CCS
inFocus
Carbon Capture & Storage

CO_2 Transportation — Is it Safe and Reliable?

SAFELY AND RELIABLY TRANSPORTING CARBON DIOXIDE (CO_2) FROM WHERE IT IS CAPTURED TO A STORAGE SITE IS AN IMPORTANT LINK IN THE CARBON CAPTURE AND STORAGE (CCS) PROCESS. CO_2 TRANSPORT IS ALREADY A REALITY, OCCURRING ON A DAILY BASIS FOR ENHANCED OIL RECOVERY (EOR), INDUSTRIAL, FOOD AND BEVERAGE, AND OTHER USES. BUT TO ACCOMPLISH CCS ON THE SCALE NEEDED TO REDUCE ATMOSPHERIC GREENHOUSE GAS (GHG) BUILDUP, CO_2 TRANSPORT WILL HAVE TO BE GREATLY EXPANDED BEYOND WHAT CURRENTLY EXISTS.

OVERVIEW

Once CO_2 is separated and captured as part of CCS, in most cases it must be transported to a storage area, usually a geologic reservoir. As part of this process, CO_2 is compressed to a dense state — about 150 times atmospheric pressure — to make both transportation and storage more efficient. This is called a supercritical fluid, where density resembles a liquid but with qualities that allow it to move and fill a space like gas.

This supercritical CO_2 can be transported by pipeline, truck, rail, or ship, with pipelines the most common method for transporting large quantities over long distances, such as CCS usually requires. Many experts consider CO_2 pipeline technology to be mature, stemming from its use since the 1970s for enhanced oil recovery and in other industries. Tanker and ship CO_2 transportation is very limited, and mainly found in the food and beverage industries. About 100,000 short tons (91,000 tonnes) of CO_2 are transported annually for these industries — far less than the amounts expected to be associated with a commercial-scale power plant.[1]

Pipeline construction or conversion of existing natural gas pipelines to carbon dioxide transport is under consideration globally. However, at present, nearly all existing major CO_2 pipelines are located in the United States and Canada. There are 47 high-pressure pipelines of 10 miles in length or greater in North America (see table). These pipelines total some 6,600 kilometers (4,100 miles) in length and transport 3 billion cubic feet of CO_2 daily, or 99 million tonnes (90 million short tons) annually (see "Interstate Oil and Gas Compact Commission: A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide," December 2010, pages 14-21).

Achieving ambitious global CCS deployment rates over the next decade will require approximately $15 billion to $20 billion per year in additional investment to finance transport infrastructure and storage sites through 2020.

International Energy Agency, Technology Roadmap: Carbon Capture and Storage, 24.

Did You Know?

[1] World Resources Institute, "Guidelines for Carbon Dioxide Capture, Transport, and Storage," October 2008, 42–43.

The advantage of pipeline CO_2 transportation is that it can deliver a constant and steady supply, without the need for intermediate storage along a distribution route. Additionally, existing CO_2 pipelines have operated safely,[3] and have not resulted in any environmental or health and safety issues for the public. However, a greatly expanded worldwide pipeline infrastructure costing billions of dollars will need to be built within a relatively short timeframe in response to modeled policies designed to stabilize atmospheric CO_2 and avert possibly catastrophic climate change.

