THE INSTITUTE OF CLEAN AIR COMPANIES (ICAC)
CARBON EMISSIONS MANAGEMENT DIVISION

Issue Brief for
United States Environmental Protection Agency
Administrator E. Scott Pruitt

THE INSTITUTE OF CLEAN AIR COMPANIES

EXECUTIVE SUMMARY

Fossil fuels, including coal, will continue to be a critical energy resource, both domestically and globally. ICAC members have been involved in efforts to manage carbon from fossil fuels for decades, as described in more detail below. Further support is needed from the federal government (and other sources) to commercialize and lower the costs of these technologies. There is broad bi-partisan support for devoting additional resources for carbon management. EPA and DOE can play a key role in helping to maintain and expand our progress in the carbon management area, so that ICAC and other U.S. businesses can gain a competitive advantage globally and increase exports of valuable technology. ICAC encourages Administrator Pruitt and the Trump Administration to assist in this effort.

1. INTRODUCTION

Fossil fuels will continue to be needed for the foreseeable future in transportation, power, building heating, and heavy industry, in the U.S. and abroad. However, there is increasing pressure in both the U.S. and other countries for users of fossil energy to manage their carbon emissions. ICAC member companies have been involved for years in efforts to develop and commercialize technology to enable the capture, utilization and storage of carbon emissions (CCUS). ICAC members will continue to be involved in both the development of these technologies and efforts to lower cost and achieve greater profitability, including efforts to improve the economics of enhanced oil recovery (EOR). While there are many promising developments in the CCUS field, CCUS continues to require additional research and development support, both to lower costs of existing, proven technologies and to develop new and innovative technologies.
As noted by the Chief Executive Officer of ExxonMobil, Darren Woods:

"Carbon capture and storage technology is another key part. ExxonMobil has an interest in about one-quarter of the world's CCS capacity. Last year, we announced a technology partnership to research whether fuels cells can be used to capture carbon dioxide more economically. This potential game-changer could enable continued hydrocarbon use with greatly reduced emissions." -*Darren W. Woods at the World Petroleum Congress, July 10th, 2017*

In a blog post by Peter Grubnik, the Project Manager for the Global CCS Institute talks about his optimism for the future of CCUS technology.

Read his post here

ICAC member companies believe that the long-term utilization of fossil resources will be compromised without technologies to limit carbon emissions. Resulting constraints on the utilization of fossil fuels will have significant impact on companies, service providers, and their employees that utilize these critical national resources. Financial incentives for CCUS technology development today will assure that reliable, domestic fossil energy sources are available to power our economy for future generations. The U.S. currently leads the way in development of CCUS technologies, and is a major global producer of fossil fuels, especially coal. EPA and DOE can play a key role in helping to maintain and expand our technological progress in the CCUS area, so that ICAC members can translate that to a U.S. competitive advantage globally.

A variety of interested parties are focused on additional research. Project developers, industrial suppliers of CO2, technology vendors, ethanol producers, electric utilities, oil and gas producers, coal companies and others are supporting federal financial incentives for CCUS. They support legislation that increases the financial certainty for carbon capture project investors, increases the credit value for EOR and other geologic storage, expands industrial participation in CCUS, and enhances flexibility in utilization of the tax credit to allow multiple business models.

In March of 2017, a group of interested parties that included Peabody Energy, Arch Coal, Cloud Peak Energy and the United Mine Workers of America wrote to President Trump regarding federal investment in fossil energy technologies like CCUS, stating that:

"In light of recent calls for dramatic cuts to the federal government, we want to stress that every dollar allocated to fossil energy research is an investment in the long-term future of America's coal and fossil fuel industry. And this federal investment yields significant benefits. There are technologies under development…that will improve the performance and costs of fossil fuel technologies, make coal more competitive and enhance our energy security. That includes technology that captures carbon and uses it to increase domestic oil production through a process called enhanced oil recovery."[1]

There are a number of bipartisan bills in Congress that seek to achieve these goals, discussed more fully below. Bills to make CCUS projects eligible for private activity bonds have been proposed in both chambers. Bi-partisan legislation was also introduced in the past two Congresses to allow CCUS facilities to qualify for the Master Limited Partnership structure. Some groups have also requested the President to include several identified carbon capture projects as part of any major infrastructure effort.

Additionally, there is growing state support for CCUS and CO2-EOR. 16 states participate in the State CO2-EOR Deployment WorkGroup convened by the Great Plains Institute, which is helping state policy makers better understand states' potential for CCUS and recommending policies for states and the federal government.

