And importantly there are significant CO₂ pipeline segments that could form the critical foundation for a nationally interconnected CO₂ pipeline distribution network from the Midwest through the Gulf Coast to West Texas, up through the Rockies to the Canadian border, with opportunities for spur developments at the margin all along the way (see Fig. 2). And these existing building block pieces of pipe connect to well-characterized geological settings and available pore volume that is ripe for exploitation, both in MPZs and, for the future, ROZs.

Rethinking the Value of Depleted Oil Reservoirs

Once thought to be only a plugging liability at abandonment, depleted pore volume, with its remaining residual oil saturation and partially depleted pressure regime, provides both an economic driver and unexploited storage “vault space.” Existing EOR operations are generally being conducted in legacy operational areas where the public is accustomed to and generally supportive of an extractive industry footprint. Breathing new life into aged fields will generally be welcomed by the public. This public acceptance mitigates many of the risks of costly startup delays such as establishing access, subsurface unitization, and the establishment of effective regulatory oversight and permitting.

The “Horseshoe Pipeline”

The aforementioned foundational CO₂ pipeline building blocks that currently exist could, with a strategic blueprint, provide an efficient and effective grid to interconnect existing EOR basins with

anthropogenic sources nationally (Fig. 2). At some later stage, this system could also backhaul CO₂ back to the natural source CO₂ domes, initially to provide volumetric buffering but ultimately to refill the natural source domes as

permanent repositories. The critical but small number of natural source CO₂ domes are shrinking and most will find their historical competitive advantage diminished as their pressures deplete. This potential pipeline system “build out,” financed by a quasi-governmental effort, could become a wealth creating public asset to mitigate climate change risk caused by carbon emissions while at the same time creating new sources of revenue to finance future transformative R&D efforts in energy.

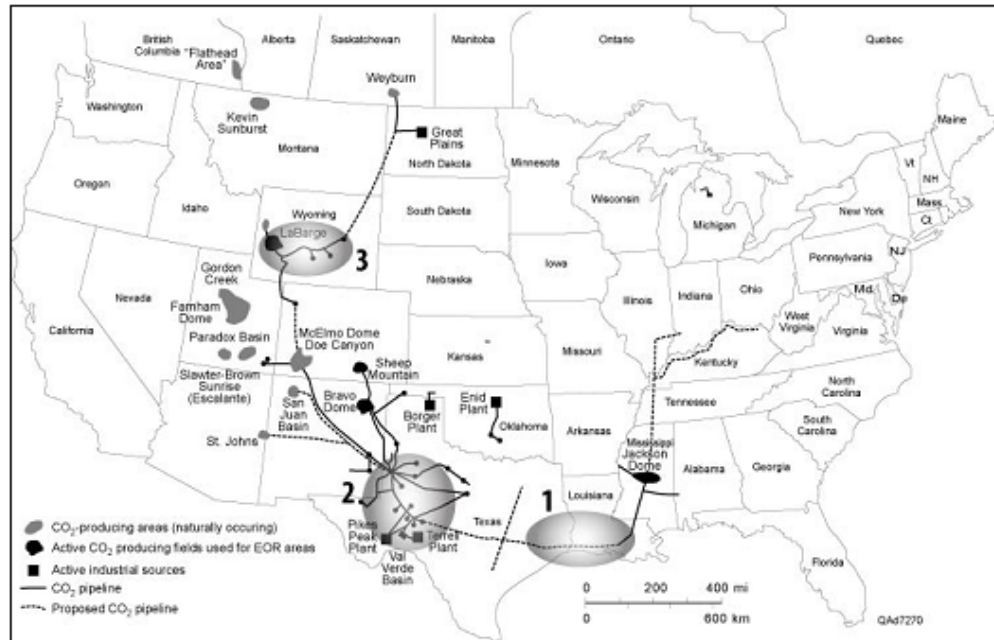


Fig 2: A Framework Depiction of a National CO₂ Pipeline Network (“The Horseshoe”). The Shaded ellipses Represent Three Areas Where Very Large EOR/CCS Projects are Active or Proposed

