Order Code RL33971

CRS Report for Congress

Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues

April 19, 2007

Paul W. Parfomak
Specialist in Energy and Infrastructure
Resources, Science, and Industry Division

Peter Folger
Specialist in Energy Policy
Resources, Science, and Industry Division

Prepared for Members and Committees of Congress

Congressional Research Service

Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues

Summary

Congress is examining potential approaches to reducing manmade contributions to global warming from U.S. sources. One approach is carbon capture and sequestration (CCS) — capturing CO_2 at its source (e.g., a power plant) and storing it indefinitely (e.g., underground) to avoid its release to the atmosphere. A common requirement among the various techniques for CCS is a dedicated pipeline network for transporting CO_2 from capture sites to storage sites.

In the 110th Congress, a number of bills include aspects of CCS, but do not discuss in any detail proposals for pipeline infrastructure to transport captured CO_2 from sources to storage sites. Many bills that mention some form of CCS focus on incentives for enhancing CO_2 capture and/or on characterizing geologic reservoirs. Some bills, such as S. 962 and H.R. 931, include sections on promoting the development of technologies needed to separate and capture CO_2 at its source, often as part of research and development provisions. Other bills, such as H.R. 1267 and S. 731, call for enhancing or expanding the national capability to assess potential U.S. capacity for safe and long-term CO_2 storage in geologic reservoirs.

That CCS and related legislation generally focuses on the capture and storage of CO_2, and not on its transportation, reflects the current perception that transporting CO_2 via pipelines does not present a significant barrier to implementing large-scale CCS. Notwithstanding this perception, and even though regional CO_2 pipeline networks already operate in the United States for enhanced oil recovery (EOR), developing a more expansive national CO_2 pipeline network for CCS could pose numerous new regulatory and economic challenges. There are important unanswered questions about pipeline network requirements, economic regulation, utility cost recovery, regulatory classification of CO_2 itself, and pipeline safety. Furthermore, because CO_2 pipelines for EOR are already in use today, policy decisions affecting CO_2 pipelines take on an urgency that is, perhaps, unrecognized by many. Federal classification of CO_2 as both a commodity (by the Bureau of Land Management) and as a pollutant (by the Environmental Protection Agency) could potentially create an immediate conflict which may need to be addressed not only for the sake of future CCS implementation, but also to ensure consistency of future CCS with CO_2 pipeline operations today.

In addition to these issues, Congress may examine how CO_2 pipelines fit into the nation's overall strategies for energy supply and environmental protection. If policy makers encourage continued consumption of fossil fuels under CCS, then the need to foster the other energy options may be diminished — and vice versa. Thus decisions about CO_2 pipeline infrastructure could have consequences for a broader array of energy and environmental policies.

Contents

List of Figures

Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues

Introduction

Congress has long been concerned about the impact of global climate change that may be caused by manmade emissions of carbon dioxide (CO_2) and other greenhouse gases.[1] Congress is also debating policies related to global warming and is examining a range of potential initiatives to reduce manmade contributions to global warming from U.S. sources.[2] One approach to mitigating manmade greenhouse gas emissions is direct sequestration: capturing CO_2 at its source, transporting it via pipelines, and storing it indefinitely to avoid its release to the atmosphere.[3] This paper explores one component of direct sequestration — transporting CO_2 in pipelines.

Carbon capture and storage (CCS) is of great interest because potentially large amounts of CO_2 emitted from the industrial burning of fossil fuels in the United States could be suitable for sequestration. Carbon capture technologies can potentially remove 80%-95% of CO_2 emitted from an electric power plant or other industrial source. Power plants are the most likely initial candidates for CCS because they are predominantly large, single-point sources, and they contribute approximately one-third of U.S. CO_2 emissions from fossil fuels.

There are many technological approaches to CCS. However, one common requirement for nearly all large-scale CCS schemes is a system for transporting CO_2 from capture sites (e.g., power plants) to storage sites (e.g., underground reservoirs). Transporting captured CO_2 in relatively limited quantities is possible by truck, rail, and ship, but moving the enormous quantities of CO_2 implied by a widespread implementation of CCS technologies would likely require a dedicated interstate pipeline network.

---

[1] This report does not explore the underlying science of climate change, nor the question of whether action is justified. See CRS Report RL33849, *Climate Change: Science and Policy Implications*, by Jane A. Leggett.

[2] For more information on congressional activities related to global warming, see CRS Report RL33776, *Clean Air Issues in the 110th Congress: Climate Change, Air Quality Standards, and Oversight*, by James E. McCarthy, and CRS Report RL33846, *Climate Change: Greenhouse Gas Reduction Bills in the 110th Congress*, by Larry Parker and Brent D. Yacobucci.

[3] This report does not address indirect sequestration, wherein CO_2 is stored in soils, oceans, or plants through natural processes. For information on the latter, see CRS Report RL31432, *Carbon Sequestration in Forests*, by Ross W. Gorte.

In the 110th Congress, a number of bills include aspects of carbon capture and storage (CCS), but do not discuss in any detail legislative proposals for pipeline infrastructure to transport captured CO_2 from sources to storage sites. Many bills that mention some form of CCS tend to focus on incentives for CO_2 capture and/or on characterizing geologic storage sites. Some bills, such as S. 962 and H.R. 931, include sections on promoting the development of technologies needed to separate and capture CO_2 at its source, often as part of research and development provisions. Other bills, such as H.R. 1267 and S. 731, call for enhancing or expanding the national capability to assess potential U.S. capacity for safe and long-term CO_2 storage in geologic reservoirs.

The legislative focus on the capture and storage components of direct carbon sequestration reflects the current perception that transporting CO_2 via pipelines does not present a significant barrier to implementing large-scale CCS. Even though regional CO_2 pipeline networks already operate in the United States for enhanced oil recovery (EOR), developing a more expansive national CO_2 pipeline network for CCS could pose numerous new regulatory and economic challenges. As one analyst has remarked,

> Each of the individual technologies involved in the transport portion of the CCS process is mature, but integrating and deploying them on a massive scale will be a complex task. "The question is, how would the necessary pipeline network be established and evolve?"[4]

A thorough consideration of potential CCS approaches necessarily involves an assessment of their overall requirements for CO_2 transportation by pipeline, including the possible federal role in establishing an interstate CO_2 pipeline network.