Although some technologies are proven, to further reduce the capital costs and operating costs, implementing new projects requires additional resources and activities that can only be provided with government support. Reductions in capture costs will flow from the research that comes from such projects. In addition, government policy can provide direct incentives (e.g., through R&D spending to fuel further innovation and pilot testing of advanced capture technologies) or incentives through the policy itself.

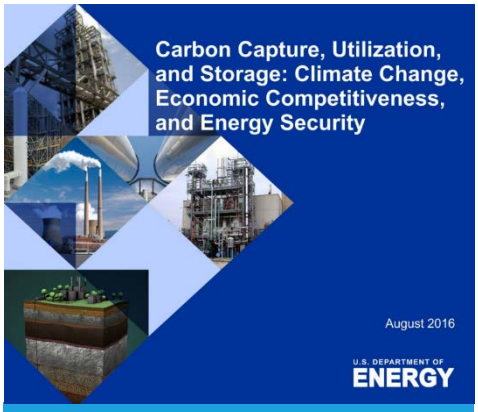
CCUS technology is proven and in use around the world. Twenty-seven large-scale CCUS projects are in operation or under construction globally of which thirteen are in the United States.

If this continues, the U.S. has the potential to be the world leader in CCUS technologies, which could provide businesses with valuable export opportunities and expand domestic manufacturing jobs. ICAC members can play an important role in helping to grow America's economy through continued development of CCUS.

1 "Letter from Top Coal Companies, Labor Unions and Organizations." Letter to President Trump. 10 Mar. 2017. MS. N.p. < https://www.eenews.net/assets/2017/03/13/document_gw_02.pdf >.

1.1 CCUS BACKGROUND

Several decades of research, development and deployment support the current state of CCUS technologies. Each of the main elements of carbon capture and storage: 1) capture, 2) transport via pipeline and 3) injection into underground formations, have been demonstrated separately by the oil and gas and chemical industry. However, use of these technologies together and at scale in a power context is a process that is still undergoing development. Significantly lower costs and reduced energy use will be required before widespread commercialization can occur.



Read the Department of Energy's 2016 report on Carbon Capture Storage and Utilization **here**

Figure 1. List of US CCUS projects. A complete list of worldwide projects is provided at the conclusion of this paper.

Name	Location	Operation date	Industry	Capture type	Capture capacity (Mtpa)	Primary storage type
Terrell Natural Gas Processing Plant (formerly Val Verde Natural Gas Plants)	United States	1972	Natural Gas Processing	Industrial Separation	0.4 - 0.5	Enhanced oil recovery
Enid Fertilizer	United States	1982	Fertiliser Production	Industrial Separation	0.7	Enhanced oil recovery
Shute Creek Gas Processing Plant	United States	1986	Natural Gas Processing	Industrial Separation	7.0	Enhanced oil recovery
Century Plant	United States	2010	Natural Gas Processing	Industrial Separation	8.4	Enhanced oil recovery
Air Products Steam Methane Reformer	United States	2013	Hydrogen Production	Industrial Separation	1.0	Enhanced oil recovery
Coffeyville Gasification Plant	United States	2013	Fertiliser Production	Industrial Separation	1.0	Enhanced oil recovery
Lost Cabin Gas Plant	United States	2013	Natural Gas Processing	Industrial Separation	0.9	Enhanced oil recovery
Illinois Industrial Carbon Capture and Storage	United States	2017	Ethanol Production	Industrial Separation	1.0	Dedicated Geological Storage
Petra Nova Carbon Capture	United States	2017	Power Generation	Post-combustion capture	1.4	Enhanced oil recovery

2. CAPTURE

Currently, there are a number of different methods used to separate and capture CO2 from power plants and industrial facilities. For power plants, technologies can generally be separated into post-combustion and pre-combustion approaches. In post-combustion CO2 capture, the CO2 is commonly removed from the flue stream via a chemical solvent (scrubbing). The carbon is absorbed into the solvent to remove it from the exhaust from combustion. Then, the carbon needs only to be separated from the solvent.

A post-combustion system is in use at NRG's Petra Nova facility located outside of Houston, Texas. After receiving a $190 million grant provided by the federal government and private industry, the Petra Nova plant opened on-time and on-budget, and is the largest post-combustion carbon capture plant in the world.