Accelerating the Value with Effective Energy Policy

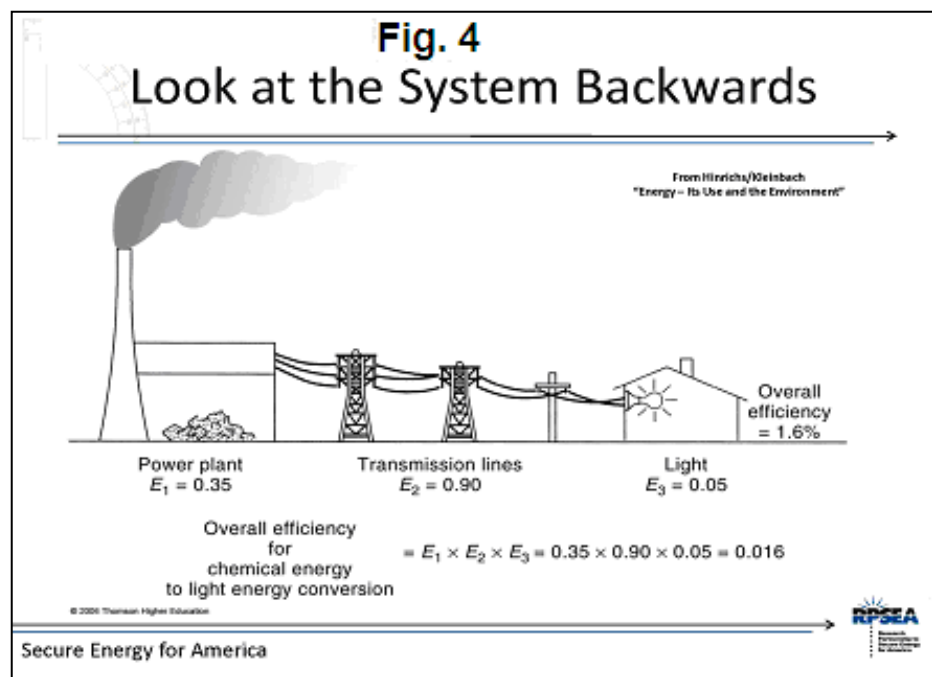
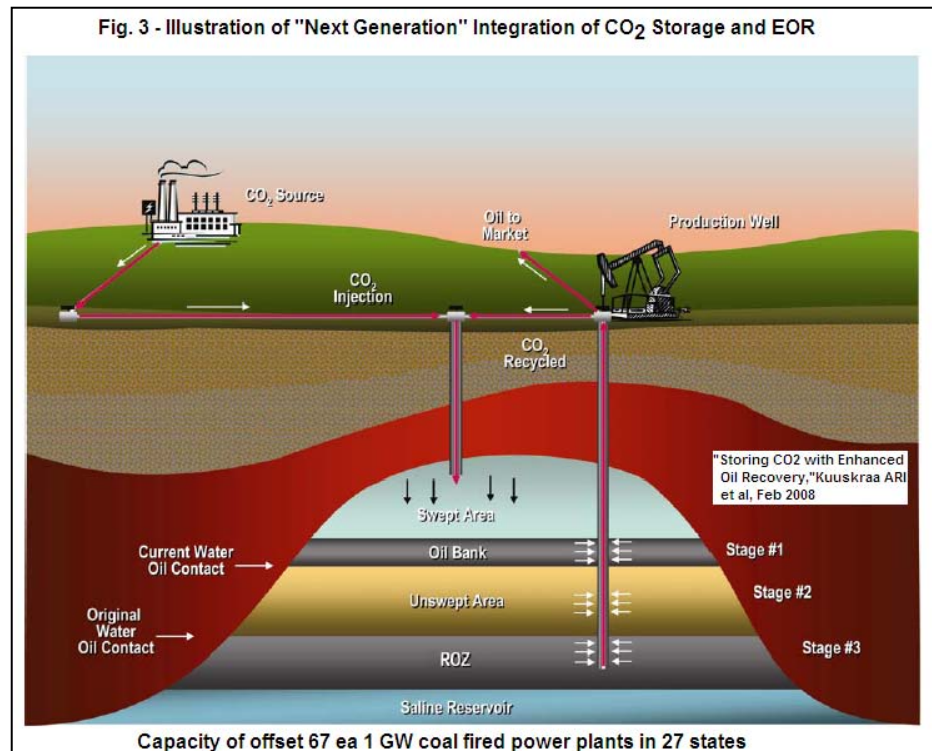
The hydrocarbon pore volume provides a quick start opportunity at scale. While studies such as Kuuskraa et al have documented the significant volumetric potential for EOR of up to 67 one gigawatt coal fired power stations, the new ROZ potential could increase that potential by orders of magnitude (Fig. 3). Yet just using the existing potential documented by Kuuskraa could be leveraged even further by effective public policy that could significantly reduce carbon emissions from a much more optimal and integrated energy system.