This report introduces key policy issues related to CO_2 pipelines which may require congressional attention. It summarizes the technological requirements for CO_2 pipeline transportation under a comprehensive CCS strategy. It characterizes these requirements relative to the existing CO_2 pipeline infrastructure in the United States used for EOR. The report summarizes policy issues related to CO_2 pipeline development, including uncertainty about pipeline network requirements, economic regulation, utility cost recovery, regulatory classification of CO_2 itself, and pipeline safety. The report concludes with perspectives on CO_2 pipelines in the context of the nation's overall energy and infrastructure requirements.

Background

Carbon sequestration policies are inextricably tied to the function and availability of the necessary technologies. Consequently, discussion of CCS policy alternatives benefits from a basic understanding of the physical processes involved, and relevant experience with existing infrastructure. This section provides a basic

---

[4] John Douglas, "Expanding Options for CO_2 Storage," *EPRI Journal*, Electric Power Research Institute (Spring 2007): 24.

overview of carbon sequestration processes overall, as well as specific U.S. experience with CO_2 pipelines.[5]

Carbon Capture and Sequestration

Carbon capture and sequestration is essentially a three-part process involving a CO_2 source facility, a long-term CO_2 storage site, and an intermediate mode of CO_2 transportation.

Capture. The first step in direct sequestration is to produce a concentrated stream of CO_2 for transport and storage. Currently, three main approaches are available to capture CO_2 from large-scale industrial facilities or power plants:

- **pre-combustion**, which separates CO_2 from fuels by combining them with air and/or steam to produce hydrogen for combustion and CO_2 for storage,
- **post-combustion**, which extracts CO_2 from flue gases following combustion of fossil fuels or biomass, and
- **oxyfuel combustion**, which uses oxygen instead of air for combustion, producing flue gases that consist mostly of CO_2 and water from which the CO_2 is separated.[6]

These approaches vary in terms of process technology and maturity, but all yield a stream of extracted CO_2 which may then be compressed to increase its density and make it easier (and cheaper) to transport. Although technologies to separate and compress CO_2 are commercially available, they have not been applied to large-scale CO_2 capture from power plants for the purpose of long-term storage.[7]

Transportation. Pipelines are the most common method for transporting large quantities of CO_2 over long distances. CO_2 pipelines are operated at ambient temperature and high pressure, with primary compressor stations located where the CO_2 is injected and booster compressors located as needed further along the pipeline.[8] In overall construction, CO_2 pipelines are similar to natural gas pipelines, requiring the same attention to design, monitoring for leaks, and protection against overpressure, especially in populated areas.[9] Many analysts consider CO_2 pipeline technology to be mature, stemming from its use since the 1970s for enhanced oil

---

[5] More detailed information is available in CRS Report RL33801, *Direct Carbon Sequestration: Capturing and Storing CO_2*, by Peter Folger.

[6] Intergovernmental Panel on Climate Change, Special Report: *Carbon Dioxide Capture and Storage, 2005* (2005): 22-23. (Hereafter referred to as IPCC 2005.)

[7] H. J. Herzog and D. Golumb, "Carbon Capture and Storage from Fossil Fuel Use," in C.J. Cleveland (ed.), *Encyclopedia of Energy* (New York, NY: Elsevier Science, Inc., 2004): 277-287.

[8] IPCC 2005: 26.

[9] IPCC 2005: 181.

recovery (EOR) and in other industries.[10] Marine transportation may also be feasible when CO_2 needs to be transported over long distances or overseas; however, many manmade CO_2 sources are located far from navigable waterways, so such as scheme would still likely require pipeline construction between CO_2 sources and port terminals. Rail cars and trucks can also transport CO_2, but these modes would be logistically impractical for large-scale CCS operations.

Sequestration in Geological Formations. In most CCS approaches, CO_2 would be transported by pipeline to a porous rock formation that holds (or previously held) fluids where the CO_2 would be injected underground. When CO_2 is injected over 800 meters deep in a typical storage formation, atmospheric pressure induces the CO_2 to become relatively dense and less likely to migrate out of the formation. Injecting CO_2 into such formations uses existing technologies developed primarily for oil and natural gas production which potentially could be adapted for long-term storage and monitoring of CO_2. Other underground injection applications in practice today, such as natural gas storage, deep injection of liquid wastes, and subsurface disposal of oil-field brines, also provide potential technologies and experience for sequestering CO_2.[11] Three main types of geological formations are being considered for carbon sequestration: (1) oil and gas reservoirs, (2) deep saline reservoirs, and (3) unmineable coal seams. The overall capacity for CO_2 storage in such formations is potentially huge if all the sedimentary basins in the world are considered.[12] The suitability of any particular site, however, depends on many factors, including proximity to CO_2 sources and other reservoir-specific qualities like porosity, permeability, and potential for leakage.

Existing U.S. CO_2 Pipelines

The oldest long-distance CO_2 pipeline in the United States is the 225 kilometer Canyon Reef Carriers Pipeline (in Texas), which began service in 1972 for EOR in regional oil fields.[13] Other large CO_2 pipelines constructed since then, mostly in the Western United States, have expanded the CO_2 pipeline network for EOR. These pipelines carry CO_2 from naturally occurring underground reservoirs, natural gas processing facilities, ammonia manufacturing plants, and a large coal gasification project to oil fields. Additional pipelines may carry CO_2 from other manmade sources to supply a range of industrial applications. Altogether, approximately 5,800 kilometers (3,600 miles) of CO_2 pipeline operate today in the United States.[14]

---

[10] CO_2 used in EOR enhances oil production by re-pressurizing geological formations and reducing oil viscosity, thereby increasing oil movement to the surface. CO_2 is used industrially as a chemical feedstock, to carbonate beverages, for refrigeration and food processing, to treat water, and for other uses.

[11] IPCC 2005: 31.

