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Onshore U.S. Carbon Pipeline Deployment: Siting, Safety, and Regulation



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Prepared by Public Sector Consultants
www.publicsectorconsultants.com

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Executive Summary

Carbon capture, utilization, and storage (CCUS) technology has significant potential to reduce greenhouse gas (GHG) emissions and mitigate the impact of climate change, particularly in hard to decarbonize industrial and commercial sectors. CCUS involves capturing carbon dioxide (CO₂) from industrial processes or power generation and utilizing it for other purposes, such as enhanced oil recovery (EOR), or storing the captured CO₂ underground. CCUS technology can reduce the environmental impact of continued fossil fuel use while smoothing the transition to a low-carbon economy. CCUS can create new economic opportunities, such as the development of new industries and job creation, and can enhance energy security by diversifying energy sources. For these reasons, enabling CCUS has become a key objective of the Biden-Harris administration's clean energy policy and has received bipartisan support.

Despite its environmental and economic potential, CCUS faces multiple barriers to widespread deployment. One of the main challenges is the high cost and technical difficulty of implementing and operating large-scale CCUS infrastructure. CCUS remains a relatively expensive way to reduce carbon emissions (e.g., compared to solar photovoltaic technology's displacement of coal generation). Additionally, financial incentives and supportive policies like those enacted to support solar photovoltaic development, especially at the state level, are inconsistent or nonexistent, which can discourage investment in CCUS projects. There are also technical challenges associated with safe and secure underground CO₂ storage and the development of new carbon utilization technologies. Public opposition to various aspects of CCUS technologies, ranging from concerns that CCUS will extend reliance on fossil fuels to CCUS infrastructure being sited in disadvantaged communities, is a growing challenge.

This paper focuses on another significant barrier to broad CCUS deployment: the need for considerable expansion of the dedicated land-based CO₂ pipeline network in the United States to meet CCUS goals and the unique regulatory challenges to its development. To reach carbon emissions targets in the United States by 2050, CCUS technology will need to be supported by tens of thousands of miles of CO₂ pipelines. Estimates range from a minimum of roughly 29,000 pipeline miles (according to a 2020 Great Plains Institute study) to 66,000 pipeline miles (as per a 2021 Princeton University-led study). As of October 2022, however, the U.S. Department of Transportation (U.S. DOT) reports fewer than 5,400 miles of U.S. pipelines carrying CO₂. This deficit—and what it means for the prospect of moving substantially larger quantities of CO₂ from source to use or storage—threatens to stifle the development of CCUS projects and technologies identified as an important tool to meet emissions targets.

The current regulatory landscape facing CO₂ pipeline development can best be described as uncertain. At the federal level, the U.S. DOT Pipeline and Hazardous Materials Safety Administration (PHMSA) oversees safety regulation of pipelines transporting hazardous materials, including CO₂ upon commencement of operation. However, PHMSA's definition of CO₂ as "a fluid consisting of more than 90 percent CO₂ molecules compressed to a supercritical state" has not been updated since its 1991 addition to the Federal Register. Because CO₂ can be transported in a gaseous, liquid, or supercritical state (indeed, the physical state of CO₂ can fluctuate within a single pipeline due to environmental changes), doubts persist about the extent of PHMSA's purview—and raise questions about what, if anything, states should do to address this apparent gap. PHMSA has begun a major revision of its existing rules, but the agency does not expect a first draft before 2024.

Economic oversight of CO₂ pipelines is even less clear. The Federal Energy Regulatory Commission (FERC) and Surface Transportation Board (STB)—which regulate the rates of interstate oil/natural gas and non-energy pipelines, respectively—have both declined jurisdiction over interstate CO₂ pipelines. This presumably leaves economic regulation to state and/or local governments, but few if any states have the laws or resources in place to oversee just and reasonable rates. Further, the interstate nature of CO₂ pipeline development creates questions around how different states should align their rate-making decisions.

Currently, regulatory responsibilities regarding CO₂ pipeline siting and permitting fall to state and local governments. The variety of laws and regulations across the country, however, creates a maze of requirements for pipeline developers to navigate. To secure necessary permits, most states require pipeline companies to be “common carriers” that provide transport service to the public at uniform rates. However, the specific definition of that term varies. Some states require clear evidence that a pipeline services the public, while others automatically deem any pipeline company transporting energy products or hazardous materials to be a “common carrier”—with little consideration for accessibility to third parties. Other states have eschewed common-carrier terminology entirely, placing private and publicly accessible pipelines on equal footing. Much like the variation in common-carrier requirements, laws governing eminent domain authority to secure rights-of-way (ROW) to commence construction on a planned pipeline route differ by state.

Several states have no laws or rules governing CO₂ pipelines. In addition to creating questions about whether long-standing rules for other pipelines (e.g., natural gas or petroleum products) apply to CO₂, this policy vacuum leaves local governments as the sole authority over sections of pipe within their boundaries. With dozens of counties along a given route, the probability of inconsistent regulation of the same pipeline is significant. Even in states with CO₂ pipeline laws in place, local regulatory attempts to address rising concerns over pipeline routing and safety have triggered lawsuits by pipeline companies seeking to delimit areas of federal, state, and local government responsibility. Meanwhile, legislators across the country have introduced bills to restrict the application of eminent domain to CO₂ pipeline projects, which could threaten a key means of securing ROW that companies cannot secure through negotiation with landowners.