Efficiency leverages all forms of supply. Deploying an optimal electric power portfolio that incorporates natural gas, efficiency, and renewable power could alone reduce carbon intensity by 10 to 20 fold in certain applications over a current antiquated coal fired system with conventional distribution and end use components (See Fig. 4). MIT and others have estimated

that just the replacement of the bottom third of antiquated and worst performing pulverized coal plants could alone reduce carbon emissions by almost 10%.

Reducing carbon emissions is the logical and most economical first step to leveraging the potential of CCS, as the CO₂ units that are ultimately sequestered then become a larger percentage of total emissions. Making the emission problem more manageable makes CCS more practical, otherwise the sheer scale of the problem may prove unsolvable. Continuing to unnecessarily combust fossil fuels in inefficient process produces unnecessary CO₂ emissions. It has been estimated by Lawrence Livermore National Laboratory that the U.S. wastes 60% of its primary energy, the energy equivalent of 30 million barrels of oil per day (MMBOPD), mostly in waste heat. Capturing

just 10% of that waste, certainly easily technically achievable, with effective public policy would amount to 3 MMBOPD. And that is then 3 MMBOPD that is no longer emitting CO₂ from its combustion. Increasing U.S. domestic oil production by another 3 MMBOPD (by 2030) through state of the art EOR either in MPZs or ROZs (Kuuskraa NRDC), for a total of 6 MMBOPD, would then equal one half of the energy equivalent of the total level of current oil imports of 12 MMBOPD.



The Chicken and Egg Dilemma

So how does this proposal address the previously mentioned chicken and egg problem for R&D? Matching large scale readily available sinks with anthropogenic sources incentivizes the development of economic capture technology which is all enabled by the ability to get the CO₂ from the source to the sink. The private sector provides the sources and the sinks, possibly a quasi governmental agency finances the connection of the sources and the sinks, and effective public R&D provides the funding for the relevant scientific overlay on existing operations to transform those operations from purely commercial EOR to ultimately CCS in the public interest. And in the process an existing industry transforms itself into a larger industry, creating real wealth and real jobs while addressing an urgent risk for future generations. But it is ultimately the certain availability of the large sinks that provides the assurance that is required to develop economical capture technology.

An Integrated Approach

While this proposed model is a logical approach to accelerate CCS at nearer term scale, it still requires an integrated approach, just as the transcontinental railroad required vision, leadership, and a well planned route so that the simultaneous efforts being built from the east and the west would meet at the right point. In addition the railroad required logistical support and expertise and financing. The proposed EOR model requires many of these same attributes but can also significantly leverage a partially yet well developed infrastructure just as unconventional natural gas has done. And the science for CCS is just as formidable as was the development of unconventional gas. It is not without its risks, but it is also achievable with the appropriate engagement of the research community. The analogy to substantiate the value of the integrated approach could be taken one step further to compare the potential of conventional traps to the much larger volume of source rocks for unconventional development – in this case the pore volume potential of MPZs is a small fraction of the larger ROZ volumes, just as unconventional resources have been estimated to be as much as nine times the potential of conventional resources in a given basin by Holdtich et al.

Vision and Leadership

The vision and leadership for CCS has yet to fully emerge, and the public debate seems bogged down in waste disposal type proposals which ignore the difficult issues with waste handling, the valuable potential contribution of the oil and natural gas industry, and the invaluable commercial driver incentive that the oil revenue provides. And finally the continued avoidance of the issue of scale remains problematic in anything energy related, be it production, consumption, waste, or emissions. Utilizing 'bird-in-the-hand' pore volume and managing emissions have unique synergies to deal with the scale issues in the near term. The point is CCS is best addressed in the context of effective and integrated national energy policy.

Americans in the 1800's were no longer willing to continue to sail around South America and risk shipwreck, trek across the Isthmus of Panama and risk malaria, or wagon train across the west and risk attacks from those not happy with them intruding. Each travel option took about six months, and the passenger had the option to choose their risk. So in looking for alternatives

such as developing better ships, a cure for malaria, or the complete extermination of native Americans, Americans instead chose to build the railroad. They greatly reduced the travel risks, decreased the travel time ten-fold, created a new industry and global economy, and possibly established a new tourism industry. Today America can step up to the global leadership role the world expects, enhance its national security and the security of the world, and mitigate the risk of filling the atmosphere with carbon. The choice is before us now.

So where and how should this to begin? While there are many hydrocarbon pore volume opportunities where CCS is and will be applicable, certainly one of the largest and most promising areas in the world is the Permian Basin (PB) in West Texas. It is here where groundbreaking ROZ R&D is underway, and it is here where the largest tertiary CO₂ EOR operations in the world are occurring.