Pre-combustion takes the CO2 from the fossil fuels before combustion is completed. In this process, a syngas is created from coal. CO2 and hydrogen in the syngas are separated after purification. The CO2 can be sent for EOR or sequestration and the hydrogen can be used as fuel to generate electricity. This process has been used at the Polk plant in Florida for some time. This is also the process that was planned for the Kemper facility in Mississippi, but that plant has been subject to cost overruns and recently announced its intention to convert to a gas plant. The Kemper plant is indicative of the need for further government support into research and development before full commercialization of CCUS technology can be successfully implemented widely.

In EOR, CO2 is pumped down into existing mature oil fields to the oil-bearing formation and then, usually in conjunction with injected water, it mobilizes the remaining oil for recovery at the production wellbore. Much of the injected CO2 remains in the reservoir. The CO2 that does return to the surface with the produced oil is recovered and reinjected creating a closed-loop system.

Currently, about 65 million tons of CO2 (mostly from natural sources with the rest from industrial and power plants) are used annually for EOR in over 5,000 wells. Larger companies, such as Occidental Petroleum, and smaller ones, such as Denbury Resources, are active EOR operators. Under the Greenhouse Gas Reporting Program, EPA allows companies to receive credit for carbon stored via CO2-EOR by reporting data on CO2 injected and stored (mass balance) in the oil field and implementing a measurement, reporting and verification plan. The longest onshore EOR project has been the SACROC project in West Texas for over 40 years, and the largest onshore EOR project, with 7 million tons of CO2 per year used in EOR or stored, is the Shute Creek operation in Wyoming.

While significant commercial experience with carbon capture exists in certain industrial sectors, too few facilities have been built and tested in the power sector to bring costs

down significantly. Thus, new plants using current CCUS technology are estimated to cause increases in electricity generation cost varying from about $20-$50/MW-hr (2013$) for a natural gas combined cycle (NGCC) plant to $30-$70/MW-hour for a supercritical pulverized coal (SCPC) plant. The added cost for an integrated gasification combined cycle (IGCC) plant is estimated to be midway between those values. These values represent increased costs per MW-hour of between 50% to 60% for an NGCC plant and 30-50% for an SCPC plant.

In all cases, the cost of capture (including compression) accounts for the vast majority (approximately 80%) of the cost of capturing, transporting and injecting CO2. The overall cost of CCUS can be reduced significantly if the captured CO2 is sold for use in EOR (with the magnitude of savings dependent on the prevailing oil price).

The DOE lists a number of Carbon Capture and Storage projects within the industrial sector. Various projects and technologies are highlighted. View the DOE page **here**

Second generation technologies will improve these economics and could result in 25-30% lower capital costs and 20-30% lower operating costs if current R&D goals are met. There are many ideas in various stages of development that may reduce capture costs, such as using membranes, fuel cells, solid sorbents, biomass co-firing, ionic liquids and advanced, more efficient power plant designs. Combining approaches where two different capture technologies are used in sequence could provide a cheaper approach to CO2 capture. It is also worth mentioning that large scale projects outside the power sector with proven carbon capture capabilities include methane capture projects from coal mines. ICAC member companies have installed very large scale methane capture units at coal mines around the world and ICAC members are developing new and innovative ways to capture methane from coal mines using a variety of technologies.

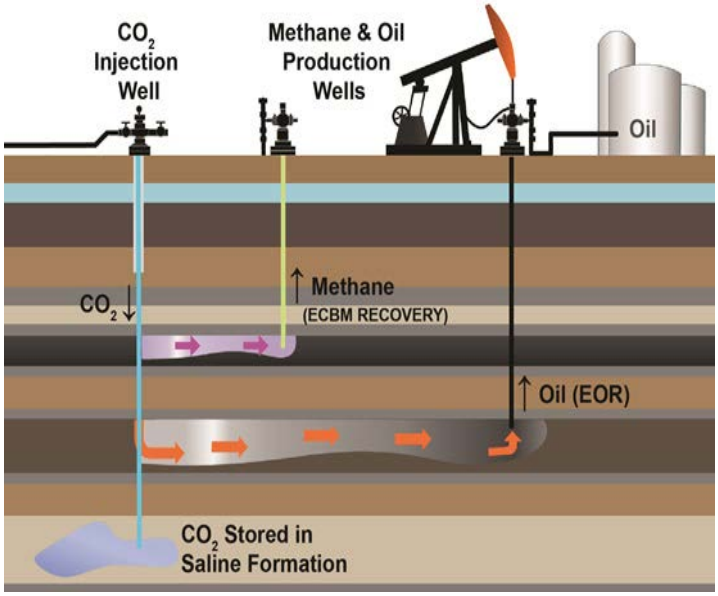
A list of large scale projects and test centers can be found at the conclusion of this paper.

