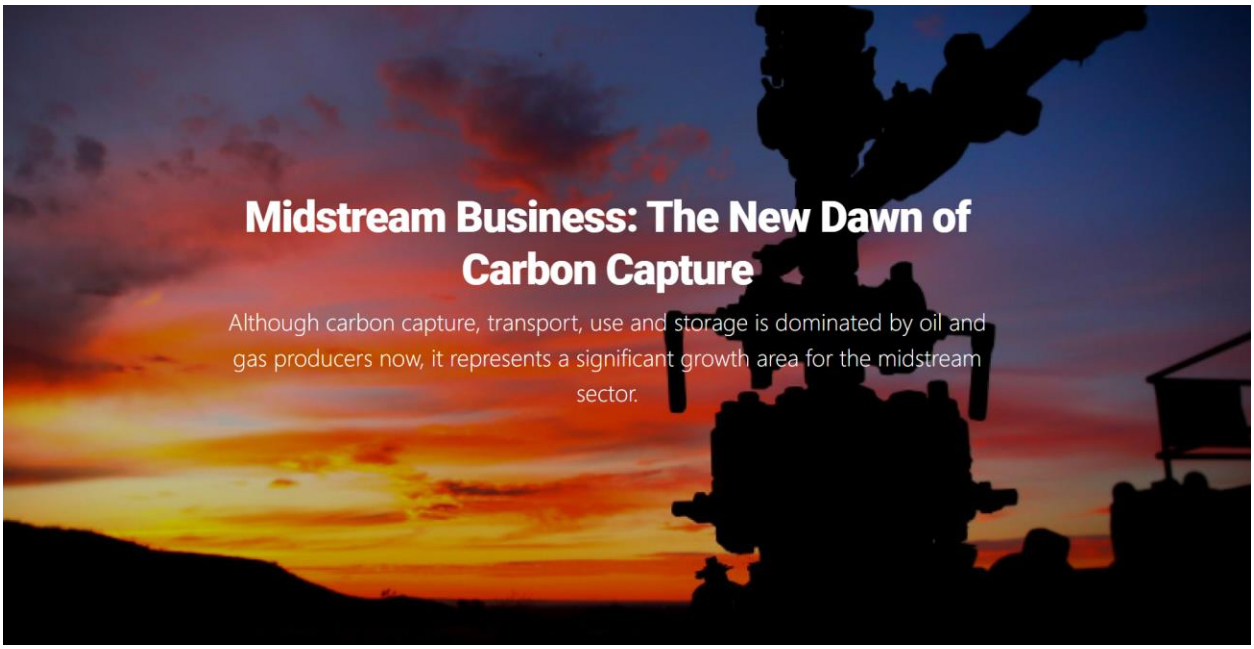

Oil and Gas Investor

Midstream Business: The New Dawn of Carbon Capture

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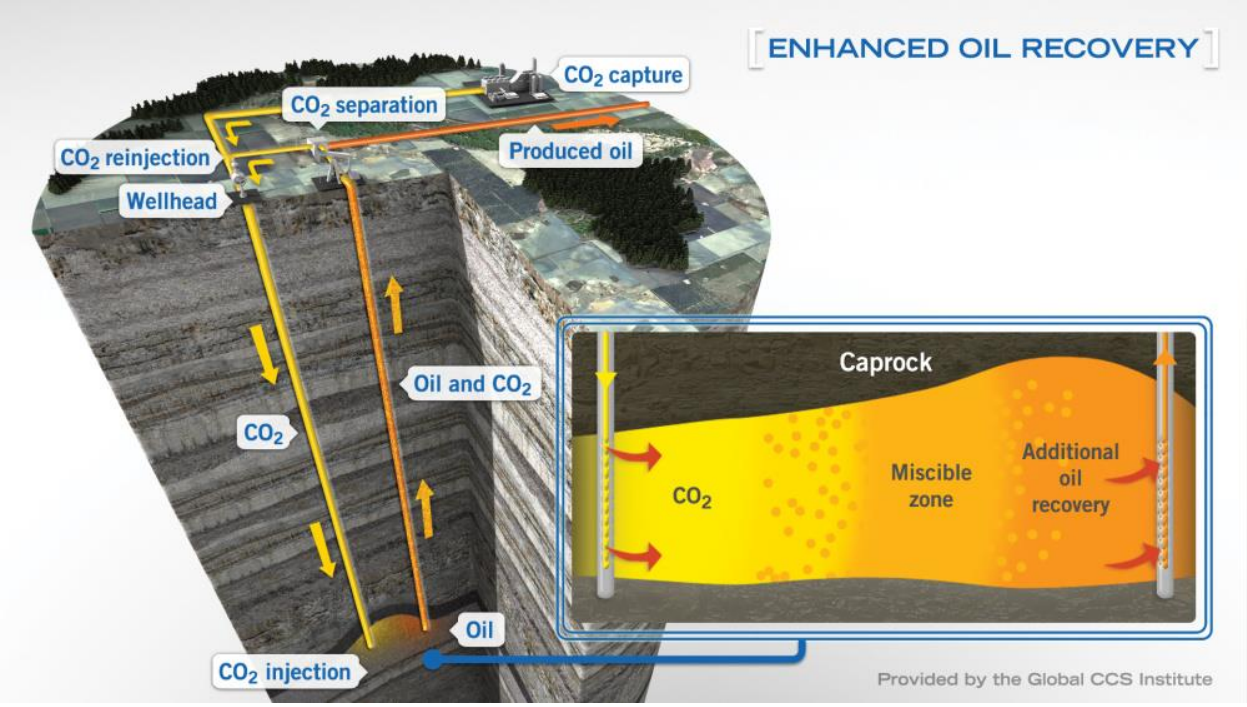
With ever-sharpening investors, shareholders and government focus on climate issues, oil and gas companies around the world are increasingly on the defensive to justify their businesses and adjust their operations to reduce carbon footprint and cut greenhouse gases. Some argue that instead of resisting this macroeconomic shift, oil and gas companies should modify their business model to capture the entire value chain by selling carbon fuel and capturing/storing waste carbon, merging “Big Oil” with “big sink.”

There is an array of green initiatives on the menu, including solar, wind, geothermal, battery and hydrogen. One area of decarbonization technologies, carbon capture, utilization and storage (CCS, or CCUS), is particularly suited for oil and gas operators due to their vast expertise in managing large and complex infrastructure, industrial gas treating, pipelines and reservoir management. It is an understated component critical to achieving net-zero emission goals. With governments beginning to price carbon and offer incentives or disincentives ranging from emissions credits, tradable certificates, carbon taxes, grants and penalties to encourage CCS development, a viable revenue model is taking shape, and a large addressable market is emerging.