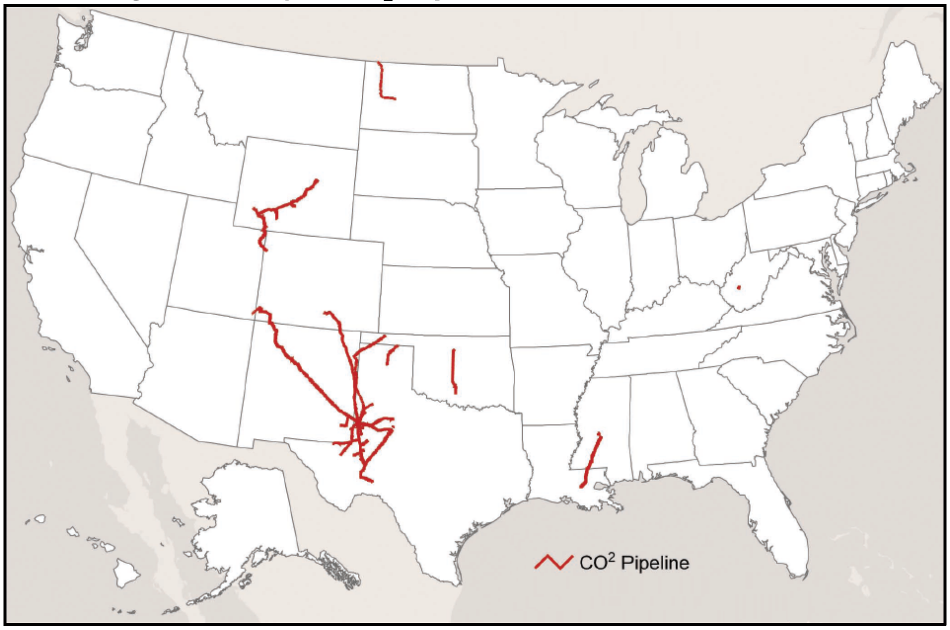
[12] Sedimentary basins are large depressions in the Earth's surface filled with sediments and fluids.

[13] Kinder Morgan CO_2Company, "Canyon Reef Carriers Pipeline (CRC)," web page (2007). [http://www.kindermorgan.com/business/co2/transport_canyon_reef.cfm]

[14] U.S. Dept. of Transportation, National Pipeline Mapping System database (June 2005).

(continued...)

Figure 1. Major CO_2 Pipelines in the United States



Source: U.S. Dept. of Transportation, National Pipeline Mapping System, For official use only. (June 2005). [https://www.npms.phmsa.dot.gov]

The locations of the major U.S. CO_2 pipelines are shown in **Figure 1**. By comparison, nearly 800,000 kilometers (500,000 miles) of natural gas and hazardous liquid transmission pipelines crisscross the United States.[15]

Key Issues for Congress

Congressional consideration of potential CCS policies is still evolving, but so far initiatives have focused more on developing capture and sequestration technologies than on transportation. Specific legislative proposals in the 110th Congress reflect the current perception that CO_2 capture probably represents the largest technological hurdle to implementing widespread CCS, and that CO_2 transportation by pipelines does not present as significant a barrier. While these perceptions may be accurate, industry and regulatory analysts have begun to identify important policy issues related specifically to CO_2 pipelines which may require congressional attention.

---

[14] (...continued)
[https://www.npms.phmsa.dot.gov]

[15] Bureau of Transportation Statistics (BTS), National Transportation Statistics 2005 (Dec. 2005), Table 1-10. In this report *oil* includes petroleum and other hazardous liquids such as gasoline, jet fuel, diesel fuel, and propane, unless otherwise noted.

CO_2 Pipeline Requirements for CCS

Although any widespread CCS scheme in the United States would likely require dedicated CO_2 pipelines, there is considerable uncertainty about the size and configuration of the pipeline network required. This uncertainty stems, in part, from uncertainty about the suitability of geological formations to sequester captured CO_2 and the proximity of suitable formations to specific sources. One recent analysis concludes that 77% of the total annual CO_2 captured from the major North American sources may be stored in reservoirs directly underlying these sources, and that an additional 18% may be stored within 100 miles of additional sources.[16] If this were the case, the need for new CO_2 pipelines would be limited to onsite transportation and a relatively small number of long-distance pipelines (only a subset of which might need to be interstate pipelines).

Other analysts suggest that captured CO_2 may need to be sequestered, at least initially, in more centralized reservoirs to reduce potential risks associated with CO_2 leaks.[17] They suggest that, given current uncertainty about the suitability of various on-site geological formations for long-term CO_2 storage, certain specific types of formations (e.g., salt caverns) may be preferred as CO_2 repositories because they have adequate capacity and are most likely to retain sequestered CO_2 indefinitely. As geologic formations are characterized in more detail and suitable repositories identified, CO_2 sources can be mapped against storage sites with increasing certainty. The current uncertainty over proximity of sources to storage sites, however, implies a wide range of possible pipeline configurations and a wide range of possible costs.

Whether CCS policies ultimately lead to centralized or decentralized storage configurations remains to be seen; however, pipeline requirements and storage configurations are closely related. A 2007 study at the Massachusetts Institute of Technology (MIT) concluded that "the majority of coal-fired power plants are situated in regions where there are high expectations of having CO_2 sequestration sites nearby."[18] In these cases, the MIT study estimated the cost of CO_2 transport and injection to be less than 20% of total CCS costs. However, the study also stated that the costs of CO_2 pipelines are highly non-linear with respect to the quantity transported, and highly variable due to "physical ... and political considerations."[19] Another 2007 study, at Duke University, concluded that "geologic sequestration is

---

[16] R.T. Dahowski, J.J. Dooley, C.L. Davidson, S. Bachu, N. Gupta, and J. Gale, "A North American CO_2 Storage Supply Curve: Key Findings and Implications for the Cost of CCS Deployment," *Proceedings of the Fourth Annual Conference on Carbon Capture and Sequestration* (Alexandria, VA: May 2-5, 2005). The study addresses CO_2 capture at 2,082 North American facilities including power plants, natural gas processing plants, refineries, cement kilns, and other industrial plants.

[17] Jennie C. Stevens and Bob Van Der Zwaan, "The Case for Carbon Capture and Storage," *Issues in Science and Technology*, vol. XXII, no. 1 (Fall 2005): 69-76. (See page 15 of this report for a discussion of safety issues.)

[18] John Deutch, Ernest J. Moniz, et al., *The Future of Coal*. (Cambridge, MA: Massachusetts Institute of Technology: 2007): 58. (Hereafter referred to as MIT 2007.)

[19] MIT 2007: 58.

not economically or technically feasible within North Carolina," but "may be viable if the captured CO_2 is piped out of North Carolina and stored elsewhere."[20] There are also significant scale economies for large, integrated CO_2 pipeline networks that link many sources together rather than single, dedicated pipelines between individual sources and storage reservoirs.[21] As Congress considers CCS policies, it may examine the relationship between CO_2 reservoir sites and pipeline requirements.

