Quadrennial Technology Review 2015

Chapter 4: Advancing Clean Electric Power Technologies

Technology Assessments

U.S. DEPARTMENT OF ENERGY

Carbon Dioxide Capture and Storage Value-Added Options

Chapter 4: Technology Assessments

Introduction

Technology advances are being pursued to decrease the cost to capture and store CO_2. There are also opportunities to reduce costs through CO_2 utilization, and accelerate carbon capture and storage (CCS) deployment and technology improvements such that eventually CO_2 utilization and other value-added approaches will not be required for CCS to be commercially viable and widely deployed. Second generation CCS technologies are targeted to achieve a 20% reduction in cost of electricity (COE) compared to state-of-the-art (SOTA) technology for coal-fired power generation with CCS. Advanced technology will make anthropogenic CO_2 sources more affordable, which in turn can be incorporated in a variety of uses to reduce overall CCS cost.

While CO_2 is currently used as a feedstock in a variety of chemical processes for carbon-based products (e.g., industrial products such as inorganic and organic carbonates and polyurethanes which have long decay times of decades to centuries), enhanced oil recovery (EOR) in certain regions of the U.S is by far the largest market for CO_2, and a significant number of the 2,000 large oil reservoirs evaluated in the lower 48 states are amenable to CO_2 EOR.[1] In fact, 205 out of the 217 large reservoirs of the Gulf Coast hold as much as 17.7 billion barrels of residual oil in place (ROIP) which is favorable to CO_2-EOR. EOR provides an economic opportunity to utilize and store CO_2 and catalyze a substantial number of first-mover CCS projects. Most of the major CCS demonstration projects in North America have relied on EOR for financial viability.

The economics for CCS retrofits are highly sensitive to the economic life of the project. For a subset of existing domestic coal plants, this highlights a need for rapid demonstration and deployment of 2nd Generation technology before the age of these plants prohibits significant CCS deployments. However, substantial opportunity will still remain for 2nd generation and especially transformational technology to be applied to natural gas combined cycle (NGCC) CCS retrofits and international coal CCS retrofits consistent with expected deployment timelines.

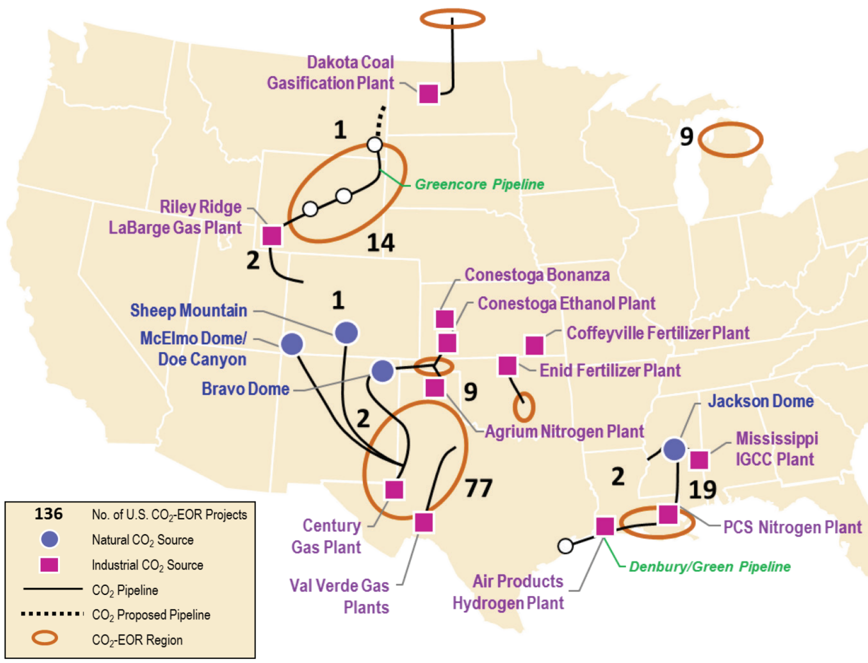
EOR and other Technology Options

Crude oil development and production in U.S. oil reservoirs can include up to three distinct phases: primary, secondary, and tertiary (or enhanced) recovery. During primary recovery only about 10 % of a reservoir's original oil in place is typically produced. Secondary recovery techniques extend a field's productive life generally by injecting water (or sometimes gas) to displace oil and drive it to a production well, resulting in the recovery of 20 to 40 percent of the original oil in place. However, with much of the easy-to-produce oil already recovered from U.S. oil fields, producers have attempted several tertiary, or enhanced oil recovery (EOR), techniques that offer prospects for ultimately producing 30 to 60 percent, or more, of the reservoir's original oil in place.[2]