The Permian Basin as an EOR Sink

Two very recent discoveries in the PB have converged with higher oil prices to create a new excitement. The enormity of the prize is just beginning to be understood and is challenging the long held myths that on-shore oil production is scheduled for the ash heap of history and that CO₂ EOR is insignificant in the grand scheme of volumetric requirements for carbon sequestration.

Discovery Number 1: ROZ Science: Zones Below the Oil/Water Contact are Widespread and Rich in Residual Oil Saturation

Work originally sponsored by the U.S. Department of Energy and accelerated by the Research Partnership to Secure Energy for America (RPSEA) has demonstrated both the origin and now the distribution of what have come to be known as Residual Oil Zones (ROZs). For many years, the intervals were believed to owe their existence solely due to capillary forces between the oil, water and rock and called transition zones. Although these forces, including surface tension, are crucial to the oil saturation profile, they do not explain the massive thicknesses observed under existing field's main pay zones (MPZ) nor their presence in places where no MPZs are present. Beyond capillarity, what is additionally at work are two or more stages of tectonics wherein the entrapment phase was followed by a subsequent one that 1) tilted the original entrapment, or partially flushed it by 2) a seal breach that reformed in time and reentrapped hydrocarbons {a vertical flush} or 3) lateral sweep by hydrodynamics (Fig. 5). This third type creates a tilted oil/water contact and offer ROZs with thicknesses of 300 feet or more in the San Andres Formation of West Texas. These reservoirs and the associated phenomena of sulfur generation, pervasive dolomitization and oil wetting are being more fully characterized in the Permian Basin by the RPSEA work conducted by The University of Texas of the Permian Basin (UTPB) .