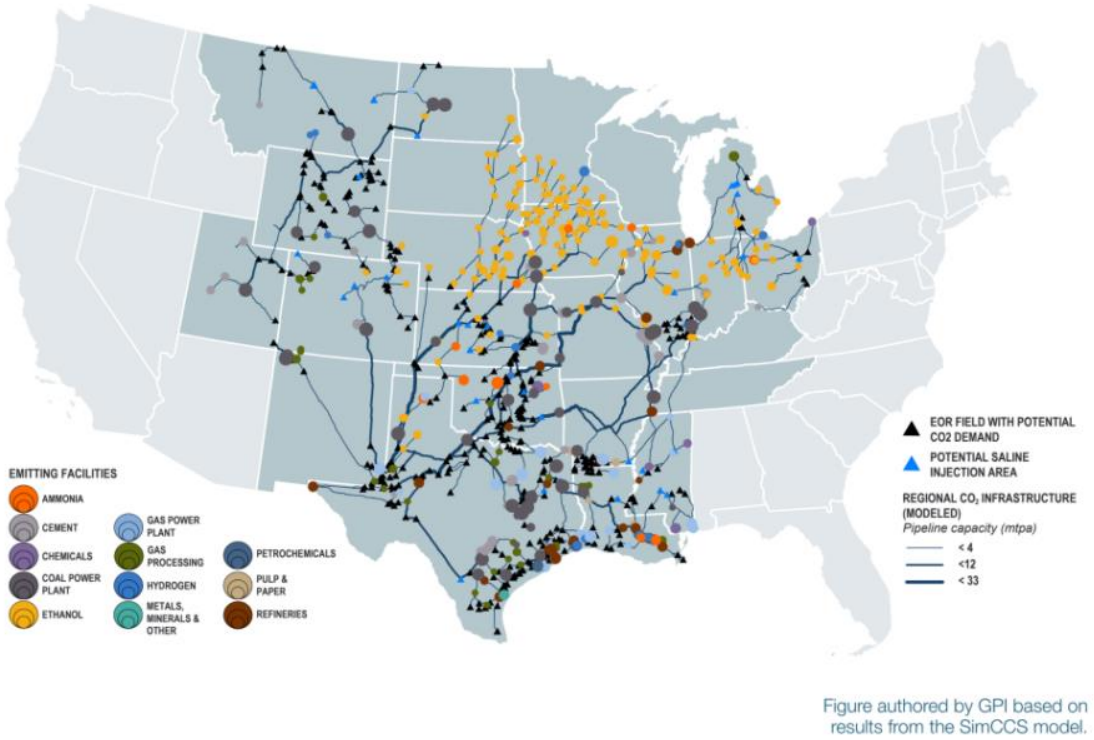
Midstream attraction

Historically, oil and gas companies have used CO_2 for EOR. Decades of data have shown that high-pressure CO_2 that acts like a lubricant can coax out as much oil as primary production methods. Occidental Petroleum Corp., Royal Dutch Shell Plc, Exxon Mobil Corp., Kinder Morgan CO_2 and Denbury Inc. are active in this space. It all started by drilling for naturally occurring CO_2, but the trend is now shifting toward anthropogenic (manmade) CO_2 captured from industrial sources. Oxy Low Carbon Ventures LLC, Occidental Petroleum's venture capital arm, has even partnered with a Canadian firm to deploy direct air capture from the atmosphere. Exxon Mobil, under recent shareholder pressure, has committed $3 billion for low emission energy solutions and CCS through 2025.

CCUS used to be dominated by producers, but in recent years, it is attracting midstream companies with tariffs in mind. Wolf Midstream Inc. operates the Alberta Carbon Trunk Link, transporting captured CO_2 from refineries and fertilizer plants. Valero Energy Corp. and BlackRock Global Energy & Power Infrastructure Fund III announced plans in March to develop industrial scale CO_2 pipeline systems to match sources and sinks in the Midwest.



An overview of a CO_2 EOR operation.



Map of optimized transport network for economy-wide CO_2 capture and storage-emitting facilities.

In the U.S., the 2018 bipartisan passing of 45Q, a reformed federal carbon oxide sequestration tax credit, has brought about much interest among project developers in oil and gas and industrial sectors. It places values on carbon oxide at $50/ton for geologic storage or $35/ton for EOR/utilization, according to a progressive schedule indexed to inflation, provided that the project commences by Jan. 1, 2024.

The ability of project developers to transfer the credit allows for tax equity investors to participate and thus increases the appeal of CCS. In addition, this credit can be combined with other state and local incentives, such as the $200/ton Low Carbon Fuel Standard in California, where applicable. The minimum storage thresholds are fairly low to qualify. However, the economic viability of projects is highly dependent on the sources as the concentration of captured CO_2 can play an important role.

According to recent data from the Global CCS Institute, an advocacy group, the capture cost from ethanol, chemical and natural gas processing plants ranges in the teens, coal power plants and refineries can range in the $40 to $60/ ton and steel and cement plants can fall in the $60s to $70s/ton range. With the incremental oil revenue from EOR at a lift ratio of 0.5:1.5 ton CO_2/bbl of oil, many projects appear feasible with the tax credit.

Methods of CO_2 capture

Captured CO_2 can be used or sequestered in a variety of ways, such as fuel production and injection into concrete. Most take significant energy input and thus emit more CO_2 than is sequestered. Currently, the most economic CCUS subset is EOR, which requires CO_2 capture equipment at the emission source, typically process/flue gas from a gas processing plant, chemical plant, power plant or other industrial facilities.

The methods of CO_2 capture are primarily solvents (physical, chemical) or membranes. The CO_2 concentration in the gas stream varies across industrial sectors, and it is the key factor in optimizing capture efficiency. In most cases, there are even several process gas streams at the same facility, but only some are economical to recover.

The lowest cost capture option is often liquid solvent/regeneration that is tried-and-true in the gas processing industry, e.g. amine. Other emerging technologies are being developed but will need to show commercial viability. Captured gas is typically at atmospheric pressure and is compressed into a supercritical phase for transportation.

Safe, long-term storage options are primarily oil fields that utilize the CO_2 for EOR while sequestering the gas or deep saline formations that have the right geologic characteristics. Many suitable reservoirs exist along the Gulf Coast and in the Permian Basin, but the Gulf Coast has the added advantage of proximity to large clusters of emission sources.