Economic Regulation

An interstate pipeline constructed exclusively for transporting CO_2 falls under the regulatory jurisdiction of the U.S. Surface Transportation Board (the Board), a decisionally independent federal agency administratively affiliated with the Department of Transportation. Under the Interstate Commerce Commission Termination Act of 1995 (P.L. 104-88) the Board regulates interstate pipelines transporting commodities other than water, oil, or natural gas (49 U.S.C. § 15301).[22] Although the Board has regulatory authority over CO_2 pipelines, its oversight is limited compared to federal regulation of natural gas and oil pipelines by the Federal Energy Regulatory Commission (FERC). This regulatory structure raises a number of questions related to economic regulation of CO_2 pipelines for CCS.

Rate Regulation. Board regulation of pipelines is intended to ensure pipelines fulfill *common carrier* obligations by charging reasonable rates; providing rates and services to all upon reasonable request; not unfairly discriminating among shippers; establishing reasonable classifications, rules, and practices; and interchanging traffic with other pipelines or transportation modes.[23] Although the Board is tasked with ensuring that pipeline rates are reasonable, the Board may not begin a rate proceeding for an existing pipeline on its own initiative. It may only do so upon a complaint filed against a pipeline operator by a third party (49 U.S.C. § 15503(b)). Pipeline operators are free to set their own rates and service practices, with no requirements to file their rates with the Board. By contrast, natural gas and oil pipeline operators must obtain rate approval from FERC *prior* to placing a new pipeline in service, and the Commission may review rates on its own initiative.

If the U.S. CO_2 pipeline network were to expand dramatically under a CCS scheme, with many more pipeline users and interconnections than exist today,

---

[20] Eric Williams, Nora Greenglass, and Rebecca Ryals, "Carbon Capture, Pipeline and Storage: A Viable Option for North Carolina Utilities?" Working paper prepared by the Nicholas Institute for Environmental Policy Solutions and The Center on Global Change, Duke University (Durham, NC: March 8, 2007): 4.

[21] MIT 2007: 58.

[22] The term *oil* includes crude petroleum as well as refined petroleum products, such as diesel fuel and gasoline. The term *gas* includes only energy-related gases such as natural gas and propane.

[23] General Accounting Office (now Government Accountability Office), *Surface Transportation: Issues Associated With Pipeline Regulation by the Surface Transportation Board*, RCED-98-99 (Washington, DC: April 21, 1998):3; and 49 U.S.C. § 155.

complex common carrier issues might arise.[24] One challenge, for example, is whether rates should be set separately for existing pipelines carrying CO_2 as a valuable commercial commodity (e.g., for EOR), versus new pipelines carrying CO_2 as industrial pollution for disposal. Furthermore, since the Board may review rates only upon receiving a complaint, it might be difficult for regulators to ensure the reasonableness of CO_2 pipeline rates until after the pipelines were already in service. If CO_2 pipeline connections become mandatory under future regulations, such arrangements might expose pipeline users to abuses of potential market power in CO_2 pipeline services, at least until rate cases could be heard. Presiding over a large number of CO_2 rate cases of varying complexity in a relatively short time frame might also be administratively overwhelming for the Board, which today has limited resources available for pipeline regulatory activities.

Although CO_2 pipelines are not explicitly excluded from FERC jurisdiction by statute, FERC ruled in 1979 that they are not subject to the Commission's jurisdiction because they do not transport *natural gas* for heating purposes.[25] There have been proposals, however, to transfer regulatory authority over CO_2 and other Board-regulated pipelines (e.g., hydrogen) to FERC to secure regulatory advantages. The benefits and costs of such a transfer could require careful consideration to determine whether it would achieve specific policy objectives for CO_2 pipelines.[26] In particular, legislation placing CO_2 under FERC's jurisdiction might imply that CO_2 transportation by pipeline be considered interstate commerce, and that captured CO_2 be classified as a commodity rather than a pollutant. Such a classification might have broader regulatory implications, as discussed below.

Siting Authority. A company seeking to construct a CO_2 pipeline must secure siting approval from the relevant regulatory authorities and must subsequently secure rights of way from landowners along the pipeline right by purchasing easements or by eminent domain. However, the Board has no regulatory authority with respect to pipeline construction, so potential builders of new CO_2 pipelines do not require, and could not obtain, the Board's approval to construct new pipelines under the Board's jurisdiction. Likewise, the Board lacks eminent domain authority for pipeline construction, and so cannot ensure that pipeline companies can secure rights of way to construct new pipelines. By contrast, companies seeking to build interstate *natural gas* pipelines must first obtain certificates of public convenience and necessity from FERC under the Natural Gas Act (15 U.S.C. §§ 717, et seq.). Such certification may

---

[24] A Beard Company 2000 annual report (10-k) filed with the U.S. Securities and Exchange Commission states that the company (with other plaintiffs) filed a lawsuit in 1996 against CO_2 pipeline owner Shell Oil Company and other defendants alleging, among other things, that the defendants "controlled and depressed the price of CO2" from a field partially owned by Beard and "reduc[ed] the delivered price of CO2 while ... simultaneously inflating the cost of transportation." [http://www.secinfo.com/dRxzp.424.htm#1fmr]

[25] *Cortez Pipeline Company,* 7 FERC ¶ 61,024 (1979).

[26] Interstate Oil and Gas Compact Commission, *Carbon Capture and Storage: A Regulatory Framework for States*. (Oklahoma City, OK: 2005): 44 (Hereafter referred to as IOGCC 2005); and G. Birgisson and W. Lavarco, "An Effective Regulatory Regime For Transportation of Hydrogen," *International Journal of Hydrogen Energy*, vol. 29 (2004): 771-780.

include safety and security provisions with respect to pipeline routing, safety standards and other factors.[27] A certificate of public convenience and necessity granted by FERC (15 U.S.C. § 717f(h)) confers eminent domain authority.

Absent federal siting authority, CO_2 pipeline siting is regulated to varying degrees by the states (as is also the case for oil pipelines and other types of energy infrastructure). The state-by-state siting approval process for CO_2 pipelines may be complex and protracted, and may face public opposition, especially in populated or environmentally sensitive areas. As the National Commission on Energy Policy (NCEP) states in its 2006 report:[28]

> Recent developments notwithstanding, most new energy projects are still regulated primarily at the state level and public opposition remains inextricably intertwined with local concerns, including environmental and ecosystem impacts as well as, in some cases, complex issues of property rights and competing land uses.... In some cases, upstream or downstream infrastructure requirements — such as the need for ... underground carbon sequestration sites ... may generate as much if not more opposition than the energy facilities they support. At the same time — and despite recent moves toward consolidated oversight by FERC or other regulatory authorities — fragmented permitting processes, nonstandard permitting requirements, and interagency redundancy often still compound siting challenges.