Figure 5a: Hypothetical Original Trap

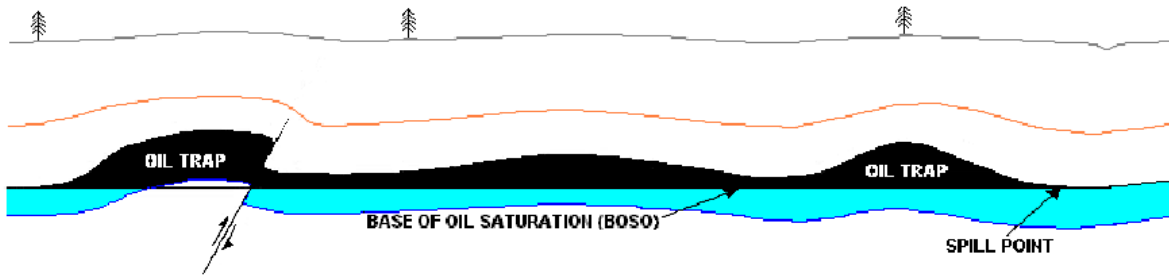


Figure 5b: Type 2 ROZ, Tilted Trap

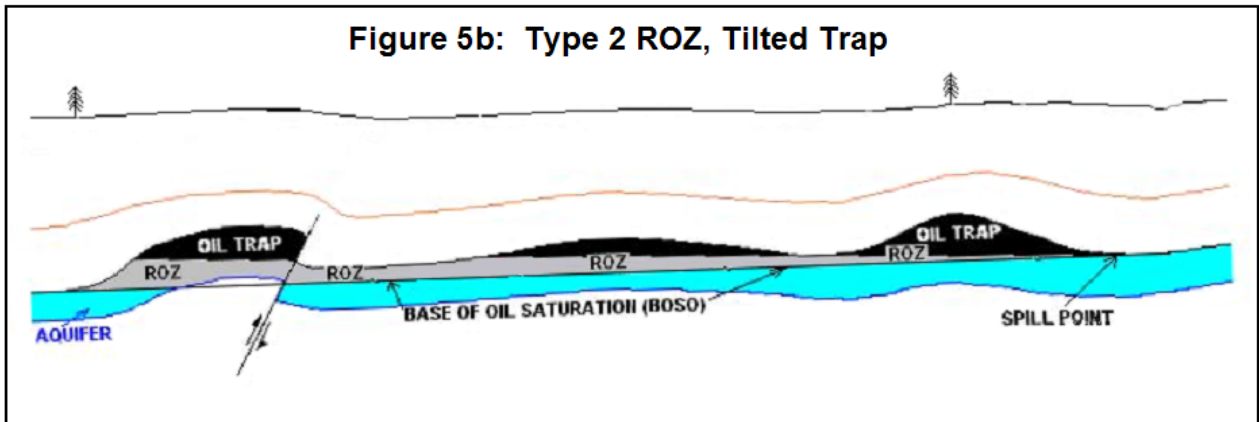


Figure 5c: Type 2 ROZ, Breached & Reformed Seal

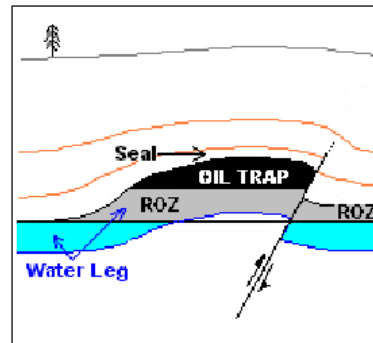
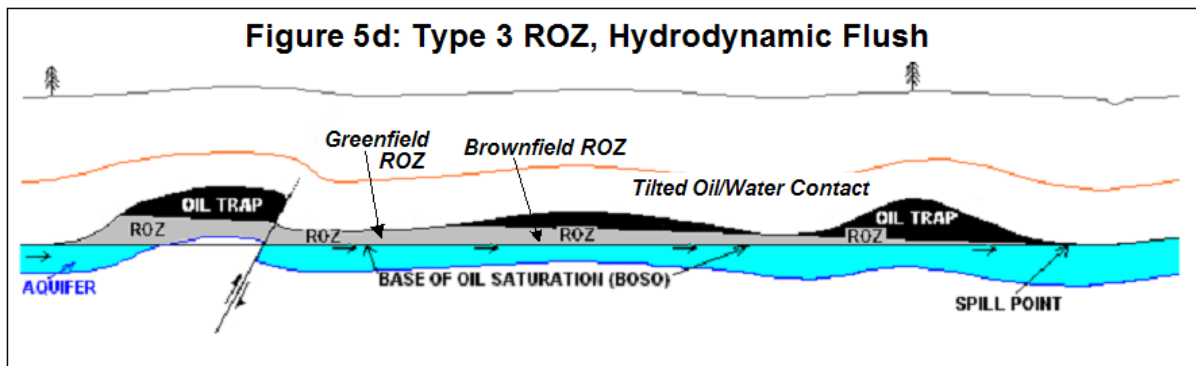


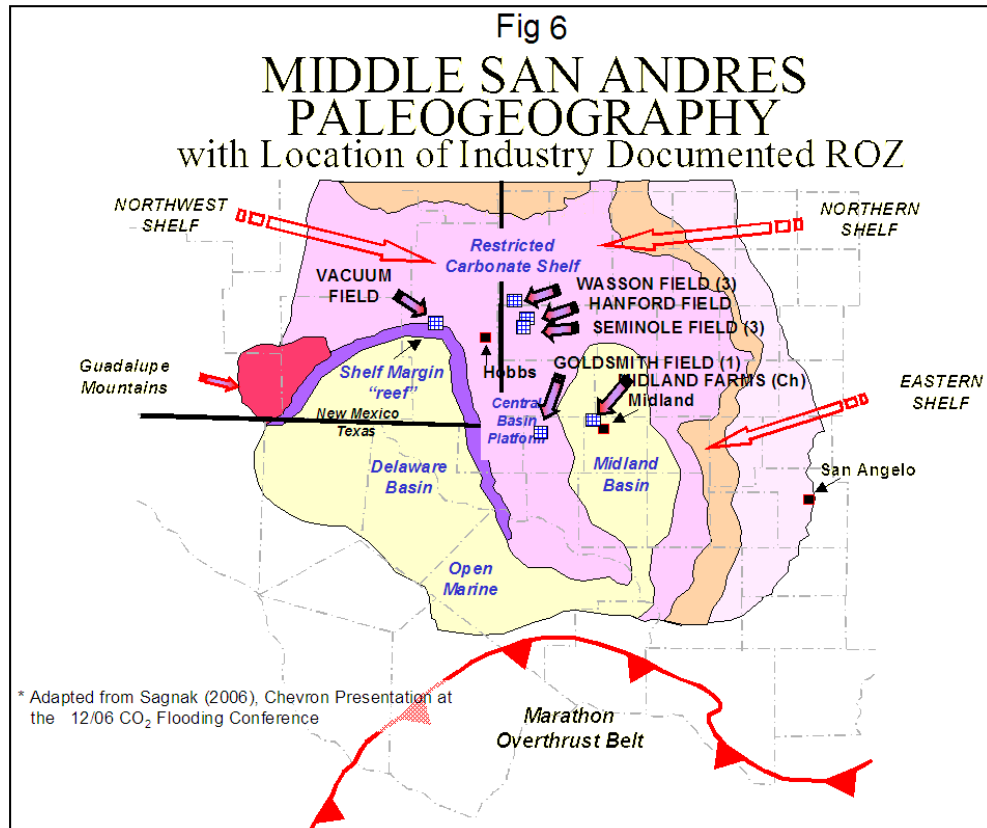
Figure 5d: Type 3 ROZ, Hydrodynamic Flush



