[PS]Potential for Long Term Uses of Anthropogenic CO_2 in the Permian Basin*

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Abstract

Presently, 3+ BCF of CO_2 are processed daily in the Permian Basin. In addition to the 1+ BCF of daily recycle CO_2 utilized in the EOR projects in the basin, an additional 2 BCF of "new" CO_2 are imported into the basin. It is estimated that a volume of CO_2 equal to the new CO_2 or ~2 BCF a day in our EOR projects is incidentally sequestered. Since 1986, the number of CO_2 EOR projects in the basin has grown from <20 to 62, including 9 projects where CO_2 is being injected into the Residual Oil Zones beneath the Main Pay. This total volume of new CO_2 is estimated to have a value near $700 million per year and is currently restricted by the sources or, in the case of the Cortez line from Cortez, CO to Denver City, TX, by pipeline capacity. CO_2 from the Marathon Thrust Belt and expansions at McElmo Dome and Doe Canyon, in Colorado, have the potential for adding additional supplies, but a significant backlog of EOR projects remains. Two CO_2 capture-equipped coal-fired power plants are being permitted in the basin; however, additional long term supplies of anthropogenic CO_2 will be needed.

With the addition of Residual Oil Zone EOR projects and the long term potential for Greenfield CO_2 EOR ROZ projects, significant additional supplies of CO_2 will be necessary in the long term. With the potential for CO_2 utilization in the Permian Basin and the long term potential for CO_2 utilization in existing fields and Greenfield ROZ projects, it is critical that CO_2 be treated as a commodity and not as a waste product from an industrial source. All CO_2 EOR projects have incidental CO_2 Storage and long-term potential for CO_2 Storage in conjunction with additional oil production. For energy security and environmental reasons, these types of projects should be the first place industry and government look to store anthropogenic CO_2.

Potential for long term uses of Anthropogenic CO_2 in the Permian Basin.

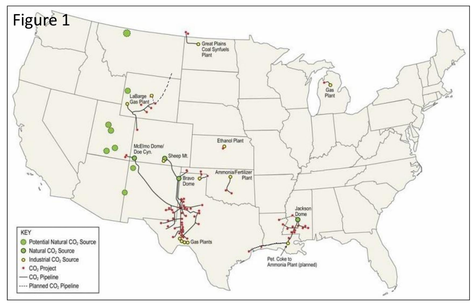
Dr. Bob Trentham, University of Texas of the Permian Basin & Steve Melzer, Melzer Consulting.

Abstract
Presently, 3+ BCF of CO_2 are processed daily in the Permian Basin. In addition to the 1+ BCF of daily re-cycle CO_2 utilized in the EOR projects in the basin, an additional 2 BCF of "new" CO_2 are imported into the basin. It is estimated that a volume of CO_2 equal to the new CO_2 or ~2 BCF a day in our EOR projects is incidentally sequestered. Since 1986, the number of CO_2 EOR projects in the basin has grown from <20 to 62, including 9 projects where CO_2 is being injected into the Residual Oil Zones beneath the Main Pay. This total volume of new CO_2 is estimated to have a value near $700 million per year and is currently restricted by the sources or, in the case of the Cortez line from Cortez, CO to Denver City, Tx, by pipeline capacity. CO_2 from the Marathon Thrust Belt and expansions at McElmo Dome and Doe Canyon, in Colorado, have the potential for adding additional supplies but a significant backlog of EOR projects remain. Two CO_2 capture equipped coal fired power plants are being permitted in the basin; however, additional long term supplies of anthropogenic CO_2 will be needed.
With the addition of Residual Oil Zone EOR projects and the long term potential for Greenfield CO_2 EOR ROZ projects, significant additional supplies of CO_2 will be necessary in the long term. With the potential for CO_2 utilization in the Permian Basin, and the long term potential for CO_2 utilization in existing fields and Greenfield ROZ projects, it is critical that CO_2 be treated as a commodity and not as a waste product from an industrial source. All CO_2 EOR projects have incidental CO_2 Storage and long term potential for CO_2 Storage in conjunction with additional oil production. For energy security and environmental reasons, these types of projects should be the first place industry and government look to store anthropogenic CO_2.