In the United States there are currently over 100 EOR operations and more than 3,900 miles of CO_2 pipeline.[3] Figure 4.C.1 shows current CO_2 pipeline systems. Much of the CO_2 used for current EOR operations involves CO_2 extracted from natural CO_2 domes. However, anthropogenic CO_2 sources are being successfully used in some locations. As an example, the Dakota Gasification Company's Great Plains Synfuels Plant in Bismarck, North Dakota, has been capturing more than 1.5 million tons CO_2 per year from a coal gasification plant and selling it for EOR for more than fifteen years.

Figure 4.C.1 Current CO2-EOR Operations and Infrastructure.[4]

Credit: Advanced Resources International Inc.



U.S. Regions with Large-scale CO_2 Pipeline Systems in Operation	Miles of Pipeline
Permian Basin (W. TX, NM, and S. CO)	2,600
Gulf Coast (MS, LA, and E. TX)	740
Rocky Mountains (N. CO, WY, and MT)	730
Mid-Continent (OK and KS)	480
Other (ND, MI, Canada)	215

There also exists a strong synergy between technology development in the areas of CO_2 capture and CO_2 EOR. Development of advanced CO_2 EOR technology could triple the demand for captured CO_2, and advanced CO_2 capture technology could lower the required selling price for anthropogenic CO_2 such that coal-fired power plants and other point sources of CO_2 could meet the demand. With technical validation and assessment, residual oil zones (ROZ) may offer a new opportunity for combined oil production and CO_2 storage.[5] ROZs exist in many mature fields and in migration fairways between fields. Within fields, residual oil can be found below the oil/water contact, or in areas that were bypassed in the normal production processes. CO_2 EOR for producing oil in ROZs began in the 1990s. The oil in the ROZ is immobile (i.e., at irreducible saturation) and cannot be produced by primary or secondary recovery means. It does, however, appear to respond well to CO_2 EOR, and eight fields within the US currently produce oil using this technique. It appears possible in some formations to store more carbon as part of the EOR-ROZ operation than carbon that is contained in the produced oil. More research is needed to understand the size and extent of ROZs, and how to minimize their carbon footprint. ROZ resources located predominantly in the Permian Basin have over 250 billion barrels of oil-in-place.

There are other potential value-added products associated with CCS systems. Gasification-based processes can use a portion of the produced syngas to make chemicals and fuels if warranted by market conditions. For example, the Summit Texas Clean Energy project[6] plans to demonstrate an Integrated Gasification Combined

Cycle (IGCC) poly-generation system that produces both power and other value added products such as urea. Of the CO_2 expected to be captured per year, approximately 0.5 million metric tons will be consumed to produce urea. The remaining 1.65 million metric tons of CO_2 will be compressed and used for EOR in the west Texas Permian Basin, the largest CO_2 flood EOR region in the world.

Other utilization technologies under development include conversion or incorporation of CO_2 into building and construction materials such as cement and concrete, and also conversion into plastics and polymers. An example is the Skyonic Skymine project,[7] which opened October 2014 in San Antonio, Texas, at Capitol Aggregates cement plant, and is demonstrating a patented integrated process for removing CO_2 from industrial or utility power plant flue gas streams, and converting the CO_2 into usable products. The project (shown in Figure 4.C.2) is located adjacent to a coal-fired rotary cement kiln and is the first commercial-scale technology of its kind for capturing and reusing CO_2 for production of saleable sodium bicarbonate from captured CO_2. Hydrochloric acid and bleach solution is also produced for commercial sale. The technology will have a lower CO_2 foot print than current commercialized processes for making sodium bicarbonate. About 75,000 metric tons per year of CO_2 will be captured from the cement kiln flue gas stream and converted to saleable sodium bicarbonate. There will also be an additional avoidance of about 100,000 metric tons per year of CO_2 when compared to existing commercial processes for making sodium bicarbonate and hydrochloric acid. The process also removes most of the sulfur oxides, nitric oxides, mercury and other heavy metals from the treated flue gas.

Figure 4.C.2 Skyonic Project Carbon Capture Unit.