Securing rights of way along existing easements for other infrastructure (e.g., natural gas pipelines, electric transmission lines) may be one way to facilitate the siting of new CO_2 pipelines. However, existing easements may be ambiguous as to the right of the easement holder to install and operate CO_2 pipelines. Questions may also arise as to compensation for landowners or easement holders for use of such easements, and as to whether existing easements can be sold or leased to CO_2 pipeline companies.[29] A related issue is whether state condemnation laws, which are often used to secure sites for infrastructure deemed to be in the public interest, allow for CO_2 pipelines to be treated as public utilities or common carriers. This issue also arises on federal lands managed by the Bureau of Land Management (BLM). New CO_2 pipelines through BLM lands potentially may be sited under right of way provisions in either the Federal Land Policy and Management Act (FLPMA; 43 U.S.C. § 35) or the Mineral Leasing Act (MLA; 30 U.S.C. § 185). However, the MLA imposes a common carrier requirement while the FLPMA does not. Although the agency currently permits CO_2 pipelines for EOR under the MLA,[30] CO_2 pipeline

---

[27] 18 C.F.R. § 157.

[28] National Commission on Energy Policy, *Siting Critical Energy Infrastructure: An Overview of Needs and Challenges*. (Washington, DC: June 2006): 9. (Hereafter referred to as NCEP 2006.)

[29] Partha S. Chaudhuri, Michael Murphy, and Robert E. Burns, "Commissioner Primer: Carbon Dioxide Capture and Storage" (National Regulatory Research Institute, Ohio State Univ., Columbus, OH: Mar. 2006): 17.

[30] U.S. Dept. of the Interior, Bureau of Land Management, *Environmental Assessment for Anadarko E&P Company L.P. Monell CO_2 Pipeline Project*, EA #WY-040-03-035 (Feb.

(continued...)

companies seeking to avoid common carrier requirements under CCS schemes may litigate to secure rights of way under FLPMA.[31]

Another complicating factor in the siting of CO_2 pipelines for CCS is the types of locations of existing CO_2 sources. Although a network of long-distance CO_2 pipelines exists in the United States today for EOR, these pipelines are sited mostly in remote areas accustomed to the presence of large energy infrastructure. However, many potential sources of CO_2, such as power plants, are located in populated regions, many with a history of public resistance to the siting of energy infrastructure. If a widespread CO_2 pipeline network is required to support CCS, the ability to site pipelines to serve such facilities may become an issue requiring congressional attention. As the NCEP concluded, "In sum, it seems probable that the siting of critical infrastructure will continue to present a major challenge for policymakers."[32]

Commodity vs. Pollutant Classification

Under a comprehensive CCS policy, captured CO_2 arguably could be classified as either a commodity or as a pollutant. CO_2 used in EOR is considered to be a commodity, and is regulated as such by the states. Because captured CO_2 may be sold as a valuable commodity for EOR, and may have further economic potential for enhanced recovery of coal bed methane (ECBM), some argue that all CO_2 under a CCS scheme should be classified as a commodity.[33] However, it is unlikely that the quantities of CO_2 captured under a widely implemented CCS policy could all be absorbed in EOR or ECBM applications. In the long run, significant quantities of captured CO_2 will have to be disposed as industrial pollution, with negative economic value.[34] Furthermore, on April 2, 2007, the U.S. Supreme Court held that the Clean Air Act gives the U.S. Environmental Protection Agency (EPA) the authority to regulate greenhouse gas emissions, including CO_2, from new motor vehicles.[35] The court also held that EPA cannot interpose policy considerations to refuse to exercise this authority. While the specifics of EPA regulation under this ruling might be subject to agency discretion, it has implications for the regulation of CO_2 emissions from stationary sources, such as power plants.

Separately, EPA has also concluded that geologic sequestration of captured CO_2 through well injection meets the definition of "underground injection" in §

---

[30] (...continued)
2003): 71.

[31] Chaudhuri et al: 17.

[32] NCEP 2006: 9.

[33] IOGCC 2005: 41.

[34] S.M. Frailey, R.J. Finlay, and T.S. Hickman, "CO_2 Sequestration: Storage Capacity Guideline Needed," *Oil & Gas Journal* (Aug. 14, 2006): 44.

[35] *Massachusetts v. EPA*; at [http://www.supremecourtus.gov/opinions/06pdf/05-1120.pdf]. For further information see CRS Report RL33776, *Clean Air Issues in the 110th Congress: Climate Change, Air Quality Standards, and Oversight*, by James E. McCarthy.

1421(d)(1) of the Safe Drinking Water Act (SDWA).[36] EPA anticipates protecting underground sources of drinking water, through its authority under the SDWA, from "potential endangerment" as a result of underground injection of CO_2 in anticipated CCS pilot projects. EPA's assertion of authority under SDWA for underground injection of CO_2 during CCS pilot studies may contribute to uncertainty over future classification of CO_2 as a commodity or a pollutant.

Conflicting classification of captured CO_2 as either a commodity or pollutant has important implications for CO_2 pipeline development. For example, classifying all CO_2 as a pollutant not only would contradict current state and BLM treatment of CO_2 for EOR, but would also undermine the interstate commerce rationale for FERC regulation of CO_2 pipelines. On the other hand, classifying all CO_2 as a commodity would create other policy contradictions, for example, in regions like New England where EOR may be impracticable. Under either scenario, legislative and regulatory ambiguities would arise — especially for an integrated, interstate CO_2 pipeline network carrying a mixture of "commodity" CO_2 and "pollutant" CO_2. Resolving these ambiguities to establish a consistent and workable CCS policy could likely be an issue for Congress.

Pipeline Costs

If an extensive network of pipelines is required for CO_2 transportation, pipeline costs may be a major consideration in CCS policy. MIT estimated overall annualized pipeline transportation (and storage) costs of approximately $5 per metric ton of CO_2.[37] If CO_2 sequestration rates in the United States were on the order of 1 billion metric tons per year at mid-century, as some analysts propose, annualized pipeline costs would run into the billions of dollars. Furthermore, because most pipeline costs are initial capital costs, up-front capital outlays for a new CO_2 pipeline network would be enormous. The 2007 Duke study, for example, estimated it would cost approximately $5 billion to construct a CO_2 trunk line along existing pipeline rights of way to transport captured CO_2 from North Carolina to potential sequestration sites in the Gulf states and Appalachia.[38] Within the context of overall CO_2 pipeline costs, several specific cost-related issues may warrant further examination by Congress.