Taken separately, any of these regulatory issues—the narrow federal definition of CO₂, FERC’s and STB’s decisions that CO₂ pipelines are not within their jurisdiction, and the considerable variation in state and local governments’ laws regulating CO₂ pipeline technologies—are extremely difficult to resolve. Adding the required scale of CO₂ pipeline expansion and the currently identified narrow window of time in which to reach climate target goals, the task becomes even more difficult—and raises a host of urgent questions for regulators. How should CO₂ be defined in federal regulations to ensure consistent safety standards across the country? What is the potential impact radius of a CO₂ pipeline rupture, and how should that inform local emergency response? In the absence of centralized federal oversight, what should state legislatures do to increase alignment for interstate CO₂ pipeline projects? This paper intends to serve as a primer for regulators and stakeholders who seek to better understand the regulatory challenges and opportunities facing this critical infrastructure.

Carbon Capture, Utilization, and Storage Background

To understand the regulation of CCUS technology, it is first important to understand each CCUS component. Carbon capture is the process of collecting CO₂ from either the atmosphere (direct air capture [DAC]) or a source of direct CO₂ emissions, such as a fossil fuel power plant or an industrial facility (point-source capture). After CO₂ is captured, it is transported to another location, where it is either utilized or stored (National Grid n.d.). Carbon utilization broadly refers to the process of using captured carbon in another application, such as the extraction of oil from depleted wells through EOR or in the production of products like construction materials, plastics, or chemicals (Bobeck et al. 2019). Carbon storage is the act of permanently storing, or sequestering, CO₂ in an underground geologic formation where it will not reenter the atmosphere. Options for geologic storage locations include oil and gas reservoirs, deep saline formations, coal beds, basalt formations, and shale basins (Center for Climate and Energy Solutions n.d.). CCUS can be defined as the process of capturing CO₂ from the atmosphere or sources of direct emission and either reusing the CO₂ or permanently storing it so it will not reenter the atmosphere (U.S. DOE n.d.a).

CCUS's Current Market Size, Potential Contribution to Decarbonization Goals, and Deployment Opportunities

CCUS technologies can contribute to decarbonization goals by reducing anthropogenic CO₂ emissions and removing CO₂ already in the atmosphere. In addition to these environmental benefits, CCUS can support the economy by creating jobs and increasing opportunities for companies to sell or export low-carbon products. Fortune Business Insights estimated in September 2022 that the CCUS global market size was worth about \$2.1 billion, up about \$140 million from the previous year. The global CCUS market is expected to continue growing at an annual rate of about 19.5 percent over the next five years, eventually reaching \$7 billion in 2028 (Fortune Business Insights 2022). This expected growth can largely be attributed to increasing pressures from public and private entities to lower GHG emissions.

Since the mid-1990s, the federal government has provided billions of dollars of funding for CCUS research, development, and demonstration projects (Jones and Lawson 2022). Between 2010 and 2018, the U.S. Department of Energy (DOE) spent approximately \$1.1 billion on nine large carbon capture and storage demonstration projects (U.S. GAO 2018). More recently, two historic pieces of federal legislation—the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA)—have dedicated more than \$110 billion (\$11 billion and \$99 billion, respectively) to the development of CCUS and other emission reduction and decarbonization-related projects (Johnson et al. 2021; Trabish 2022).

Congress has also incentivized CCUS deployment since 2008 by providing a tax credit for facilities that capture and sequester CO₂. The credit, colloquially known as the “Section 45Q” tax credit, is codified in Section 45Q of the U.S. Internal Revenue Code (26 U.S.C. §45Q; IEA 2022c). In 2022, the IRA modified the Section 45Q tax credit to provide even greater incentives for CCUS deployment. The 2022 revision increased the amount of the tax credit from \$35–\$50 per metric ton to \$60–\$180 per metric ton, depending on the CO₂'s destination and use (e.g., geologic sequestration, geological sequestration with EOR, or other qualified uses). Additionally, the IRA expanded the availability of 45Q credits for CCUS projects, increased the number of facilities that can qualify for the credit, provided additional options for monetizing the credits, and extended the deadline to begin construction on eligible projects from 2026 to 2033 (Gibson Dunn 2022). As of June 2020, the Section 45Q credit had been claimed for approximately 72 million metric tons of carbon (Congressional Research Service 2021). Because of the 2022 revisions, the credit is expected to accelerate CCUS deployment in the United States in coming years by making previously uneconomic projects more commercially viable for developers (Bright 2022).

Barriers to CCUS Deployment

Despite the rapid progress and increased commercialization of CCUS technology, there are barriers hindering widespread deployment. This section provides a brief overview of the most common barriers to CCUS deployment in the United States. This is not an exhaustive list, and other barriers may exist. Additionally, barriers that apply to any given CCUS project may vary depending on the project's unique characteristics.

Technical Feasibility of Capture Systems

Elements of CCUS technology have been in operation for decades and are mature technologies (e.g., utilizing CO₂ for EOR). However, certain aspects of CCUS have been slow to develop and are still in the research and development (R&D) phase. In particular, the deployment of large-scale carbon capture systems in certain emissions-intensive industrial settings (e.g., mineral, natural gas, hydrogen, and iron and steel production plants) is still being explored. Though R&D efforts have led to higher CO₂ capture rates as well as reductions in both capital and operating costs of capture systems, more work is needed to ensure these larger systems are efficient, cost-effective, and scalable (United Nations Economic Commission for Europe 2021). DOE's National Energy Technology Laboratory (NETL) is actively supporting the R&D of point-source carbon capture from power generation and industrial facilities through its Point Source Carbon Capture Program (U.S. DOE NETL n.d.b). Also of note, on February 23, 2023, DOE's Office of Clean Energy Demonstrations announced up to \$820 million in funding for up to ten large-scale carbon capture pilot projects (U.S. DOE Office of Clean Energy Demonstrations 2023).