Major North American CO_2 Pipelines

Pipeline	Owner/Operator	Length (mi)	Length (km)	Diameter (in)	Estimated Max Flow Capacity (MMcfpd)	Estimated Max Flow Capacity (million tons/yr)	Location
Adair	Apache	15	24	4	47	1.0	TX
Anton Irish	Oxy	40	64	8	77	1.6	TX
Beaver Creek	Devon	85	137				WY
Borger, TX to Camrick, OK	Chaparral Energy	86	138	4	47	1.0	TX,OK
Bravo	Oxy Permian	218	351	20	331	7.0	NM, TX
Centerline	Kinder Morgan	113	182	16	204	4.3	TX
Central Basin	Kinder Morgan	143	230	16	204	4.3	TX
Chaparral	Chapparral Energy	23	37	6	60	1.3	OK
Choctaw (aka NEJD)	Denbury Onshore, LLC	183	294	20	331	7.0	MS, LA
Comanche Creek (currently inactive)	PetroSource	120	193	6	60	1.3	TX
Cordona Lake	XTO	7	11	6	60	1.3	TX
Cortez	Kinder Morgan	502	808	30	1117	23.6	TX
Delta	Denbury Onshore, LLC	108	174	24	538	11.4	MS, LA
Dollarhide	Chevron	23	37	8	77	1.6	TX
El Mar	Kinder Morgan	35	56	6	60	1.3	TX
Enid-Purdy (Central Oklahoma)	Merit	117	188	8	77	1.6	OK
Este I to Welch, TX	ExxonMobil, et al	40	64	14	160	3.4	TX
Este II to Salt Creek Field	ExxonMobil	45	72	12	125	2.6	TX
Ford	Kinder Morgan	12	19	4	47	1.0	TX
Free State	Denbury Onshore, LLC	86	138	20	331	7.0	MS
Green Line I	Denbury Green Pipeline, LLC	274	441	24	850	18.0	LA
Joffre Viking	Penn West Petroleum, Ltd	8	13	6	60	1.3	Alberta
Llaro	Trinity CO_2	53	85	12-8	77	1.6	NM
Lost Soldier/Werrz	Merit	29	47				WY
Mabee Lateral	Chevron	18	29	10	98	2.1	TX
McElmo Creek	Kinder Morgan	40	64	8	77	1.6	CO, UT
Means	ExxonMobil	35	56	12	125	2.6	TX
Monell	Anadarko			8	77	1.6	WY
North Ward Estes	Whitting	26	42	12	125	2.6	TX
North Cowden	Oxy Permian	8	13	8	77	1.6	TX
Pecos County	Kinder Morgan	26	42	8	77	1.6	TX
Powder River Basin CO_2 PL	Anadarko	125	201	16	204	4.3	WY
Raven Ridge	Chevron	160	257	16	204	4.3	WY, CO
Rosebud	Hess						NM

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Major North American CO_2 Pipelines (continued)

Pipeline	Owner/Operator	Length (mi)	Length (km)	Diameter (in)	Estimated Max Flow Capacity (MMcfpd)	Estimated Max Flow Capacity (million tons/yr)	Location
Sheep Mountain	Oxy Permian	408	656	24	538	11.4	TX
Shute Creek	ExxonMobil	30	48	30	1117	23.6	WY
Slaughter	Oxy Permian	35	56	12	125	2.6	TX
Sonat (reconditioned natural gas)	Denbury Onshore, LLC	50	80	18	150	3.2	MS
TransPetco	TransPetco	110	177	8	77	1.6	TX, OK
W. Texas	Trinity CO_2	60	97	12-8	77	1.6	TX, NM
Wellman	PetroSource	26	42	6	60	1.3	TX
White Frost	Core Energy, LLC	11	18	6	60	1.3	MI
Wyoming CO_2	ExxonMobil	112	180	20-16	204	4.3	WY
Canyon Reef Carriers	Kinder Morgan	139	224	16	204	4.3	TX
Dakota Gasification (Souris Valley)	Dakota Gasification	204	328	14-13	125	2.6	ND, Sask
Pikes Peak	SandRidge	40	64	8	77	1.6	TX
Val Verde	SandRidge	83	134	10	98	2.1	TX
	Totals:	4,111	6,611				

*Tabulation does not include many shorter high pressure truck lines to individual fields

Adapted from "A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide," Interstate Oil and Gas Compact Commission, September 10, 2010, pages 20-21.

Why are pipelines considered by many experts as the best choice for CCS-related CO_2 transport?

CO_2 pipelines are an existing, safe, and efficient technology, with significant long-term operating experience in the EOR industry in the United States. While the nature and extent of a more extensive CO_2 pipeline network in the U.S. and elsewhere will depend on many factors, it is expected that early projects are likely to rely on a mix of options. These options may include not only the use of existing infrastructure, but also the development of dedicated pipelines sized and located for individual projects. Tanker ship transportation of large quantities of CO_2 may be possible for some long distance or overseas shipments; however, many human-generated carbon dioxide sources are located far from navigable waterways, meaning pipelines between sources and port terminals would still have to be built. While rail cars and trucks can also transport CO_2, these modes would be logistically impractical for large-scale CCS operations.[2]

How do we know that CO_2 pipelines will likely be safe and reliable?

Experience from decades of pipeline operations suggests that designing and operating CO_2 pipelines do not pose any new challenges. In the United States, pipeline companies have successfully operated a substantial CO_2 pipeline infrastructure for nearly 40 years, mainly for use in EOR. The oldest of these is the 225 kilometer (140-mile) Canyon Reef Carriers pipeline, which has operated since 1972 in regional Texas oil fields. The longest, the 502-mile (808 kilometers) Cortez pipeline, has been delivering about 20 million tonnes of CO_2 annually to Denver City, Texas, since 1984.[3] To date, U.S. CO_2 pipelines have experienced few incidents — 12 leaks were reported from

[2] Ibid, 4.