Materials Costs. Analysts commonly develop cost estimates for CO_2 pipelines based on comparable construction costs for natural gas pipelines, and to a lesser extent, petroleum product pipelines. In most cases, these comparisons appear appropriate since CO_2 pipelines are similar in design and operation to other pipelines, especially natural gas pipelines. A University of California (UC) study analyzing the costs of U.S. transmission pipelines constructed between 1991 and 2003 found that, on average, labor accounted for approximately 45% of the total construction costs. Materials, rights of way, and miscellaneous costs accounted for 26%, 22%, and 7%

---

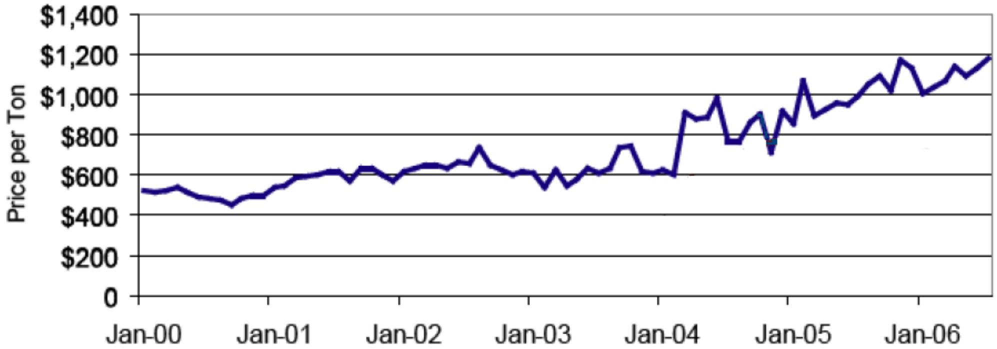
[36] U.S. Environmental Protection Agency, memorandum (July 5, 2006). Available at [http://www.epa.gov/OGWDW/uic/pdfs/memo_wells_sequestration_7-5-06.pdf].

[37] MIT 2007: xi.

[38] Eric Williams et al. (2007): 20.

of total costs, respectively.[39] Materials cost was most closely dependent upon pipeline size, accounting for an increasing fraction of the total cost with increasing pipeline size, from 15% to 35% of total costs. The MIT study estimated that transportation of captured CO_2 from a 1 gigawatt coal-fired power plant would require a pipe diameter of 16 inches.[40] According to the UC analysis, total construction costs for such a pipe between 1991 and 2003 averaged around $800,000 per mile (in 2002 dollars), although the study stated that costs for any individual pipeline could vary by a factor of five depending its location.[41]

Figure 2. U.S. Prices for Large-Diameter Steel Pipe



Source: *Preston Pipe & Tube Report*. Pipe prices represent average transaction price (by weighted average value) for double-submerged arc-welded pipe > 24" diameter, combining both domestic and import shipments.

Since pipeline materials make up a significant portion of CO_2 pipeline construction costs, analysts have called attention to rising pipeline materials costs, especially steel costs, as a concern for policymakers.[42] Following a period of low steel prices and company bankruptcies earlier in the decade, the North American steel industry has returned to profitability and enjoys strong domestic and global demand.[43] Now, higher prices resulting from both strong demand and increased production costs for carbon steel plate, used in making large-diameter pipe, may alter the basic economics of CO_2 pipeline projects and CCS schemes overall. As **Figure 2** shows, the price of large-diameter pipe was generally around $600 per ton in late 2001 and early 2002. By mid-2006, the price of pipe was approaching $1,200 per ton.

---

[39] N. Parker, "Using Natural Gas Transmission Pipeline Costs to Estimate Hydrogen Pipeline Costs," UCD-ITS-RR-04-35, Inst. of Transportation Studies, Univ. of California (Davis, CA: 2004): 1. [http://hydrogen.its.ucdavis.edu/people/ncparker/papers/pipelines]; see, also, G. Heddle, H. Herzog, and M. Klett, "The Economics of CO_2 Storage," MIT LFEE 2003-003 RP (Laboratory for Energy and the Environment, MIT, Cambridge, MA: Aug. 2003). [http://lfee.mit.edu/public/LFEE_2003-003_RP.pdf]

[40] MIT 2007: 58.

[41] N. Parker (2004): Fig. 23.

[42] IPCC 2005: 27.

[43] See CRS Report RL32333, *Steel: Price and Policy Issues*, by Stephen Cooney.

Analysts forecast carbon plate prices to decline over the next two years, but only gradually, and to a level still more than double the price early in the decade.[44]

If some form of CCS is effectively mandated in the future, a surge in demand for new CO_2 pipe, in competition with demand for natural gas and oil pipelines, may exacerbate the trend of rising prices for pipeline materials, and could even lead to shortages of pipe steel from North American sources. As a consequence, the availability and cost of pipeline steel to build such a CO_2 pipeline network for CCS may be a limiting factor for widespread CCS implementation.

Cost Recovery. In states where traditional rate regulation exists, construction and operation of CO_2 pipelines for CCS could raise questions about cost recovery for electric utilities under state utility regulation. If, for example, a CO_2 pipeline is constructed for the exclusive use of a single power plant for on-site (or nearby) CO_2 sequestration, and is owned by the power plant owners, it logically could be considered an extension of the plant itself. In such cases, the CO_2 pipelines could be eligible for regulated returns on the invested capital and their costs could be recovered by utilities in electricity rates. Alternatively such a CO_2 pipeline could be owned by third parties and considered a non-plant asset providing a transportation service for a fee. In the latter case, the costs could still be recovered by the utility in its rates as an operating cost.

Two complications arise with respect to pipeline cost recovery. First, because utility regulation varies from state to state (e.g., some states allow for competition in electricity generation, others do not),[45] differences among states in the economic regulation of CO_2 pipelines could create economic inefficiencies and affect the attractiveness of CO_2 pipelines for capital investment. Second, if CO_2 transportation infrastructure is intended to evolve from shorter, stand-alone, *intra*state pipelines into a network of interconnected *inter*state pipelines, pipeline operators wishing to link CO_2 pipelines across state lines may face a regulatory environment of daunting complexity. Without a coherent system of economic regulation for CO_2 pipelines, whether as a commodity, pollutant, or some other classification, developers of interstate CO_2 pipelines may need to negotiate or litigate repeatedly issues such as siting, pipeline access, terms of service, and rate "pancaking" (the accumulation of transportation charges assessed by contiguous pipeline operators along a particular transportation route). It is just these kinds of issues which have complicated and impeded the integration of individual utility electric transmission systems into larger regional transmission networks.[46]

CO_2 Pipeline Incentives. Oil industry representatives frequently point to EOR as offering a market-based model for profitable CO_2 transportation via pipeline. It should be noted, however, that much of the existing CO_2 pipeline network in the

---

[44] Global Insight, *Steel Industry Review* (2nd Qtr. 2006), tabs. 1.11-1.12; and *American Metal Market*, "West Sees More Steel Plate But Prices Holding Ground" (Aug. 31, 2006).