Cost of Capture

Carbon capture is considered a cost-effective approach to decarbonizing some industrial operations that produce a relatively pure CO₂ stream (e.g. ammonia production) though high costs of building and operating CCUS systems remain a challenge to deployment (IEA 2019). A 2022 report from the U.S. Government Accountability Office (GAO) estimates the total cost to capture one metric ton of CO₂ (including one-time capital and ongoing operating costs) using point-source capture to be between \$40 and \$290 for high-emitting sectors (e.g., power generation and iron and steel manufacturing). For DAC, the total cost is estimated to be higher, at about \$100 to \$600 per metric ton, with an upper limit of \$1,200 per metric ton (U.S. GAO 2022). By comparison, Yale University professor of environmental and energy economics Kenneth Gillingham notes that the cost to reduce one metric ton of CO₂ emissions by displacing coal generation with unsubsidized utility-scale photovoltaic solar is approximately \$24 per metric ton (in 2017 US\$). He further identifies a significant variance in additional costs associated with photovoltaic system subsidies, noting from a survey of primarily U.S.-based programs an additional \$140–\$2,100 per metric ton from public subsidies (Gillingham 2019). More recent DOE research further highlights the potential need for revenue or policy intervention to spur the carbon capture market to meet midcentury climate CO₂ reduction goals, estimating a necessary total investment of \$300–\$600 billion (U.S. DOE 2023). Current BIL- and IRA-funded demonstration projects do not result in a baseline that is economically viable for developers (U.S. DOE 2023). At least one expert has said that point-source capture and DAC remain financially unviable without public incentives (Brown and Ung 2019).

Industry's rising interest in carbon capture's ability to lower the carbon emissions of energy consumption could significantly impact the cost of CCUS and its associated infrastructure. As industrial operations look for ways to decarbonize, partnerships with utilities and power generators to add carbon capture to combined cycle gas turbine plants, for example, could drive affordability through improved economies of scale (IEA 2019). The new tranch of 45Q incentives and growing demand for decarbonized supply chains will spur investments that make CCUS technology more accessible and affordable for an increasing number of industrial operations.

Inconsistent State-level Incentives

While multiple federal programs support CCUS projects (e.g., DOE's Carbon Capture and Storage program, DOE's Loan Programs Office financing, federal tax credits, and others), state-level incentives for CCUS are uneven, and in some cases nonexistent (U.S. Executive Office of the President 2021). For example, Wyoming has enacted a set of laws and regulations that directly address and incentivize CCUS project development (Coddington 2022). States like Indiana, Montana, and North Dakota have also passed similar CCUS legislation (MRCI 2022). In contrast, a majority of states have yet to implement incentive packages directly related to CCUS development.

Another variable impacting the viability of CO₂ storage projects is the timeline associated with permit approval for Class VI injection wells. In 2010, the U.S. Environmental Protection Agency (EPA) issued its final rule updating the Underground Injection Control (UIC) program, to include a new class of well (Class VI) for the deep geologic sequestration of CO₂ (U.S. EPA 2010). Along with this new class of UIC well came the opportunity for states to seek primacy over the administration and enforcement of the Class VI program. States may take responsibility for UIC programming if the EPA determines that state regulations meet minimum federal standards (U.S. EPA n.d.). To date, only North Dakota and Wyoming have received primacy for Class VI wells, though Louisiana's application is in the final rulemaking and codification phase and Arizona, Texas, and West Virginia have initiated the pre-application process (U.S. EPA n.d.). Though not a direct financial incentive, the opportunity to seek UIC permits directly from a state entity familiar with local projects is likely appealing to developers aiming to reduce their regulatory burden, increase the speed of issuance, and work with regulators with greater local environmental familiarity. The BIL provided the EPA with \$50 million in one-time funding for grants to states interested in seeking primacy, which are currently under review (U.S. EPA 2023).

Scarcity of Opportunities for Utilization

To date, the most common method of utilizing captured carbon in the United States is enhanced oil recovery. EOR has been used for decades to help extract residual oil from oil reservoirs and maximize production. EOR also permanently sequesters CO₂ underground (U.S. DOE NETL 2010). However, as oil reservoirs are depleted or global oil demand declines, EOR opportunities will diminish. Non-EOR carbon utilization opportunities are based on the production of carbon-based chemicals and materials like construction supplies, fuels, plastics, and algae-based animal feed and fertilizers (U.S. DOE NETL 2010). However, many of these opportunities are still being studied and refined through R&D and demonstration efforts, and are not yet scalable for large applications. Further, opportunities to leverage current CO₂ capture and transportation infrastructure for non-EOR utilization projects are limited because most existing infrastructure has been developed specifically for EOR and connects sources of CO₂ with oil reservoirs (National Academies of Sciences, Engineering, and Medicine 2022). Thus, opportunities for utilization, especially at large scales, are limited.