CO2 in the Permian Basin

3+ BCF of CO_2 are processed daily in the Permian Basin in Enhanced Oil Recovery (EOR) projects. In addition to the 1+ BCF of re-cycle CO_2 utilized in the EOR projects, an additional 2 BCF of "new" CO_2 are imported into the basin daily. It is estimated that a volume of CO_2 equal to that ~2 .0 BCF is incidentally sequestered in the EOR projects daily. This total volume of new CO_2 is estimated to have a value near $700 million per year and is currently restricted by the sources or, in the case of the Cortez line from Cortez, CO to Denver City, TX, by pipeline capacity (Figure 1).
CO_2 from the Marathon Thrust Belt and expansions at McElmo Dome and Doe Canyon, in Colorado, have the potential for adding additional supplies. Bravo and West Bravo will do well to hold their own. However, a significant backlog of EOR projects will remain.

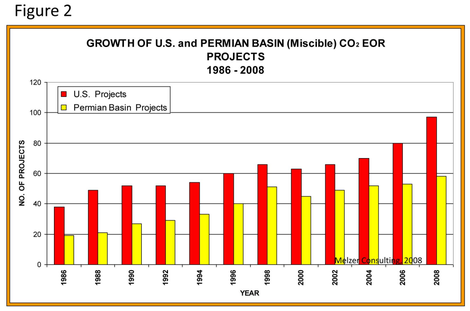
Figure 1



FIELDS

Since 1986, the number of CO_2 EOR projects in the basin has grown from <20 to 62 (Figure 2). The Permian Basin is the only basin in the world where Residual Oil Zones are under CO_2 flood, which include 9 projects where CO_2 is being injected into the Transition Zones/Residual Oil Zones (TZ/ROZ) beneath the Main Pay Zones (MPZ). A similar growth is seen nationwide and worldwide in CO_2 projects in the MPZ's.

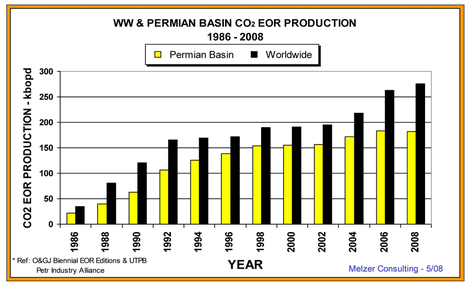
Figure 2



PRODUCTION

Over 180,000 BOPD are produced from CO_2 EOR projects daily in the basin, and over 1.2 BBbls of total CO_2 EOR oil have been produced to date (Figure 3). Total daily production from ROZ CO_2 floods is 5-10,000 BOPD. Similar growth is seen nationwide and worldwide in the MPZ's and is anticipated in ROZ floods.

Figure 3



POTENTIAL

Advanced Resources International (ARI) has studied 56 fields in five major Permian Basin San Andres/Grayburg oil plays and identified significant potential in the TZ/ROZ's of those fields. Based on reservoir modeling applying CO_2-EOR to the TZ/ROZ resources, ARI (Figure 4 & 5) estimates that **11.9 Billion BO is technically recoverable from the 30.7 Billion BO of TZ/ROZ oil in-place.** This exceeds the estimated CO_2 recoverable reserves of ~7 Billion Barrels present in the MPZ's in these five Permian Basin oil plays.

With a utilization/sequestration factor of 10 MCF CO_2/Barrel of oil produced, 200 Trillion Cubic Feet of CO_2 will be needed to recover the oil from these projects alone.

Field/Unit	MPZ OOIP (BB)	TZ/ROZ OOIP (BB)	No. of Fields	No. of MPZ Fields with CO_2-EOR Projects	No. of Fields with TZ/ROZ CO_2-EOR Projects
1. Northern Shelf Permian Basin (San Andres)	13.0	13.2	13	5	1
2. North Central Basin Platform (San Andres/Grayburg)	2.9	2.6	6	2	1
3. South Central Basin Platform (San Andres/Grayburg)	9.9	7.9	16	5	0
4. Horseshoe Atoll (Canyon)	5.4	2.9	10	4	2
5. East New Mexico (San Andres)	2.3	4.1	11	2	0
Total	**33.5**	**30.7**	**56**	**18**	**4**

Field/Unit	Total CO_2-EOR (BB)	MPZ CO_2-EOR (BB)	TZ/ROZ CO_2-EOR (BB)
1. Northern Shelf Permian Basin (San Andres)	8.3	2.8	5.5
2. North Central Basin Platform (San Andres/Grayburg)	1.5	0.6	0.9
3. South Central Basin Platform (San Andres/Grayburg)	4.6	1.7	2.9
4. Horseshoe Atoll (Canyon)	2.7	1.4	1.3
5. East New Mexico (San Andres)	1.7	0.4	1.3
Total	18.8	6.9	11.9

Figures 4 & 5. MPZ and TZ/ROZ OOIP in these 56 fields are is estimated to be 33.5 and 30.7 Billion Barrels From ARI, 2006. Total CO_2 EOR reserves are conservatively estimated to be >20 BBO .