[45] In market-based states, cost recovery may affect electricity markets.

[46] For further information of electric transmission regulation, see CRS Report RL33875, *Electric Transmission: Approaches for Energizing a Sagging Industry*, by Amy Abel.

United States for EOR has been established with the benefit of federal tax incentives. Although current federal tax law provides no special or targeted tax benefits specifically to CO_2 pipelines, investments in CO_2 pipelines *do* benefit from tax provisions targeted for EOR. They also benefit from accelerated depreciation rules, which apply generally to any capital investment including petroleum and natural gas (non-CO_2) pipelines. For example, the Internal Revenue Code provides for a 15% income tax credit for the costs of recovering domestic oil by one of nine qualified EOR methods, including CO_2 injection (I.R.C. § 43).[47] Also, extraction of naturally occurring CO_2 may qualify for percentage depletion allowance under I.R.C. § 613(b)(7). Prior federal law, both tax and nontax, also provided various types of incentives for EOR which stimulated investment in CO_2 pipelines. In particular, oil produced from EOR projects was exempt from oil price controls in the 1970s. Development of CO_2 pipeline infrastructure in the 1980s benefitted from tax advantages to EOR oil under the crude oil windfall profits tax law, which was in effect from March 1980 to August 1988.

Although there were never incentives explicitly for CO_2 pipelines under federal tax and price control regulation in the 1970s and 1980s, it is clear that CO_2 pipeline infrastructure development benefitted from these regulations. In a CCS environment where some captured CO_2 is a valuable commodity, but the remainder is not, establishing similar regulatory incentives for CO_2 pipelines becomes complex. As debate continues about the economics of CO_2 capture and sequestration generally, and how the federal government can encourage CCS infrastructure investment, Congress may seek to understand the implications of CCS incentives specifically on CO_2 pipeline development.

Cost Implications for Network Development. In light of the overall costs associated with CO_2 pipelines, including the uncertainty about future materials costs and cost recovery, some analysts anticipate that a CO_2 network for CCS will begin with shorter pipelines from CO_2 sources located close to sequestration sites. Larger CO_2 trunk lines are expected to emerge to capture substantial scale economies in long-distance pipeline transportation. According to the 2007 MIT report, "it is anticipated that the first CCS projects will involve plants that are very close to a sequestration site or an existing CO_2 pipeline. As the number of projects grow, regional pipeline networks will likely evolve."[48] It is debatable, however, whether piecemeal growth of a CO_2 pipeline network in this way, presumably by individual facility operators seeking to minimize their own costs, would ultimately yield an economically efficient and publically acceptable CO_2 pipeline network for CCS. Weaknesses and failures in the North American electric power transmission grid, which was developed in this manner, may be one example of how piecemeal, uncoordinated network development may fail to satisfy key economic and operating objectives.

---

[47] Unfortunately for EOR investors, while this tax credit is part of current federal tax law, its phaseout provisions mean that presently it is not available — the credit is zero — due to high crude oil prices.

[48] Ibid., MIT. (2007): 59.

As an alternative to piecemeal CO_2 pipeline development, some analysts suggest that it may be more cost effective in the long run to build large trunk pipelines when the first sites with CO_2 capture come on line with the expectation that subsequent users could fill the spare capacity in the trunk line. In addition to lower per-unit transport costs for CO_2, such an arrangement would smooth out potentially intermittent CO_2 flows from individual capture sites (especially discontinuously operated power plants), provide a greater buffer for overall CO_2 supply fluctuations, and generally allow for more operational flexibility in the system.[49] Planning and financing such a CO_2 trunk line system would present its own challenges, however. As another analysis points out, "implementation of a 'backbone' transport structure may facilitate access to large remote storage reservoirs, but infrastructure of this kind will require large initial upfront investment decisions."[50] How a CO_2 network for CCS would be configured, and who would configure it, may be issues for Congress.

CO_2 Pipeline Safety

CO_2 occurs naturally in the atmosphere, and is produced by the human body during ordinary respiration, so it is commonly perceived by the general public to be a relatively harmless gas. However, at concentrations above 10% by volume, CO_2 may cause adverse health effects and at concentrations above 25% poses a significant asphyxiation hazard. Because CO_2 is colorless, odorless, and heavier than air, an uncontrolled release may accumulate and remain undetected near the ground in low-lying outdoor areas, and in confined spaces such as caverns, tunnels, and basements.[51] Exposure to CO_2 gas, as for other asphyxiates, may cause rapid "circulatory insufficiency," coma, and death.[52] Such an event occurred in 1986 in Cameroon, when a cloud of naturally-occurring CO_2 spontaneously released from Lake Nyos killed 1,800 people in nearby villages.[53]

The Secretary of Transportation has primary authority to regulate interstate CO_2 pipeline safety under the Hazardous Liquid Pipeline Act of 1979 as amended (49 U.S.C. § 601). Under the act, the Department of Transportation (DOT) regulates the design, construction, operation and maintenance, and spill response planning for CO_2 pipelines (49 C.F.R. § 190, 195-199). The DOT administers pipeline regulations through the Office of Pipeline Safety (OPS) within the Pipelines and Hazardous

[49] John Gale and John Davidson, "Transmission of CO_2 — Safety and Economic Considerations," *Energy*, Vol. 29, Nos. 9-10 (July-August 2004): 1326.

[50] IPCC 2005: 190.

[51] J. Barrie, K. Brown, P.R. Hatcher, and H.U. Schellhase, "Carbon Dioxide Pipelines: A Preliminary Review of Design and Risks," Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies (Vancouver, Canada: Sept. 5-9, 2004): 2.

[52] Airco, Inc., "Carbon Dioxide Gas," *Material Safety Data Sheet* (Aug. 4, 1989). [http://www2.siri.org/msds/f2/byd/bydjl.html]

[53] Kevin Krajick, "Defusing Africa's Killer Lakes," *Smithsonian*, v. 34, n. 6. (2003): 46 — 55.