Scarcity of Transportation Infrastructure

CO₂ is generally transported using one or more of the following options: barges, ships, pipelines, trains, and trucks (IEA 2022a). Of these options, pipelines are generally understood to be the safest, most scalable, and relatively low-cost mode of land-based transportation, particularly when large volumes of CO₂ must be transported over long distances (Witkowski et al. 2014). According to a 2021 Princeton University-led study, reaching net-zero carbon emissions in the United States will require CCUS technology supported by roughly 66,000 miles of CO₂ pipelines (Larson et al. 2021).

As of February 2023, the U.S. DOT reported fewer than 5,400 miles of U.S. pipelines carrying CO₂ (U.S. DOT PHMSA 2023a). Currently, more than half of existing CO₂ pipelines in the United States are in the Permian Basin region of West Texas and eastern New Mexico. Pipelines are also located in the states of Colorado, Kansas, Louisiana, Michigan, Mississippi, Montana, North Dakota, Oklahoma, and Wyoming. The majority of the pipeline system is dedicated to supporting EOR operations, with a small portion being used for other

purposes, such as transporting CO₂ to the beverage industry. According to DOE, as of 2015, the entire U.S. CO₂ pipeline system was operated by about twelve companies (e.g., ExxonMobil, Chevron, Kinder Morgan, Trinity CO₂, and others; Wallace et al. 2015).

According to industry observers, the minimum 29,000–66,000 miles of new CO₂ pipelines required to reach net-zero emissions will require the development of an overall system of interstate CO₂ trunk pipelines connected to an expansive network of smaller spur pipelines. The network is likely to result in linking carbon capture facilities to clusters—which include groupings of individual CO₂ sources or geologic storage sites—and/or hubs—which collect CO₂ from multiple sources and transport it to storage locations. For example, the Permian Basin has several clusters of EOR fields that are linked to a network of CO₂ pipelines (Global CCS Institute 2018).

Public Opposition

In the past, public opposition has contributed to CCUS project cancellation or relocation. CCUS opponents have voiced concerns around extending reliance on fossil fuels, infrastructure siting, and environmental justice (EJ). This section is not meant to provide an exhaustive account of these concerns, but rather an overview of the most prevalent reasons why groups and communities have engaged in public opposition to CCUS projects in the United States.

CCUS Extends Reliance on Fossil Fuels

Significant CCUS opposition rests on concerns that CCUS technology will extend reliance on fossil fuels and delay the transition to cleaner energy sources. Critics worry that equipping GHG-emitting facilities with CCUS technology will effectively enable those facility operators to continue operation without seeking other means of generation. Additionally, carbon capture is energy-intensive—the power required for carbon capture systems may generate even more emissions if supplied by fossil fuels. Many in the environmental community have also argued that EOR (i.e., the primary utilization end for CCUS) serves to extend the use of fossil fuels by boosting oil production and prolonging the life of oil fields that would be otherwise uneconomical.

CCUS Infrastructure Siting and NIMBYism

Public opposition to CCUS infrastructure siting can be generally characterized as fitting into one of three categories: pipeline safety concerns, property ROW issues, and opposition to development near where people live, commonly referred to as NIMBYism (“not in my backyard”). Concerns about CO₂ pipeline safety have emerged as a prominent issue for proposed CCUS projects, particularly after a CO₂ pipeline ruptured near Satartia, Mississippi, in 2020. This is the first known outdoor mass exposure to CO₂ due to a pipeline rupture in the world, which resulted in a local evacuation and caused at least 45 people to be hospitalized (Zegart 2021).

Developers are also having difficulties securing CO₂ pipeline routes due to trouble negotiating easements with landowners for pipeline ROW. In some instances, developers may secure ROW using eminent domain; however, eminent domain rights vary from state to state, and they can also be controversial when exercised. For more information about state eminent domain laws, please refer to the section on state and local responsibilities on page 20.

The third and final category of opposition to CCUS infrastructure siting is NIMBYism. NIMBY is a term used to describe resistance to the siting of a project near one’s place of residence while showing acceptance of similar projects elsewhere (Sanya et al. 2020). CO₂ pipeline developers have faced NIMBYism about CCUS infrastructure siting, often based on concerns regarding increased safety risks and diminution of property values (Krause et al. 2014).

Environmental Justice Concerns

Advocates have raised EJ concerns about CCUS projects sited in or near disadvantaged communities. High-GHG-emitting facilities (e.g., coal plants, oil refineries, cement manufacturers) tend to be located near

disadvantaged communities and/or communities of color (Donaghy 2021). Even if carbon capture reduces CO₂ emissions at these facilities, the facilities may continue to pose other environmental risks, with the surrounding communities continuing to bear the pollution burden. Some EJ advocates have also raised concerns about the safety risks of CO₂ pipelines and how those risks may disproportionately impact disadvantaged communities (Smith 2022). CCUS proponents have countered by citing CCUS's potential environmental benefits and local economic benefits due to investment in CCUS infrastructure (IEA 2019).

Studies of Optimal Locations for CCUS Infrastructure Build-outs

In the last five years, dozens of studies have analyzed the need for CCUS infrastructure (U.S. Executive Office of the President 2021). This section provides summaries of three studies frequently referenced by experts when discussing optimal locations for the build-out of CO₂ transportation infrastructure. There is strong consensus among the authors that reaching the federal government's decarbonization goals will require widespread implementation of CCUS technology supported by a robust build-out of CO₂ pipelines (U.S. Department of State 2021).