Discovery Number 2: Demonstration of Project Commerciality of CO₂ EOR Below the Oil/Water Contact

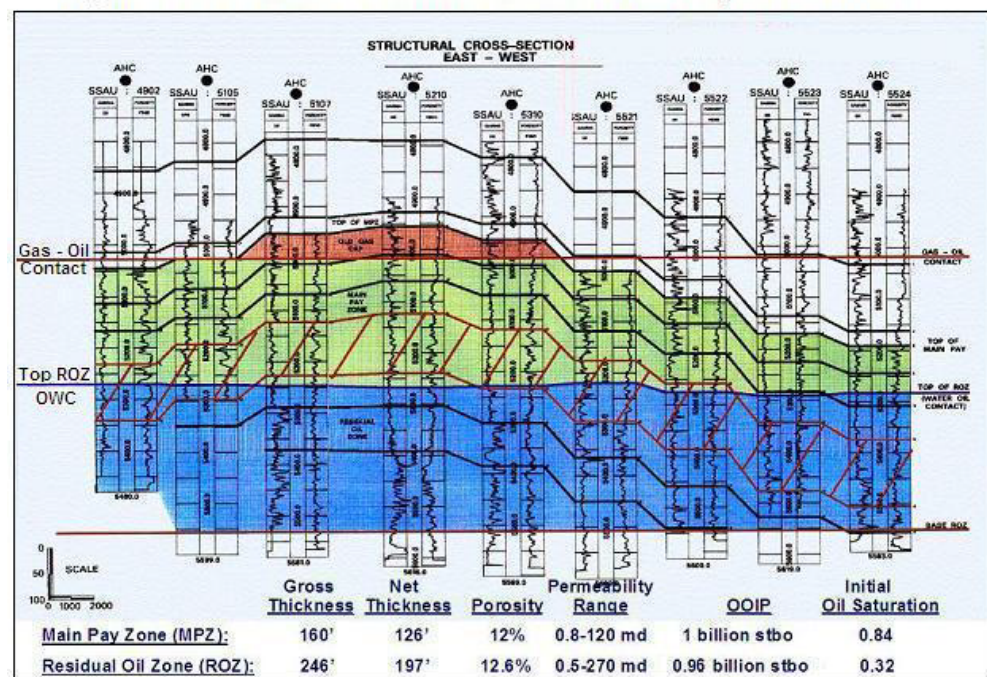
The on-going science and resource characterization is accompanied by commercial demonstration projects. The nine CO₂ and one chemical EOR projects are shown in Fig. 6.

Two operators of these demonstrations have been open about sharing results: Hess Corporation and Legado Resources. Hess operates the Seminole San Andres Unit (SSAU) in Gaines County about 60 miles north of Midland. Fig. 7 illustrates the idealized west to east crosssection in the south part of the field. Note the 250' thickness of the ROZ and the in-place oil comparisons in the MPZ and ROZ.



Hess has been operating the SSAU CO₂ project in the MPZ since 1983. It is one of the most successful CO₂ EOR projects in the world and has produced 65% of the billion barrels of original oil in place to date with 20% coming from the CO₂ EOR operations. They had long observed the residual oil saturation targets below the oil/water contact and began their commercial tests of the ROZ in 1997 with a