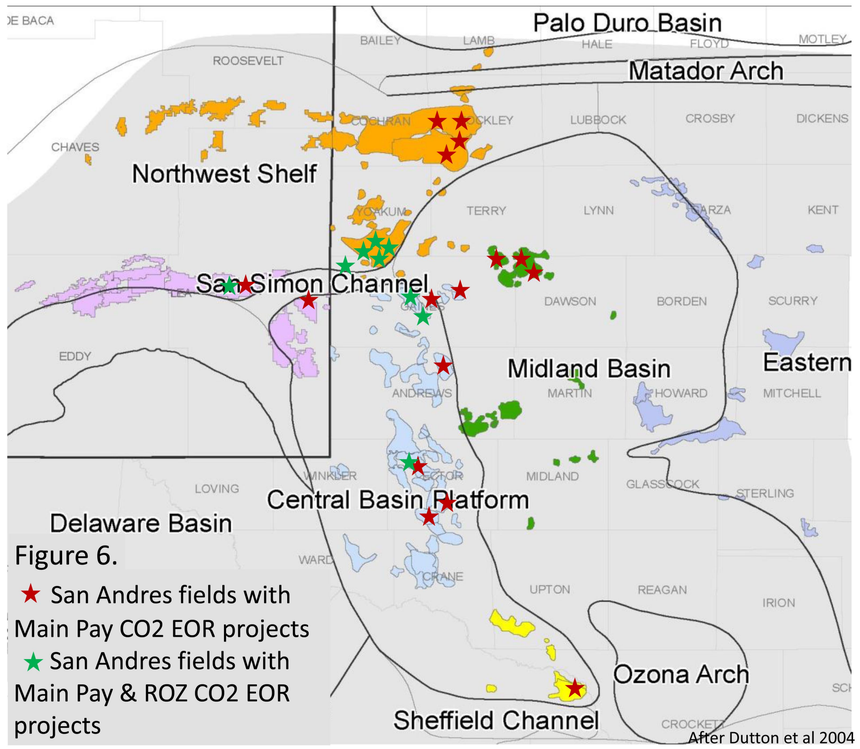


Figure 6.
★ San Andres fields with Main Pay CO2 EOR projects
★ San Andres fields with Main Pay & ROZ CO2 EOR projects

After Dutton et al 2004

CO_2 Projects

Many of the major San Andres Fields, in a variety of different stratigraphic settings ,are currently, or soon will be, in CO_2 EOR (**RED STARS**). However, there are many other potential floods awaiting a source of CO_2.
Today, only a few projects have, or will have, both MPZ and TZ/ROZ CO_2 floods (**GREEN STARS**). This number is anticipated to increase sharply over the next few years as economically successful TZ/ROZ CO_2 floods are reported.

Central Vacuum, East Vacuum, Means and East Seminole are all recent additions to the list of ROZ floods.

There are presently no "Green Field" CO_2 floods.

GREEN FIELDS

What is a "Green Field"? A Green Field is an area where an original oil column has been swept during geologic time by a naturally occurring lateral flushing event. These areas exist between producing fields as well as within field boundaries where they are isolated vertically from production and associated TZ/ROZ's in producing horizons. These intervals have similar reservoir fluid properties to those of efficient MPZ waterfloods and TZ/ROZ's prior to CO_2 EOR. In the future, these areas will become important "Carbon Sequestration" targets as they are both EOR and Geologic Sequestration targets.

Figure 7

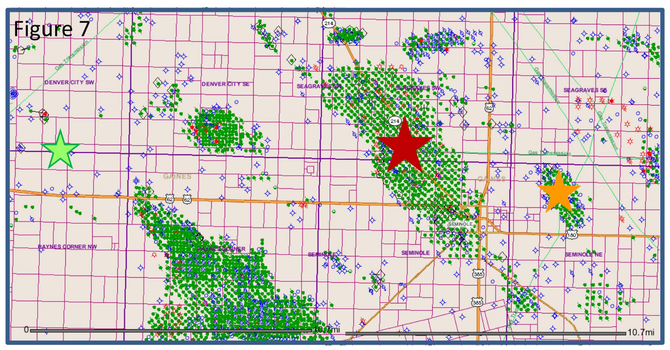


Fig 7. Relationship of an established CO_2 flood in the MPZ which is being expanded into the TZ/ROZ at Seminole Field [**RED STAR**]; a field being investigated for ROZ potential, Seminole East Field [**ORANGE STAR**]; and "Green Field" area with no established production but potential for TZ/ROZ EOR development [**GREEN STAR**].