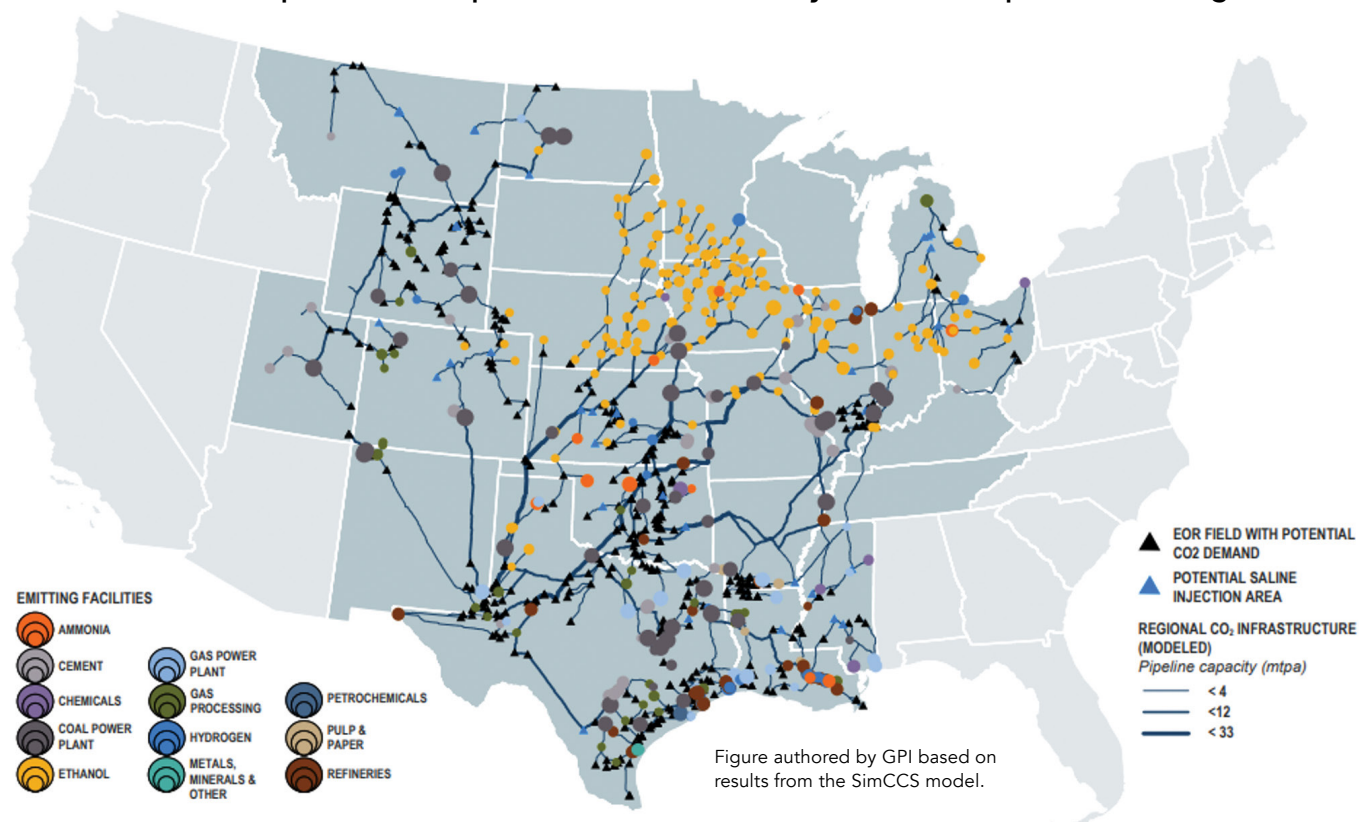
Princeton Net-Zero America

This 2021 Princeton University–led study presents five different “pathways” by which the United States could achieve net-zero GHG emissions by the year 2050. The authors conclude that in all scenarios, a CCUS industry supported by more than 62,000 miles of new CO₂ pipelines is necessary to meet net-zero GHG emissions. Based on analysis of factors like geologic storage site potential, locations of carbon capture facilities and existing pipeline ROWs as well as economic costs, the authors provide several maps illustrating what an optimized CO₂ pipeline network could look like in 2050 (Greig and Pascale 2021).

Great Plains Institute

In 2020, the Great Plains Institute (GPI) completed a two-year modeling effort evaluating the scale and design of CO₂ transportation infrastructure necessary for the United States to meet midcentury decarbonization goals in the industrial and power sectors. As part of this effort, GPI used the SimCCS Gateway tool to model an optimal pipeline transportation network that would most efficiently transport CO₂ from capture sites to permanent storage locations like geologic deep saline formations and EOR operations. The SimCCS Gateway tool considers multiple economic factors (e.g., cost savings, revenue streams, and economic risks) and geospatial factors (e.g., existing infrastructure, urban areas, bodies of water, publicly owned lands and natural resources, and indigenous or tribal lands) when determining routes for CO₂ transport. Based on this study, GPI estimates that a CO₂ pipeline network will require a minimum of 29,000 miles of CO₂ pipelines located primarily throughout Texas, the Midwest, and the Great Plains region to meet the United States' midcentury decarbonization goals in the industrial and power sectors (Abramson et al. 2020). Exhibit 1 displays emitting facilities and the optimal locations for CO₂ infrastructure modeled by GPI.