2.2 CO2 TRANSPORTATION

Transportation of CO2 via pipelines in the U.S. is not significantly different than transporting oil, gas or natural gas liquids, all of which are currently regulated by the U.S. Department of Transportation. Over 5,000 miles of CO2 pipelines operate today in the U.S., and over their 40-year history have an outstanding safety record with zero associated fatalities from CO2 release. Pipeline pressures can be higher because the CO2 is transported in a dense phase liquid state to sites where it is stored. Most CO2 pipelines operate under a standard that requires low water content and low concentrations of H2S.

2.3 CO2 UTILIZATION AND CONVERSION

Figure 2. Enhanced oil recovery process



As noted previously, a principal use of converted CO2 has been for use in EOR. The Petra Nova project is perhaps the best example of CO2 captured from a powerplant and used in an EOR operation. The CO2 is pipelined to an oil field where it is injected, along with water, into oil bearing formations as a means of forcing additional oil to the surface.

CO2 is a valuable product in this context and, depending on the price of oil, significant amounts of captured CO2 could be used for this purpose. Under certain conditions, the CO2 will remain underground for decades and centuries.

Converting captured CO2 into useful products is an activity that is in its early stages, with DOE supporting a number of research projects and new technologies for converting CO2 to chemical and solid products. Captured CO2 can be converted to useful profitable products, like dry ice or carbonated beverages, which do not convert the carbon long-term, or building materials, which do offer a long-term conversion opportunity. DOE is also supporting early stage research to develop technologies that use biological or mineralization-based concepts or novel physical and chemical processes, which aim to generate economic value with a lower rate of carbon emissions. Some recent projects selected by DOE include direct electron beam synthesis to create chemical products, using microalgae to convert CO2 to bioplastics, and development of construction materials via industrial waste re-processing and power plant heat integration. Unfortunately, most processes will

take years to mature and it appears that markets are unlikely to be large enough to utilize all the CO2 being produced by such processes if they were to be implemented at full-scale.

3. SUPPORT FOR CCUS

CCUS has received significant financial support from the federal government and industrial partners, however, more is needed to lower the costs of existing technologies, to support commercialization of emerging technologies and development of additional new and innovative technologies. This support can come in at least two forms: 1. Direct, early-stage support for projects and technologies and 2. Long-term, stable financial incentives that provide certainty, such as a tax credit, for CCUS activities. Both forms have had strong federal support for 20 years and should be continued and even increased.

3.1 GOVERNMENT RESEARCH AND DEVELOPMENT

DOE has pursued research and development of CCUS since 1997. Since FY 2008, Congress has appropriated more than $7 billion for CCUS activities at DOE. This funding expired at the end of 2015.

The 2017 DOE budget has set aside $1.4 billion for CCUS and sequestration projects. The FY 2017 budget proposal includes $170.4 million, 30 percent above FY 2016 enacted, to continue R&D on carbon capture technologies. This includes $101 million to support construction of four large (10 MWe scale) post-combustion capture pilot plants, three for coal-fired power plants and one optimized to capture CO2 from a natural gas power system. Funding also supports front-end engineering and design (FEED) studies for two large scale pilot plants (10+MWe) to test advanced low-carbon combustion systems, such as chemical looping and pressurized oxy-combustion.

The Department of Treasury has set aside $5+ billion in tax incentives for CCUS deployment technologies. The FY 2017 budget re-proposes $5 billion in two tax incentives that will complement each other in making the deployment of CCUS technologies cost competitive, which in turn will enable additional technology improvements and drive down the costs of follow-on CCUS deployment.

The FY 2017 budget proposes $2 billion in refundable investment tax credits for projects that capture and permanently sequester CO2. Credits would be available to new and retrofitted electric generating units. Projects must capture and store at least one million metric tons of CO2 per year.

The Global CCS Institute has an extensive data base of multiple projects using new and experimental technologies.