With the potential for CO_2 utilization in the MPZ's in existing fields, the near term potential for CO_2 utilization in TZ/ROZ's beneath existing fields, and the long term potential for "Greenfield" ROZ projects in the Permian Basin, significant additional supplies of CO_2 will be required. Anthropogenic CO_2 must be considered as a component of the long term supply. In the short term, therefore, it is critical that CO_2 be treated as a commodity and not as a waste product from an industrial source.
The old rule of thumb for recycle = newly purchased volumes is true for very mature projects but goes out the window for new projects where recycle volumes are low. Large volumes have been added in recent years so it therefore follows that the ratio of recycle to new is probably closer to 0.65-0.75 today.

Permian Basin Geologic Sequestration of Carbon Dioxide

All CO_2 EOR projects have incidental CO_2 Storage and long term potential for CO_2 Storage in conjunction with additional oil production. For Energy Security and Environmental reasons, these types of projects should be the first place industry and government look to store anthropogenic CO_2.
The oil industry has over 40 years of experience in CO_2 Geologic Sequestration. Yet, few outside our industry know about our expertise.

Hard Lessons:

During the 40+ years that operators have been injecting CO_2 into our reservoirs, we have learned many valuable (and expensive) lessons that can be passed on to those researchers studying geologic sequestration elsewhere.

The primary lesson is that the behavior of CO_2 in even a simple reservoir will be more complex than modeled. Our heterogeneous reservoirs should serve as models for geologic sequestration in brine aquifers. Breakthroughs, sweep efficiencies, injectivity, and cross formation migration (out of zone) are all issues that have been a part of CO_2 EOR from the beginning. Multiple approaches to these and other problems have been tried and the most economic solutions determined.

Our understanding of TZ/ROZ's reservoirs and their potential EOR targets have expanded greatly over the past 15 years. We are only now beginning to realize the huge potential for TZ/ROZ EOR. This, in turn, leads us to the real potential for Geologic Sequestration in the Permian Basin. Research into the TZ/ROZ's potential in other basins will eventually lead to the development of multiple plays in multiple basins nationwide. Already, CO_2 EOR is being developed in the Main Pay Zones in a number of basins in Wyoming, and the potential TZ/ROZ targets identified.

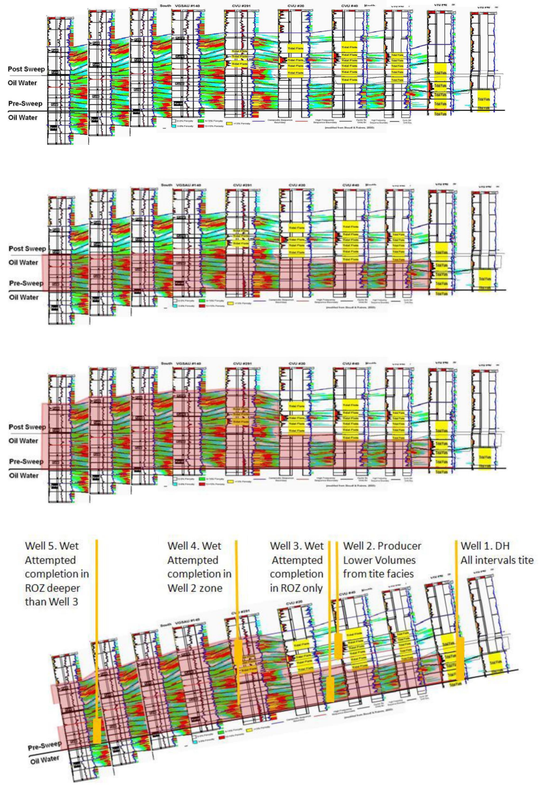


Figure 8. Model for the development of "Mother Natures Waterflood" and the types of production responses expected.

The Price Is Right

As a result of recent studies of the potential for CO_2 utilization in Residual Oil Zone Enhanced Oil Recovery, the mindset that geological sequestration has 10 or 20 fold capacity of CO_2 EOR for the long term sequestration of CO_2 is proving to be unsupportable. For both short term CO_2 EOR and Long Term Geologic Storage, the best, least risky, most practical, and least expensive method of storing CO_2 is in EOR projects.
There are five components of cost related to CO_2 Capture and Storage:

- Capture
- Compression
- Transportation
- Injection and
- Monitoring Verification and Accounting.