Exhibit 1. Optimized Transport Network for Economy-Wide CO₂ Capture and Storage



Source: Abramson et al. (2020)

Decarb America

Decarb America created an interactive map showing a build-out of CO₂ pipelines (in five-year increments) that is compatible with reaching net-zero GHG emissions by the year 2050. The map depicts eight different scenarios: constrained renewables, constrained renewables plus slow consumer adaptation, high conservation, high renewables plus high electrification, highly constrained renewables, low biomass, no fossil, and slow consumer adaptation. In all scenarios, initial pipeline deployment begins in 2025 and expands primarily off the existing CO₂ pipeline networks used for EOR in the Permian Basin. By 2050, a system of large trunk pipelines and smaller spur pipelines connect areas with large-scale ethanol production (largely in the Midwest) to opportunities for EOR, geologic storage, and industrial-scale CO₂ utilization (e.g., cement and chemical production plants; Decarb America 2021).

CO₂ Pipeline Primer

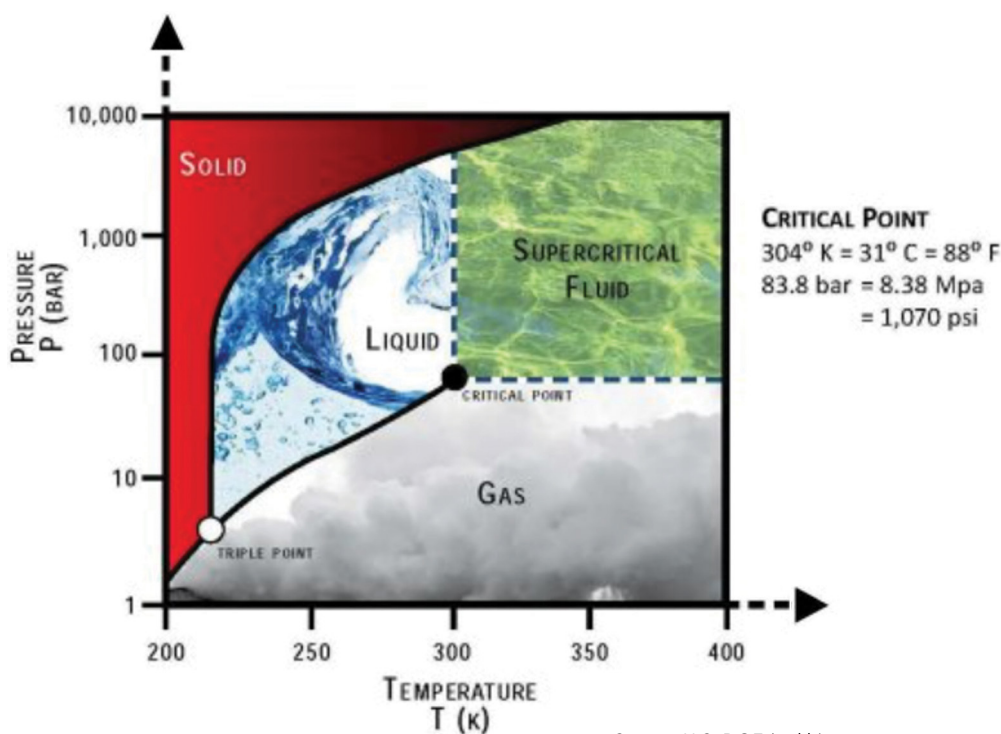
Transmission Technology and Infrastructure

Captured CO₂ must be transported to a location where it can be either utilized or stored. CO₂ is typically transported using one of the following options: barges, ships, pipelines, trains, and trucks. Of these options, pipelines are, and will likely continue to be, the most common land-based mode of transportation for large quantities of CO₂ (Global CCS Institute n.d.). Industry experts have noted several advantages of using pipelines to transmit large amounts of CO₂ as compared to other modes of transportation, including lower operating costs and energy requirements; overall reliability, safety, and convenience; and less sensitivity to economic inflation (Jacobson 2020). This section provides an overview of CO₂ pipeline transmission technology and infrastructure.

Transmission States: Supercritical, Liquid, and Gas

As illustrated in **Exhibit 2**, depending on pressure and temperature conditions, CO₂ can exist in four different states: solid,¹ gas, liquid, or supercritical fluid. Though it is technically possible to transport CO₂ through pipelines as a supercritical fluid, liquid, or gas, CO₂ is most often transported through pipelines either as a supercritical fluid or a liquid (Witkowski et al. 2021).

Exhibit 2. Pressure-Temperature Phase Diagram for CO₂



In its supercritical state, CO₂ takes on properties both of a gas and a liquid, which allows it to move through pipelines efficiently and with minimal drag (National Petroleum Council 2020). This is important to pipeline operators from a cost standpoint because higher throughput can be achieved when transmitting supercritical CO₂ as compared to transmitting CO₂ in other phases (Paul et al. 2010). CO₂ becomes a supercritical fluid at a temperature above 31.1 degrees Celsius (88 degrees Fahrenheit) and a pressure above 72.9 atm (standard

¹ Due to the high costs and energy requirements associated with transporting solidified CO₂ (i.e., "dry ice"), it is not economical to transport CO₂ in this state for large-scale CO₂ transmission operations, and so the transport of solid CO₂ is omitted from this discussion.

atmosphere), which is approximately 1,057 pounds per square inch (U.S. DOE NETL n.d.a). Therefore, to sustain CO₂'s supercritical condition, pipelines must maintain a relatively high internal temperature and pressure (above 88 degrees Fahrenheit and 72.9 atm).

