

The Development of Residual Oil Zones
Enhancement of Domestic Oil Reserves and an
Economic Driver for Sequestration of Carbon Dioxide

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The use of injected carbon dioxide for Enhanced Oil Recovery (EOR) is a process that was first used on January 26, 1972 at the SACROC unit in Scurry County, Texas. Since then the use of carbon dioxide enhanced oil recovery in primary production zones has expanded across the Permian Basin in west Texas and eastern New Mexico and to a more limited extent in Kansas, Mississippi, Wyoming, Oklahoma, Colorado, Utah, Montana, Alaska, and Pennsylvania, and in other countries. As of 2010 it is estimated that there are 114 active carbon dioxide injection projects that inject over 2 billion cubic feet of carbon dioxide per year from largely geologic sources to produce 280,000 barrels of oil per day. .

It is further estimated that 10,000 of those barrels are being produced from a type of newly recognized oil deposit that is still in the process of being characterized and that is beginning to be perceived as a significant source of future oil production in terms of production and geographic foot print, the Residual Oil Zone or ROZ. The basic concept of the ROZ is a zone in which oil is not present at saturations that have historically thought to be required for primary or secondary oil production (typically over 50%). Under current economic conditions viable production can take place from ROZs with oil saturations as low as 20% to 25%. To do this requires the injection of carbon dioxide.

Residual Oil Zones (ROZs) are associated with petroleum migration and primary production areas. "Brown Fields" are ROZs located beneath existing primary production zones and "Green Fields" are ROZ zones with no associated primary production. Green field offer the potential for the geographic expansion of areas to which carbon dioxide EOR may be applied. Aside from purely commercial projects a series of strategic projects for the development of ROZs for petroleum production and utilization/control of carbon dioxide in the United States are underway in the Permian Basin of Texas and New Mexico with funding directly from the DOE and the Research Partnership to Secure Energy for America (RPSEA, a DOE program). These projects include the creation of a regional groundwater model to evaluate groundwater sweeping and formation of ROZs in the San Andres along the Northwest Shelf and Central Basin Platform bordering the Delaware Basin. The initial results from this modeling effort have shown that groundwater flushing through the San Andres Formation along the edge of the North West Shelf and the Central Basin Platform adjacent to the Delaware Basin over a 15 million year period between late Oligocene and the middle Miocene took place at realistic rates that match those inferred from other physical features in the unit such as the inclination of tilted oil water contacts.

The field application of the results of that modeling program is also under way. In addition, petroleum, water and gas (including flash gas) are being collected from ROZ production wells in their native state and during carbon dioxide flooding to more closely evaluate the biological/chemical/physical processes

that govern the formation and location of ROZs and the specific response of those ROZs to carbon dioxide flooding.

It is currently estimated that there are 30.7 billion barrels of ROZ oil in the Permian Basin and that 11.9 billion barrels of that are producible using carbon dioxide EOR. Furthermore It takes somewhere in the range of 6,000 to 20,000 cubic feet of carbon dioxide to produce a barrel of oil, with 16,000 cubic feet the average.

Carbon dioxide as used for EOR programs is a commodity that has value and an associated cost. The specific value/cost is established in contracts between the suppliers and consumers of that carbon dioxide; as such the specific costs are often closely held and considered proprietary. However, a useful rule of thumb is that the cost of 1000 cubic feet of carbon dioxide is 2% of the cost of a barrel of oil. When carbon dioxide is used for enhanced oil recovery a portion is retained in each usage cycle with ultimately 90% to 100% of it irretrievably retained, in spite of rigorous recovery and recycle that are strongly driven the economics of the EOR program. Those recapture efforts are driven by the fact that the carbon dioxide is a commodity, must be purchased and has significant value to the field operator. There is another word for that retained carbon dioxide, sequestration. For a practical illustration, currently 3 billion cubic feet of carbon dioxide is handled each day in the Permian Basin. Of that 2 billion cubic feet are new stocks and 1 billion is from recycle. The 2 billion cubic feet is for new projects, project expansions and that needed to replace that retained or sequestered.

Although to date not a primary driving factor in the development of this resource, there is also a perspective regarding the control of greenhouse gas emissions. Carbon dioxide is used as a commodity for EOR during which sequestration takes place, this is increasingly being recognized as a viable and practical means to implement greenhouse gas control as part of a profit making commercial activity. The DOE is literally in the process of shifting their focus on the management of carbon dioxide from Carbon Capture and Sequestration (CCS) where the carbon dioxide is to be managed as a regulated waste to Carbon Capture and Utilization (CCU) where carbon dioxide has very real economic value. For example on October 21, 2011 a senior DOE official at a federal coal advisory board meeting in Washington, DC announced the decision to officially shift their focus from CCS to CCU. Based on what is known to day the DOE estimates that the capacity of carbon dioxide EOR in the United States is 45 billion metric tons, which is 21 times the yearly emissions of coal and natural gas power plants in the United States in 2009. Those estimates are dominated by simple application of tertiary EOR to existing primary petroleum production zones. The exploitation of ROZs will add to that capacity.

The bottom line is that the development of ROZs is estimated to increase producible oil reserves in the United States by 30% to 50% or more. In addition, the process provides a means to sequester carbon dioxide that is driven by economics not regulation; offsetting unavoidable parasitic costs associated carbon dioxide capture. That first represents the opportunity to enhance domestic petroleum production in the United States and worldwide. It will also allow for the immediate and cost effective means of managing carbon dioxide captured from power plants via proven technology and in an economic environment that has the potential to offset the parasitic costs associated with the capture of carbon dioxide. That capacity is of critical importance during the early stages of the implementation of carbon capture at a commercial scale because it will also offset costs associated with implementing the fundamental and field scale research that will be needed to make carbon capture a viable and effective technology.