A list of Pilot and Demonstration Projects can be viewed here: https://www.globalccsinstitute.com/projects/pilot-and-demonstration-projects

A list of Test Centers and other Initiatives can be found here:

https://www.globalccsinstitute.com/projects/test-centers-and-other-initiatives

A list of Co2 Utilization Projects can be found here: https://www.globalccsinstitute.com/projects/co2-utilisation-projects

3.2 SECTION 45Q SEQUESTRATION TAX CREDITS

Section 45Q of the Internal Revenue Code was enacted in 2008 as part of the Energy Improvement and Extension Act, and it was amended by the 2009 stimulus bill. Section 45Q gives a tax credit for carbon capture and sequestration. The credit is available for any taxpayer who: (1) captures "qualified CO_2" (i.e., CO2 that otherwise would have been released into the atmosphere) and (2) ensures (either physically or contractually) that the CO2 is captured in secure geological storage or is used as a tertiary injectant (i.e., pumped into oil and gas reservoirs in order to enhance the amount of oil that is extracted from the reservoir).

If the CO2 is geologically stored, the credit is $21.85 per metric ton of qualified CO2. If the CO_2 is used in EOR, the credit is $10.92 per metric ton of qualified CO2.

Section 45Q is not a permanent credit and expires when the Treasury Department and EPA together determine that 75 million metric tons of qualified carbon dioxide have been stored or used in EOR. Over half of the 75 million metric tons of CCS have already been credited under Section 45Q. Text of Section 45Q can be found **here.**

3.3 LEGISLATION

There are a number of bills pending in Congress that aim to extend or make permanent the 45Q tax credit program and to increase the amount of the credit from its current $10/$20 level.

S.1663 Senator John Hoeven (R-ND) introduced S.1663, the CO2 Regulatory Certainty Act on July 27, 2017. This bill is cosponsored by Senators Steve Daines (R-MT), Roger Wicker (R-MS), John Barrasso (R-WY), and Thad Cochran (R-MS). The bill amends the Internal Revenue Code to revise requirements for secure geological storage of CO2 for the purpose of 45Q tax credits. Under the bill, the IRS regulations must consider the CO2 to be disposed of in secure geological storage if it is in

compliance with specified rules promoted by the EPA under the Clean Air Act (CAA) and the Safe Drinking Water Act (SDWA).

S.1535 U.S. Senators Heidi Heitkamp (D-ND), Sheldon Whitehouse (D-RI), Shelley Moore Capito (R-WV) and John Barrasso (R-WY) introduced S.1535, The FUTURE Act on July 12, 2017. The bill has two dozen bipartisan Senate cosponsors, and is supported by the coal sector and a number of environmental groups, including the Natural Resources Defense Council. The bill was crafted with the purpose of both accelerating and incentivizing the development and use of carbon capture, utilization and storage technologies and processes. The legislation would support a path forward for existing sources of energy like coal, while spurring adoption of low-carbon technologies that can transform carbon pollution into useable products.

The FUTURE Act would extend and increase tax credits for power generators and industrial facilities that capture and sequester their carbon, as well as for carbon utilization — the conversion of carbon dioxide into useable products and fuels.

The bill would extend the 45Q tax credit and the "commence construction" window for projects from five to seven years and increase the time available to claim credits from 10 to 12 years. The bill would provide a $50 tax credit for every metric ton of carbon stored underground and $35 per ton for carbon utilized for purposes such as enhanced oil recovery. Currently, credits of $20 and $10 per ton are offered for capture and utilization, respectively.

H.R. 2010 Representative Kevin Kramer (R–ND) introduced H.R. 2010, the CO2 Regulatory Certainty Act on April 6, 2017. The bill is cosponsored by Representatives David McKinley (R-WV), Jeff Duncan (R-SC), Steven Palazzo (R-MS), Gregg Harper (R-MS), and Sam Johnson (R-TX). The House counterpart to S.1663 mentioned above, this bill aims to amend the Internal Revenue Code to enhance requirements for secure geological storage of CO2 for the purpose of 45Q tax credits.

S. 843 US Senators Rob Portman (R-OH) and Michael Bennet (D-CO) introduced S. 843, the Carbon Capture Improvement Act in April 2017.

This bill amends the Internal Revenue Code to authorize the issuance of tax-exempt facility bonds for the financing of qualified CO2 capture facilities. These bonds are exempt from a number of regulatory restrictions and can lower the cost of capital and extend the time horizon for repayment.

H.R. 4622 Representative Mike Conaway (R-TX) introduced H.R. 4622, The Carbon Capture Act, in February 2016 with the 114th Congress. As with the S. 1535 reviewed above, its primary aim was to extend the 45Q tax credit. However, it made four changes to 45Q.