Industry experts have noted that it can be difficult to maintain a single-phase (i.e., in one constant state) flow of CO₂ through a pipeline (Jensen et al. 2014). Studies have shown that while a CO₂ pipeline's internal pressure varies slightly depending on factors such as flow rate and pipe wall thickness, pressure tends to stay above 72.9 atm (Peletiri et al. 2018). This prevents CO₂ from entering a gaseous state.² However, it is not uncommon for temperature to drop below 88 degrees Fahrenheit (Soraghan 2023). When this occurs, CO₂ enters a liquid state. Thus, it is typical for CO₂ to change from a supercritical fluid to a liquid state (and vice versa) as it moves through a pipeline. This variability potentially creates confusion around which, if any, governmental entity regulates CO₂ pipelines.

CO₂ Transportation Methods Depend on End Use

Depending on the CO₂'s end use and/or destination, pipelines may not always be the optimal transportation method. Generally, pipelines are the preferred land-based transportation method for transmitting large quantities of CO₂ over long distances. Other transportation options like trains or trucks may be more cost-effective for moving smaller volumes of CO₂, especially if there are multiple delivery locations (Global CCS Institute 2018). Hence, a robust CO₂ transportation network that supports a range of end uses (e.g., EOR, geologic storage, production of carbon-based materials, etc.) will likely need to include multiple interconnected modes of transportation (Becattini et al. 2022).

Pipeline Materials

CO₂ pipelines are usually constructed out of carbon steel. American Petroleum Institute (API) 5L X65, a low-carbon steel with less than 1.4 percent by weight manganese, is commonly used to construct pipelines (Suter et al. 2022). Corrosion resistant alloys, a class of metals that are engineered to resist degradation, are used in circumstances where pipelines may be particularly susceptible to corrosion. Because pipeline steel corrosion can lead to leakage, pipelines are constructed and operated using internal and external corrosion protection measures. Cathodic protection and external coatings are often used to prevent external corrosion (IEAGHG 2014). Internal corrosion is primarily prevented by minimizing the amount of water (H₂O) present in the CO₂ stream because water is the main risk factor for internal corrosion. To accomplish this, CO₂ is dehydrated before being injected into a pipeline.

Conversion of Hydrocarbon Pipelines to Transport CO₂

It is feasible, albeit challenging and costly, to convert existing hydrocarbon (e.g., natural gas or crude oil) pipelines to CO₂ pipelines. Conversion can be an attractive option for multiple reasons. Namely, it has the potential to reduce both the overall cost and time of pipeline construction and avoid obstacles associated with siting new pipelines (IEA 2022a). Additionally, transitioning fuel sources away from hydrocarbons to cleaner sources could result in the decommissioning of more than a million miles of hydrocarbon pipelines in the United States in coming years, leaving the pipelines empty and presumably ready for conversion (Kenton and Siltan n.d.). EnLink Midstream, a midstream oil and gas company (an entity that transports oil or gas but does not extract or refine it), recently announced plans to convert underutilized natural gas pipelines in Louisiana into CO₂ pipelines (Nickel et al. 2022).

Pipelines for transporting hydrocarbons are comparable to those for CO₂ transmission because both types are generally constructed out of steel and used to transport pressurized gas. However, a major difference between the two is that CO₂ is usually transported at high pressures as a supercritical fluid while hydrocarbons

² It is technically possible to transport gaseous CO₂ in pipelines. However, most CO₂ pipelines maintain pressures above 72.9 atm, which prevents CO₂ from entering a gaseous state.

are transported at lower pressures as a gas or liquid. Pipelines transporting supercritical CO₂ operate at higher pressures than most hydrocarbon pipelines are designed to maintain. Thus, in the absence of costly improvements to enable a higher maximum allowable operating pressure (MAOP), a pipeline designed for transporting hydrocarbons may only be suitable for transporting lower-pressure (i.e., gaseous) CO₂.

The process to convert a hydrocarbon pipeline to transport CO₂ involves installing a dehydration system to minimize water content in the CO₂ stream and “crack arrestors” approximately every 1,600 feet to enable the pipeline to handle greater pressure and modifying the original pipeline materials to ensure they are resistant to corrosion in the presence of concentrated CO₂ (Kenton and Silton n.d.). In some cases, the original pipeline material may need to be replaced completely due to CO₂ pipeline specification requirements (U.S. Executive Office of the President 2021). The pipeline control systems necessary to manage CO₂ transportation are particularly important and provide some challenges that are unique as compared to the transport of other fluids (Jensen et al. 2014). The variation of stream impurities based on the capture source and the supercritical state in which CO₂ is maintained for transport require pressure valves and associated control equipment to be capable of preventing pressure surges, which could require much more extensive equipment replacement than just the pipeline itself (Jensen et al. 2014). The National Petroleum Council conducted an analysis that showed that “a repurposed [natural gas] pipeline was, at best, equal in cost to a new pipeline and would more likely cost more than a new pipeline that is designed for CO₂ transport” (National Petroleum Council 2020).

Safety Considerations

Pipelines offer the ability to connect sources of captured CO₂ for storage or other end uses on a large scale in a manner that is relatively safe compared to other land-based options. However, because pipeline failure can result in the uncontrolled release of large quantities of CO₂ into the environment, transporting CO₂ via pipeline is not risk free. Risks can be mitigated by improving the regulatory framework surrounding CO₂ pipeline quality, inspection, and operation.