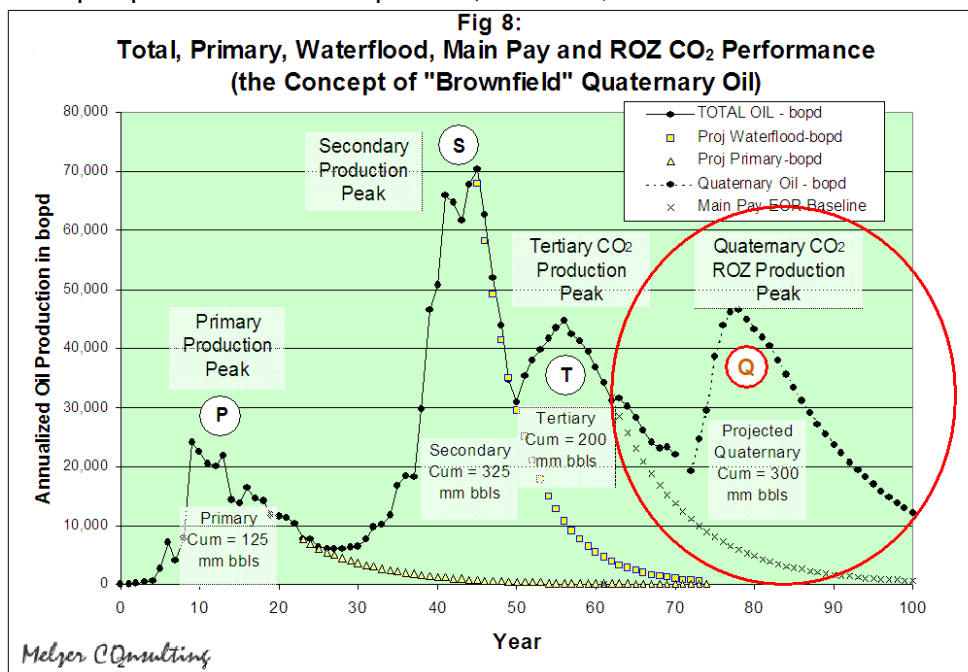
Fig 7: Crossection of Seminole Field Showing MPZ & ROZ



commingled MPZ + ROZ ten-pattern pilot. The encouraging results led to the implementation of a dedicated ROZ 9-pattern project in 2002. Results of the second demonstration were even better, leading to a full-field implementation that they began in 2007. They recently provided the

SPE Reservoir Study Group in Houston an update of the progress on Stage 1 of the full field deployment program. The UTPB team has just completed their own analysis and made a forecast for the future given the hypothetical ability of the SSAU project to gain access to unlimited volumes of market based costs of CO₂. The forecast has been termed the “quaternary” phase of oil production at SSAU (Fig. 8).

The data support for the upslope forecast is now present; however, almost no information is available for establishing the actual peak or the decline slope except for the past tertiary phase and some proprietary compositional model simulations. Time will tell which of the two forecasts is closer to reality but, suffice it to say, at present that the quaternary peak will be present and large.



This fourth phase of activity of reservoirs in the PB is what will be expounded upon in the following paragraphs. This on-going resource assessment is still in its first phase but, what is becoming very clear, the current levels of oil prices could support a very robust future for PB CO₂ EOR in the ROZ for the coming 30-50 years. What is currently missing, however, are the very large volumes of CO₂ that will be necessary.

Brownfields and Greenfields

The lateral hydrodynamic sweep of the paleo San Andres entrapments left a San Andres oil target in the MPZs of approximately 40 billion barrels. It swept an original oil entrapment more than twice as thick as SSAU MPZ. But Seminole was somewhat unique in leaving a 200' thick MPZ. Many areas have just a few feet or even no MPZ with 300+ feet of ROZ. Since the oil is immobile, those areas had no primary or secondary oil production from the San Andres Formation. We have dubbed these “greenfields” as a developer will not have MPZ wells to deepen into the ROZ and they will be required to drill the pattern injectors and producers. No greenfield examples have been implemented as yet although new wells are currently being drilled as a lateral extension from a new CO₂ EOR brownfield project planned for injection start this fall.

Demand Drivers/Resource Estimations

Breaking the myth of CO₂ EOR as small targets has been difficult. However, the idea of huge new targets below the oil water contact (OWC) has not been considered in most resource