Materials Safety Administration (PHMSA).[54] Although CO_2 is listed as a Class 2.2 (non-flammable gas) hazardous material under DOT regulations (49 C.F.R. § 172.101), the agency applies nearly the same safety requirements to CO_2 pipelines as it does to pipelines carrying hazardous liquids such as crude oil, gasoline, and anhydrous ammonia (49 C.F.R. § 195).

To date, CO_2 pipelines in the United States have experienced few serious accidents. According to OPS statistics, there were 12 leaks from CO_2 pipelines reported from 1986 through 2006 — none resulting in injuries to people. By contrast, there were 5,610 accidents causing 107 fatalities and 520 injuries related to natural gas and hazardous liquids (excluding CO_2) pipelines during the same period.[55] It is difficult to draw firm conclusions from these accident data, because CO_2 pipelines account for less than 1% of total natural gas and hazardous liquids pipelines, and CO_2 pipelines currently run primarily through remote areas. Based on the limited sample of CO_2 incidents, analysts conclude that, mile-for-mile, CO_2 pipelines appear to be safer than the other types of pipeline regulated by OPS.[56] Additional measures, such as adding gas odorants to CO_2 to aid in leak detection, may further mitigate CO_2 pipeline hazards. Nonetheless, as the number of CO_2 pipelines expands, analysts suggest that "statistically, the number of incidents involving CO_2 should be similar to those for natural gas transmission."[57] If the nation's CO_2 pipeline network expands significantly to support CCS, and if this expansion includes more pipelines near populated areas, more CO_2 pipeline accidents are likely in the future.[58]

Criminal and Civil Liability. There are no special provisions in U.S. law protecting the CO_2 pipeline industry from criminal or civil liability. In January 2003, the Justice Department announced over $100 million in civil and criminal penalties against Olympic Pipeline and Shell Pipeline resolving claims from a fatal gasoline pipeline fire in Bellingham, WA, in 1999.[59] In March 2003, emphasizing the environmental aspects of homeland security, Attorney General John Ashcroft reportedly announced a crackdown on companies failing to protect against possible terrorist attacks on storage tanks, transportation networks, industrial plants, and pipelines.[60]

Even if no federal or state regulations are violated, CO_2 pipeline operators could still face civil liability for personal injury or wrongful death in the event of an

---

[54] PHMSA succeeds the Research and Special Programs Administration (RSPA), reorganized under P.L. 108-246, which was signed by the President on Nov. 30, 2004.

[55] Office of Pipeline Safety (OPS), "Distribution, Transmission, and Liquid Accident and Incident Data." (2007). Data files available at [http://ops.dot.gov/stats/IA98.htm].

[56] John Gale and John Davidson. (2004): 1322.

[57] Barrie et al. (2004): 2.

[58] Gale and Davidson (2004): 1321.

[59] "Shell, Olympic Socked for Pipeline Accident," *Energy Daily* (Jan. 22, 2003).

[60] John Heilprin, "Ashcroft Promises Increased Enforcement of Environmental Laws for Homeland Security," *Assoc. Press*, Washington dateline (Mar. 11, 2003).

accident. In the Bellingham accident, the pipeline owner and associated defendants reportedly agreed to pay a $75 million settlement to the families of two children killed in the accident.[61] In 2002, El Paso Corporation settled wrongful death and personal injury lawsuits stemming from a natural gas pipeline explosion near Carlsbad, NM, which killed 12 campers.[62] Although the terms of those settlements were not disclosed, two additional lawsuits sought a total of $171 million in damages.[63] The MIT study concluded that operational liability for CO_2 pipelines, as part of an integrated CCS infrastructure, "can be managed within the framework that has been successfully used for decades by the oil and gas industries."[64] Nonetheless, as CCS policy evolves, Congress may seek to ensure that liability provisions for CO_2 pipelines are adequate and consistent with liability provisions in place for other CO_2 infrastructure.

Other Issues

In addition to the issues discussed above, additional policy issues related to CO_2 pipelines may arise as CCS policy evolves. These may include addressing technical transportation problems related to the presence of other pollutants, such as sulfuric and carbonic acid, in CO_2 pipelines. Some have also suggested the use or conversion of existing non-CO_2 pipelines, such as natural gas pipelines, to transport CO_2. Coordination of U.S. CO_2 pipeline policies with Canada, with whom the United States shares its existing pipeline infrastructure, may also become a consideration. Finally, the potential impacts of CO_2 pipeline development overseas on the global availability of construction skills and materials may arise as a key factor in CCS economics and implementation.

Conclusion

Policy debate about the mitigation of climate change through some scheme of carbon capture and sequestration is expanding quickly. To date, debate among legislators has been focused mostly on CO_2 sources and storage sites, but CO_2 pipelines are a vital connection between the two. Although CO_2 transportation by pipeline is in some respects a mature technology, there are many important unanswered questions about the socially optimal configuration, regulation, and costs of a CO_2 pipeline network for CCS. Furthermore, because CO_2 pipelines for EOR are already in use today, policy decisions affecting CO_2 pipelines take on an urgency that is, perhaps, unrecognized by many. It appears, for example, that federal

---

[61] Business Editors, "Olympic Pipe Line, Others Pay Out Record $75 Million in Pipeline Explosion Wrongful Death Settlement," *Business Wire* (April 10, 2002).

[62] National Transportation Safety Board, *Pipeline Accident Report,* PAR-03-01. (Feb. 11, 2003).

[63] El Paso Corp., *Quarterly Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934,* Form 10-Q, Period ending June 30, 2002. (Houston, TX: 2002). The impact of these lawsuits on the company's business is unclear, however; the report states that "our costs and legal exposure ... will be fully covered by insurance."

[64] MIT 2007: 58.

classification of CO_2 as both a commodity (by the BLM) and as a pollutant (by the EPA) potentially could create an immediate conflict which may need to be addressed not only for the sake of future CCS implementation, but also to ensure consistency between future CCS and today's CO_2 pipeline operations.

In addition to these issues, Congress may examine how CO_2 pipelines fit into the nation's overall strategies for energy supply and environmental protection. The need for CO_2 pipelines ultimately derives from the nation's consumption of fossil fuels. Policies affecting the latter, such as energy conservation, and the development of new renewable, nuclear, or hydrogen energy resources, could substantially affect the need for and configuration of CO_2 pipelines. If policy makers encourage continued consumption of fossil fuels under CCS, then the need to foster the other energy options may be diminished — and vice versa. Thus decisions about CO_2 pipeline infrastructure could have consequences for a broader array of energy and environmental policies.