Listed below are the four changes:

1. Make the 45Q credit permanent after 2015,
2. Increase the credit after 2024 for a qualified facility originally placed in service after December 31, 2015,
3. Allow credit to a person who disposes of, or uses as a tertiary injectant, the carbon dioxide; and
4. Modify the definition of "qualified facility" for purposes of eligibility for such credit to require not less than 150,000 metric tons (currently, 500,000 metric tons) to be captured at such a facility during the taxable year.

On May 24, 2017, Resources for the Future held a conference titled, **The Future of Carbon Capture, Utilization, and Storage (CCUS): Status, Issues, Needs**

It was attended by multiple experts and stakeholders from industry, academia and government.

A link to the entire conference can be found here: http://www.rff.org/events/event/2017-05/future-carbon-capture-utilization-and-storage-ccus-status-issues-needs

The proposals noted above show that there is widespread bipartisan support in Congress for legislation incentivizing and supporting CCUS, as well as significant support from a variety of constituent interests. In February 2016, a key group of outside interests, including representatives of Occidental Petroleum, Peabody Coal, Arch Coal, Cloud Peak Energy, Archer Daniels Midland and major environmental groups, including the Natural Resources Defense Council and the Clean Air Task Force, along with union representatives from the AFL-CIO sent a letter to the Chairman and Ranking Member of the House Appropriations Committee calling for a permanent extension of the 45Q credit. Support for CCUS has continued and in some contexts, even increased, following the results of the 2016 election.

4. LOOKING FORWARD

There is no question that fossil fuels will continue to play a large role in our energy mix and that coal, natural gas and petroleum will be needed for decades to come in order to provide energy independence in the U.S. and power the world economy. Carbon management, including carbon capture, utilization and storage or sequestration, is the key to an environmentally sustainable future for coal and natural gas used in power generation and industrial applications.

The U.S. is a world leader in this area and has already invested billions of dollars into developing these kinds of technologies. However, more research and development support is needed to lower costs and develop new technologies. It is critically important that the EPA and DOE work together to assess funding opportunities and to direct funding toward those opportunities with the greatest likelihood of success. Any potential infrastructure package should provide funding for CCS infrastructure, including for CO2 pipelines and other CCUS related infrastructure at both EOR sites and at other locations. Congress has shown bipartisan interest in partnering with the Executive Branch and private entities to provide the proper combination of incentives for further research, commercialization and deployment of CCUS. EPA can play a key role in fostering and augmenting this partnership. However, in order to foster long term development of CCUS and provide the stable horizon necessary for investment in such technologies at scale, both a market driver and a long-term funding/incentive program is needed. Without a regulatory driver to create on-going markets, an R&D component alone cannot fully incentivize widespread deployment of CCUS technologies. Enhanced oil recovery can provide an important bridge, as well as certain utilization technologies that can convert CO2 into marketable products. However, even these activities cannot by themselves provide sufficient drivers to achieve needed levels of CCUS.

It is imperative that the U.S. maintain its leadership role in these technologies, which can provide an important export opportunity for U.S. industry. EPA has a valuable role to play in this regard, a role that will help further the mission of environmental protection and clean air stewardship, while helping to grow the U.S economy and increase the domestic job base.

ICAC looks forward to working with EPA on these and other issues.

Figure 3. Large Scale CCS Projects Worldwide (Global CCS Institute)

Large Scale CCS Projects Around the World as Reported by the Global CCS Institute

Project name	Location	Operation date	Industry	Capture type	Capture capacity (Mtpa)	Transport type	Primary storage type	Stage
Terrell Natural Gas Processing Plant (formerly Val Verde Natural Gas Plants)	United States	1972	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.4 - 0.5	Pipeline	Enhanced oil recovery	Operate
Enid Fertilizer CO_2-EOR Project	United States	1982	Fertilizer Production	Industrial Separation	0.7	Pipeline	Enhanced oil recovery	Operate
Shute Creek Gas Processing Facility	United States	1986	Natural Gas Processing	Pre-combustion capture (natural gas processing)	7	Pipeline	Enhanced oil recovery	Operate
Sleipner CO_2 Storage Project	Norway	1996	Natural Gas Processing	Pre-combustion capture (natural gas processing)	1	No transport required (direct injection)	Dedicated Geological Storage	Operate
Great Plains Synfuels Plant and Weyburn-Midale Project	Canada	2000	Synthetic Natural Gas	Pre-combustion capture (gasification)	3	Pipeline	Enhanced oil recovery	Operate
Core Energy/South Chester Gas Processing Plant	United States	2003	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.4	Pipeline	Enhanced oil recovery	Operate
Snøhvit CO_2 Storage Project	Norway	2008	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.7	Pipeline	Dedicated Geological Storage	Operate
Chaparral/Conestoga Energy Partners' Arkalon Bioethanol Plant	United States	2009	Ethanol Production	Dehydration and compression from fermentation.	0.17	Pipeline	Enhanced Oil Recovery	Operate
Century Plant	United States	2010	Natural Gas Processing	Pre-combustion capture (natural gas processing)	8.4	Pipeline	Enhanced oil recovery	Operate