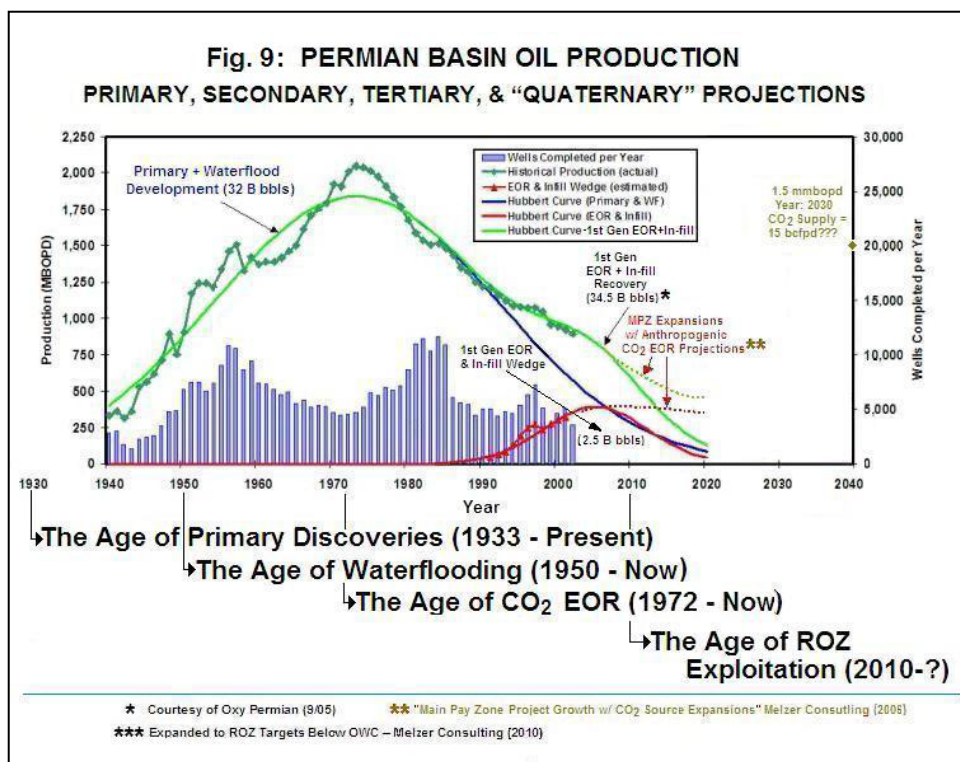
assessments of the past. While it is true that these resources will be regional and volumetrically case-by-case specific, at least one area of the country has moved out of the theoretical to proven category

All of the detailed knowledge and the above work is currently concentrated in the PB San Andres Formation. Preliminary work has been done to look at other formations including the Grayburg, Glorieta, Clearfork and Abo/Wichita Albany. Privately sponsored work is also underway to examine other areas of the U.S. and Europe. It could be true that the uniqueness of the ROZ oil resource in the PB San Andres will overwhelm these other formations and regions but they are still quite worthy of assessment studies of their own.

Through work sponsored by the U.S. DOE, Advanced Resources International and Melzer Consulting have conducted a brownfield ROZ resource assessment. The existing fields in the data base were examined and the magnitude of the oil in-place resource in the reports (Refs 2-4) was 30.7 billion in the Permian Basin (with 11.9 billion technically recoverable) and 4.4 billion of in-place oil in the Big Horn and Southern Williston Basins combined. Based upon the greenfield concepts described above, the report dramatically underestimates the total resource. But it is worthy to stop and put the 11.9 billion barrel technically recoverable resource in perspective with the current cumulative oil produced to date from the Permian Basin MPZs. The number commonly given the PB is 32 billion barrels that has been produced through its 80-year life span. If the U.S. can get the 11.9 billion barrels from just these sampled brownfield ROZs, they would add almost 1/3rd as much oil to the Permian Basin (PB) as has been produced to date.

Finally, the process of elongating the tail of the Hubbert curve is alive and well. Fig. 9 illustrates the on-going process in the Permian Basin. Note the recent departure of the production from the Hubbert curve. Some analysis conducted by Occidental and supplemented by Melzer Consulting illustrates the effect of tertiary EOR and concomitant in-field drilling. Note too the four ages of production. It is very clear that the age of ROZ exploitation is not target oil

opportunities but CO₂ supply dependent. The immense opportunity for growing reserves is very dependent on the availability of ample supplies of affordable CO₂. The magnitude of the in-situ



resource could realize a 1.5 mmbopd production level by 2040 but if, and only if, the CO₂ is available.

CCS Monetary Implications

Finally, it is also important to think about the opportunity to store CO₂ from anthropogenic sources while producing this quaternary oil. Concurrent EOR and CCS should easily get 1.5-2.0 barrels of oil for each ton of CO₂ sequestered. Using the 11.9 billion barrel, technically recoverable PB (brownfield only) resource and assuming all of that is recoverable, that equates to 11.9 BBO of new oil. This will require (and sequester) 6-8 billion tons of CO₂. If the value of the stored carbon is say \$10/ton, one can easily see the magnitude of this business. Then, if the value of oil is included at say at \$70/bbl, it adds another \$900 billion for a total of nearly one trillion dollars.

Conclusion

CO₂ EOR not only provides meaningful storage volumes, but importantly it provides the pragmatic path to move CCS from a conversation to a reality in a way that effectively and efficiently merges the public interest in carbon emission reductions with the real capability of the commercial sector for timely implementation. A purely waste-driven model, without a commercial driver, faces a much longer and more difficult path considering the magnitude of the investment which will be required. Getting started can be the most difficult task of all. With the necessary leadership and vision, CO₂ EOR provides that opportunity today.