Credit: Skyonic Corporation

Extracting water from CO_2 storage formations to manage pressure can improve CO_2 storage efficiency and minimize risks of induced seismicity and leakage. In addition, treating extracted water to reduce dissolved solids can make the water available for a variety of purposes such as power plant cooling and agricultural/potable water. The economics of one water treatment option, reverse osmosis, are particularly promising because it requires pressurized water, and the water extracted from the formation is already under pressure.[8] Water extraction and re-use for cooling has the potential to more than offset the incremental water demand for capture for some system configurations. Other CO_2 utilization options include mineralization and incorporation into building and construction materials (i.e., calcium carbonate or magnesium carbonate), CO_2 curing of concrete products to conserve energy and capture CO_2, and conversion into plastics and polymers. In addition, CO_2 can be used to promote indirect carbon storage through enhanced photosynthesis of algae for biofuels.

Table 4.C.1 Key Goals and Challenges of Several Value-Added Options of CO_2 Production and Use For Consideration.

Goals for Consideration

1. developing chemical processes for site specific use of CO_2 to produce marketable products
2. increasing commercial domestic oil production from ROZs
3. developing advanced EOR technology that will increase the demand for anthropogenic CO_2
4. treating extracted water from CCS projects for cost-effective beneficial use
5. developing advanced CO_2 capture technology that could lower the required selling price for anthropogenic CO_2

Goal 1: developing chemical processes for site specific use of CO_2 to produce marketable products

Major R&D Challenges

- identify chemical process and catalysts to achieve an energy, thermodynamic and economic balance adequate for the chemical and polymers industries[9]

Goal 2: increasing commercial domestic oil production from ROZs

Major R&D Challenges

- advancing reservoir characterization for domestic residual oil zones (ROZs) to better understand the resource potential and the level of effort required for production
- developing technology and strategies for flooding intervals far below cap rock and trapping CO_2 within the ROZ
- developing mechanisms to allow contact with CO_2 to release the oil from the forces holding the ROZ oil in place

Goal 3: developing advanced EOR technology that will increase the demand for anthropogenic CO_2

Major R&D Challenges[10]

- advancing reservoir characterization
- combining horizontal/vertical wells plus "smart" well technology to better contact bypassed oil
- developing agents for CO_2 mobility and flow path control to improve reservoir conformance
- increasing volumes of efficiently targeted CO_2 to improve oil recovery efficiency
- developing near-miscible CO_2-EOR technology to expand CO_2-EOR to additional oil reservoirs
- advancing reservoir surveillance and diagnostics technology to "see and steer" the CO_2 flood

Goal 4: treating extracted water from CCS projects for cost-effective beneficial use

Major R&D Challenges

- evaluating ability to control CO_2 and pressure plume location by management of CO_2 injection and water extraction
- modeling and field screening of CO_2 injection and water extraction scenarios in different depositional environments
- characterizing brine extraction impacts on storage resource
- understanding the economic, infrastructural, technological, and regulatory aspects of water management solutions
- conducting pilot tests of formation fluid management and associated treatment methods for the extracted water

Goal 5: developing advanced CO_2 capture technology that could lower the required selling price for anthropogenic CO_2

Major R&D Challenges

- See TA on Carbon Dioxide Capture Technologies

Endnotes

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6 Summit Texas Clean Energy project website, http://www.texascleanenergyproject.com/, and http://www.netl.doe.gov/research/coal/major-demonstrations/clean-coal-power-initiative/ccpi-summit.

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Acronyms

CBTL	Coal-biomass to liquids
CCS	Carbon capture and storage
CLC	Chemical looping combustion
CO_2	Carbon dioxide
COE	Cost of electricity
cP	Centipoise
EOR	Enhanced oil recovery
H_2	Hydrogen
H_2O	Water
IGCC	Integrated gasification combined cycle
IGFC	Integrated gasification fuel cell
MEA	Monoethanolamine
NGCC	Natural gas combined cycle
NOAK	Nth of a kind
NOC	Normal operating conditions
PC	Pulverized coal
RD3	RDD&D
RDD&D	Research, development, demonstration, and deployment
ROIP	Residual oil in place
ROZ	Residual oil zone
sCO_2	Supercritical CO_2
SOFC	Solid oxide fuel cell
SOTA	State of the art
USC	Ultra-supercritical
SWiFT	Scaled Wind Farm Technology
WFIP	Wind Forecasting Improvement Project