[3] World Resources Institute, "Guidelines for Carbon Dioxide Capture, Transport, and Storage," October 2008, 42.

1986 through 2006, none resulting in injuries to people, making them among the safest pipeline systems used industrially.[4] Even as the number of CO_2 pipeline networks expands significantly to support CCS, existing operational experience combined with adequate risk assessment and the use of best practices is expected to result in generally safe design, construction, and operation.[5]

How large will the CO_2 pipeline infrastructure need to be for CCS?

The nature and extent of pipeline networks that would be necessary to transport the large quantities of CO_2 resulting from CCS will depend on many factors, including the proximity of storage sites to the capture facilities; the costs to acquire pipeline rights-of-way and associated permits; the cost to construct the pipelines; and additional costs to operate the pipelines and comply with operational and maintenance regulations. However, even in the United States where there is an existing CO_2 pipeline network that aligns relatively well with potential geologic storage areas, additional pipelines will still need to be built. A study by a Pacific Northwest National Laboratory (PNNL) team estimates the United States would need up to 23,000 miles (37,000 kilometers) of additional dedicated CO_2 pipeline between 2010 and 2050 under the 450 parts-per-million (ppm) emissions target suggested by the Intergovernmental Panel on Climate Change; this figure would drop to 11,000 miles (17,700 kilometers) under a 550 ppm scenario.[6] In the European Union (EU), where there currently are no dedicated CO_2 pipelines, one recent estimate calls for the need to transport 400 million tonnes (440 million short tons) per year by 2030 to meet EU interim targets for carbon dioxide removal.[7] To put this amount in perspective, the number of 20-ton CO_2 trucks needed to hold 400 million tonnes would circle the earth 15 times, according to one study.[8] A 2010 study by the International Energy Agency, "Global CCS Pipeline Infrastructures," estimates the cumulative transport of 1.44 gigatonnes (GT) of carbon dioxide annually from 358 sources to storage will be needed worldwide by 2030, at a cost of $60 billion. In short, any of these and other scenarios will require a large and expensive global CO_2 pipeline infrastructure.

[4] Congressional Research Service, "Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues," 19 April 2007, 16.

[5] J. Barrie, K. Brown, P.R. Hatcher, H.U. Schellhase, Carbon Dioxide Pipelines: A Preliminary Review of Design and Risks, 2004, 6.

[6] J.J. Dooley, R.T. Dahowski, C.L. Davidson, "Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO_2 Pipeline Networks," February 2009, 4–5.

[7] McKinsey & Company, "Carbon Capture and Storage: Assessing the Economics," 22 September 2008, 12.

[8] David L. Coleman, "Transport Infrastructure Rationale for Carbon Dioxide Capture and Storage in the European Union to 2050", February 2009, 1676.

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What are the major challenges facing the creation of a CO_2 transportation infrastructure?

The cost of building new infrastructure could be steep, especially for countries or areas lacking adequate geologic storage sites. Consequently, governments may need to provide financial incentives that reduce costs for pipeline developers and operators. Aside from costs, there are also additional challenges, including pipeline network requirements, economic regulation, siting, regulatory classification of CO_2 itself, safety and health issues, and liability. Pipeline transport of CO_2 through populated areas will require that special attention be paid to design factors, overpressure protection, and leak detection. However, there is no indication that potential problems for CO_2 pipelines are any more challenging than those faced by hydrocarbon pipelines in similar areas (such as natural gas and petroleum), or that they cannot be resolved. In the final analysis, a balance must be struck between the need to protect people and the environment, and the impending requirement to rapidly deploy CCS to help mitigate the effects of climate change. Progress will be accelerated by countries working together to develop common regulatory and infrastructure approaches.

Sources for Additional Information

- United Nations Intergovernmental Panel on Climate Change, http://www.ipcc.ch/
- International Energy Agency, http://www.iea.org/
- World Coal Institute, http://www.worldcoal.org/
- The World Bank, http://www.worldbank.org/
- European Zero Emissions Platform, http://www.zeroemissionsplatform.eu/

Other inFocus Factsheets:

- Is Geologic CO_2 Storage Safe?
- Underground CO_2 Storage: A Reality?
- Why Carbon Capture and Storage?
- CO_2 Capture: Does it Work?
- 10 Facts About CCS

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