Conestoga Energy Partners/PetroSantander Bonanza Bioethanol Plant in Kansas	United States	2012	Ethanol Production	Dehydration and compression from fermentation.	0.1	Pipeline	Enhanced Oil Recovery	Operate
Air Products Steam Methane Reformer EOR Project	United States	2013	Hydrogen Production	Industrial Separation	1	Pipeline	Enhanced oil recovery	Operate
Coffeyville Gasification Plant	United States	2013	Fertilizer Production	Industrial Separation	1	Pipeline	Enhanced oil recovery	Operate
Lost Cabin Gas Plant	United States	2013	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.9	Pipeline	Enhanced oil recovery	Operate
Petrobras Santos Basin Pre-Salt Oil Field CCS Project	Brazil	2013	Natural Gas Processing	Pre-combustion capture (natural gas processing)	1	No transport required (direct injection)	Enhanced oil recovery	Operate
Boundary Dam Carbon Capture and Storage Project	Canada	2014	Power Generation	Post-combustion capture	1	Pipeline	Enhanced oil recovery	Operate
Quest	Canada	2015	Hydrogen Production	Industrial Separation	1	Pipeline	Dedicated Geological Storage	Operate
Uthmaniyah CO_2-EOR Demonstration Project	Saudi Arabia	2015	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.8	Pipeline	Enhanced oil recovery	Operate
Abu Dhabi CCS Project (Phase 1 being Emirates Steel Industries (ESI) CCS Project)	United Arab Emirates	2016	Iron and Steel Production	Industrial Separation	0.8	Pipeline	Enhanced oil recovery	Operate
Illinois Industrial Carbon Capture and Storage Project	United States	2017	Chemical Production	Industrial Separation	1	Pipeline	Dedicated Geological Storage	Operate
Petra Nova Carbon Capture Project	United States	2017	Power Generation	Post-combustion capture	1.4	Pipeline	Enhanced oil recovery	Operate

Gorgon Carbon Dioxide Injection Project	Australia	2017	Natural Gas Processing	Pre-combustion capture (natural gas processing)	3.4 - 4.0	Pipeline	Dedicated Geological Storage	Execute
Kemper County Energy Facility	**United States**	**2017**	**Power Generation**	**Pre-combustion capture (gasification)**	**3**	**Pipeline**	**Enhanced oil recovery**	**Execute**
Alberta Carbon Trunk Line ("ACTL") with Agrium CO_2 Stream	Canada	2018	Fertilizer Production	Industrial Separation	0.3 - 0.6	Pipeline	Enhanced oil recovery	Execute
Alberta Carbon Trunk Line ("ACTL") with North West Sturgeon Refinery CO_2 Stream	Canada	2018	Oil Refining	Industrial Separation	1.2 - 1.4	Pipeline	Enhanced oil recovery	Execute
Yanchang Integrated Carbon Capture and Storage Demonstration Project	China	2018	Chemical Production	Pre-combustion capture (gasification)	0.4	Combination	Enhanced oil recovery	Execute
Tomakomai Carbon Capture and Storage Demonstration Project	Japan	2017	Hydrogen Production (Oil Refining)	Industrial Separation	0.1	No transport required direct injection	Dedicated geological storage	Operate
Osaki CoolGen Project	Japan	2019	Power Generation	Pre Combustion Capture (Gasification)	1	No transport involved	Storage not involved	Execute

Note: Three U.S. projects, Core Energy/South Chester, Chaparral/Conestoga Energy Partners, and Conestoga Energy Partners/Petro Santander, were identified by Great Plains Institute and added at their suggestion.