For a Coal Fired Power Plant, each of these have an attached cost which offset potential profits (and our cost of electricity). If the CO_2 is captured at the plant and sold for EOR, the CO_2 Marketer will assume the cost of the Transportation, Injection, and Monitoring Verification and Accounting (MVA). Although the value of "Carbon Credits" the power generator will receive is unknown at this time, this will greatly reduce the cost and liability of the power generator. The CO_2 therefore goes from being a Toxic Waste to a Product. The value of 1 MMCF CO_2 is presently close to 50% of the price of 1 MMCF of Natural Gas.

Potential Anthropogenic Sources

Over 83% of the CO_2 utilized in EOR today is from pure, natural sources (Figure 9). Neither the present natural, nor anthropogenic, sources are capable of supplying the long term incremental need.
Coal fired power plants are both the largest and lowest cost potential long term sources of CO_2 (Figure 10).

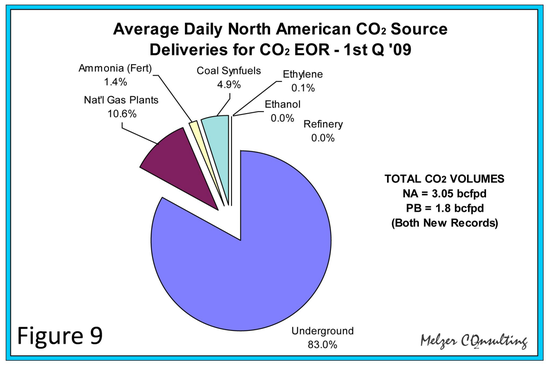
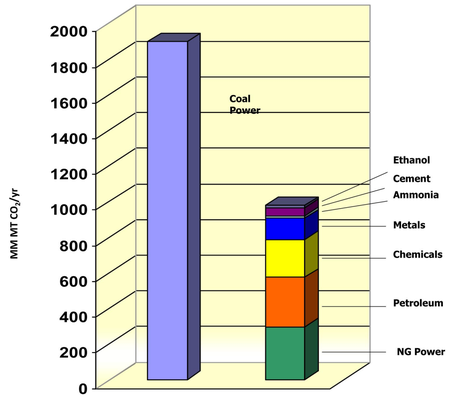


Figure 9

Figure 10. CO_2 Emissions From Different Industries



Source: EIA/Emissions of Greenhouse Gases in the United States 2004

Anthropogenic Sources…Sooner than you think

Two CO_2 capture equipped coal fired power plants are being permitted in the basin and one, the Summit Plant at Penwell, is scheduled to break ground before the end of the year. The fact that a near zero emissions coal fired power plant at Penwell and a post combustion coal fired power plant near Sweetwater will soon begin construction speaks volumes about the potential for CCS in Enhanced Oil Recovery Projects .

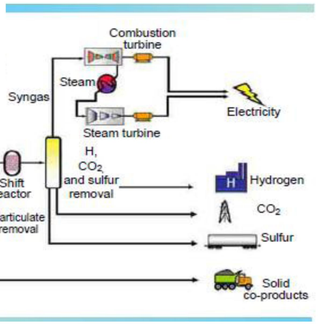
Blue Source has already agreed to be Summit's marketer to provide for the sale of the captured CO_2 into the Central Basin Pipeline less than 1 mile to the east of the Penwell plant.

Though it will be a minimum of 2-3 years before the CO_2 is available, when it comes on line, daily volumes are expected to be in the ~140 MMCF CO_2 range.

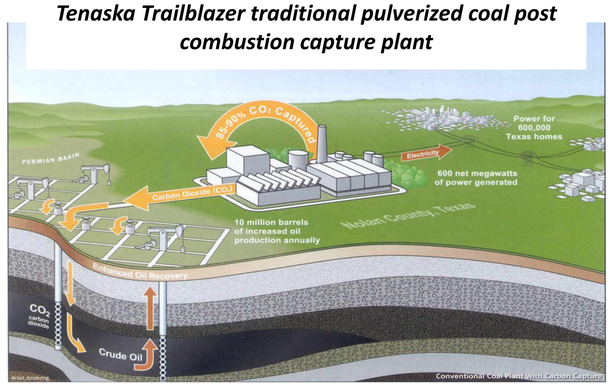
Blue Source plans to oversee the Monitoring and Verification of the geological sequestration of the project's CO_2 in Permian Basin oil fields.

Summit Penwell integrated gasification combined cycle (IGCC) with CO2 Capture

Figure 11



Tenaska Trailblazer traditional pulverized coal post combustion capture plant



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