The Department of Energy, through the sponsorship of the Midwest Regional Carbon Initiative, has studies throughout the Midwest that cover more than one-third of domestic CO_2 point sources for suitable storage reservoirs. Monitoring, measurement and verification requirements in the regulatory framework in different jurisdictions are somewhat inconsistent, but they usually entail insurance, leakage penalty, liability transfer to the state after a defined period of time and the establishment of financial security/trust. State laws are evolving on pore space rights and liabilities, but the concepts are not foreign to fossil fuel producing jurisdictions.

Source: Great Plains Institute; University of Wyoming

CO_2 Capture Costs Across Sectors

Industry	Average Estimated Cost $/ton	Range of Cost Estimates $/ton
Gas Processing	$14	$11-$16
Ethanol	$17	$12-$30
Ammonia	$17	$15-$21
Chemicals	$30	$19-$40
Hydrogen	$44	$36-$57
Refineries	$56	$43-$68
Coal Power Plant	$56	$46-$60
Cement	$56	$40-$75
Gas Power Plant	$57	$53-$63
Steel	$59	$55-$65
Petrochemicals	$59	$57-$60

"CCUS used to be dominated by producers, but in recent years, it is attracting midstream companies with tariffs in mind."

Transportation of CO_2 is generally not technically complex but plays a significant part in the cost of deployment, especially when the sources and sinks are far apart. The common assumptions for tariffs are about $10/ton and EOR purchase at $20/ton for base case analysis.

As with typical midstream infrastructure, aggregation of volume can bring down unit cost meaningfully for regional transportation and spur project development. To that end, the Great Plains Institute performed a study with Los Alamos Lab to produce the conceptual corridors. Technically, CO_2 pipelines need to be designed for mitigation of ductile fracture propagation and carbonic acid corrosion, but it is readily achievable. Maintaining supercritical conditions for high density, i.e. transport efficiency, also requires the system to be designed for higher operating pressure.

Another unique aspect of CO_2 pipelines is the asphyxiation risk in populated areas in case of an accidental release. Air dispersion modeling in the route selection process is helpful in overall risk assessment.

This chart shows a 45Q tax credit schedule and example calculations.

1 Mtpa 45Q Tax Credit—12 Years				
	EOR/Utilization		**Disposal**	
Year	**$/ton**	**$MM**	**$/ton**	**$MM**
2021	$24.0	$24	$36.0	$36
2022	$26.0	$26	$39.0	$39
2023	$28.0	$28	$42.0	$42
2024	$31.0	$31	$45.0	$45
2025	$33.0	$33	$47.0	$47
2026	$35.0	$35	$50.0	$50
2027	$35.5	$36	$50.8	$51
2028	$36.1	$36	$51.5	$52
2029	$36.6	$37	$52.3	$52
2030	$37.1	$37	$53.1	$53
2031	$37.7	$37	$53.9	$54
2032	$38.3	$38	$54.7	$55
$398			$575	

Capitalizing on CO_2

As a sign of the times, leveraging our experience implementing CCUS in the U.S., we are currently assisting a development bank and China's Ministry of Ecology and Environment to develop a CCUS pilot project that aims to demonstrate the technical and economic viability of retrofitting a coal-to-chemical plant to capture, transport and sequester ~0.4 to 1 million tonnes per annum of high-concentration CO_2 for EOR purposes. Given that China has a vast collection of coalfired power plants and industrial facilities as well as newly aggressive decarbonization targets by mid-century, we expect similar projects to proliferate in the decades to come.

Since industrial facilities are not familiar with oil and gas pipelines and reservoir management, it is generally difficult for them to assemble the components in a complex CCUS value chain. Producers and midstream companies are in an excellent position to capitalize their knowledge and experience to bring solutions to the emitters, take advantage of the tax credits and potentially the global carbon offset market, while expanding their business model for a new commodity. Climate change, ESG investment

theme, social pressure and government initiatives will provide impetus for global CCS project development.

We are excited about this multidecade trend and are well-positioned to help investors and project developers navigate the policy, economic and technical landscape of CCUS.

Jeff Lee is the principal consultant for Kronos Management, a boutique consulting firm that caters to the midstream sector. Seasoned engineers and commercial specialists work with oil and gas operators, banks, private equity companies and law firms to deliver transaction advisory, expert witness and capital project development/management services. Lee can be contacted at LeeJeff@engineer.com.