Incidents of Pipeline Failure and the Release of CO₂

Statistics on pipeline incidents in the United States are compiled and reported by the U.S. DOT’s PHMSA. PHMSA defines an “incident” as any of the following events:

- (1) An event that involves the release of gas from a pipeline, gas from an underground natural gas storage facility (UNGSF), liquified natural gas, liquified petroleum gas, refrigerant gas, or gas from an LNG facility, and that results in one or more of the following consequences:
 - (i) A death, or personal injury necessitating in-patient hospitalization;
 - (ii) Estimated property damage of \$122,000 or more, including loss to the operator and others, or both, but excluding the cost of gas lost;
 - (iii) Unintentional estimated gas loss of three million cubic feet or more.
- (2) An event that results in emergency shutdown of an LNG facility or a UNGSF.
- (3) An event that is significant to the judgment of the operator, even though it did not meet the criteria of paragraph (1) or (2) of this definition” (U.S. DOT PHMSA 2021).

PHMSA reported a total of 102 CO₂ pipeline incidents between 2003 and 2022, with one injury and zero fatalities. By comparison, PHMSA reported 4,729 incidents causing 1,032 injuries and 242 fatalities relating to natural gas distribution and transmission pipelines, and 3,725 incidents causing 31 injuries and six fatalities for crude oil pipelines over the same time period (U.S. DOT PHMSA 2022c). An analysis of CO₂ pipeline failures reported by PHMSA between the years of 1986 and 2008 showed that the single greatest cause of CO₂ pipeline failures during that time was corrosion (Barker et al. 2016).

The most high-profile incident of CO₂ pipeline failure that has occurred in the United States to date is the rupture that occurred near Satartia, Mississippi, on February 22, 2020. The rupture, which was caused by a landslide, resulted in a local evacuation and caused at least 45 people to receive medical care (Zegart 2021). PHMSA classified the rupture as an incident but did not record any adverse health impacts as “injuries” (U.S. DOT PHMSA 2021).

Health and Environmental Impacts of CO₂ Pipeline Leaks

As illustrated by the Satartia incident, CO₂ pipeline leaks can impact public and environmental health. Because it is heavier than air, CO₂ tends to move to low-lying areas and confined spaces, where it collects in high concentrations and acts as an asphyxiant (i.e., it displaces oxygen which causes suffocation). Health symptoms of exposure to high concentrations of CO₂ include headaches, drowsiness, rapid breathing, confusion, increased cardiac output, elevated blood pressure, and in extreme cases, death (USDA n.d.). CO₂ can be difficult to detect because it is naturally colorless and odorless.

Non-CO₂ Elements Appearing in Pipelines and Associated Risks

CO₂ transported through pipelines will contain some measure of impurities (e.g., oxygen, nitrogen, hydrocarbons, water, etc.). Impurity type and concentration are influenced by factors like CO₂ source, capture technologies employed, and purification system use. DOE has developed a document that provides generic recommended impurity limits for CO₂ pipeline streams (Shirley and Myles 2019). Ultimately, CO₂ pipeline operators are responsible for establishing specification requirements for CO₂ stream composition (Coleman et al. 2018). Requirements appear to vary from project to project depending on factors such as pipeline materials, environmental conditions, end use of the CO₂, and the operator’s level of acceptable risk.³ As described in the following sections, major risks associated with non-CO₂ elements appearing in CO₂ pipelines include changes in phase behavior and pipeline corrosion (Bilio et al. 2009).

Phase Behavior Change

The presence of non-CO₂ elements in a CO₂ pipeline can cause variation in a CO₂ stream’s thermodynamical properties impacting the possibility of phase change during transportation and the stability of flow in the pipeline (Morin 2013). As previously noted, if the CO₂ drops below the critical temperature of 88 degrees Fahrenheit or critical pressure of 72.9 atm, it will change phase from a supercritical fluid to a liquid or gas. Therefore, to maintain a single-phase flow in the supercritical state, pipeline streams containing impurities may need to be operated at higher temperatures or pressures than if pure CO₂ were being transported, which could result in increased costs for pipeline operators (Wetenhall et al. 2014).

Corrosion

Certain impurities in CO₂ streams can cause pipeline corrosion. Elements known to increase steel pipeline corrosion rates include water (H₂O), oxygen (O₂), hydrogen sulfide (H₂S), sulfur dioxide (SO₂), and nitrogen oxides (NO_x). Of these elements, H₂O is the most concerning with regard to pipeline integrity because CO₂ dissolves in water to form carbonic acid, which is corrosive to carbon steel. As such, industry observers have noted that the most effective method of mitigating CO₂ pipeline corrosion is to limit and continuously monitor the amount of water present in the CO₂ stream based on the variation of stream impurities by CO₂ capture source.

Interconnection

Experts agree that reaching federal decarbonization goals will require a significant expansion of CCUS technology supported by a robust build-out of CO₂ transportation infrastructure (U.S. Department of State 2021). CO₂ capture facilities (either point-source or DAC) will need to be linked to areas where CO₂ can

3 FERC addresses purity and interoperability via tariffs for natural gas pipelines. There is less clarity on petroleum and other hazardous liquid pipelines, which appear to be more reliant on industry best practices, private contracts, or individual state regulations.

either be permanently stored or utilized. The most efficient and cost-effective way to do this is to develop an interconnected national CO₂ pipeline network made up of a series of large trunkline pipelines and smaller feeder pipelines (Wallace et al. 2015).

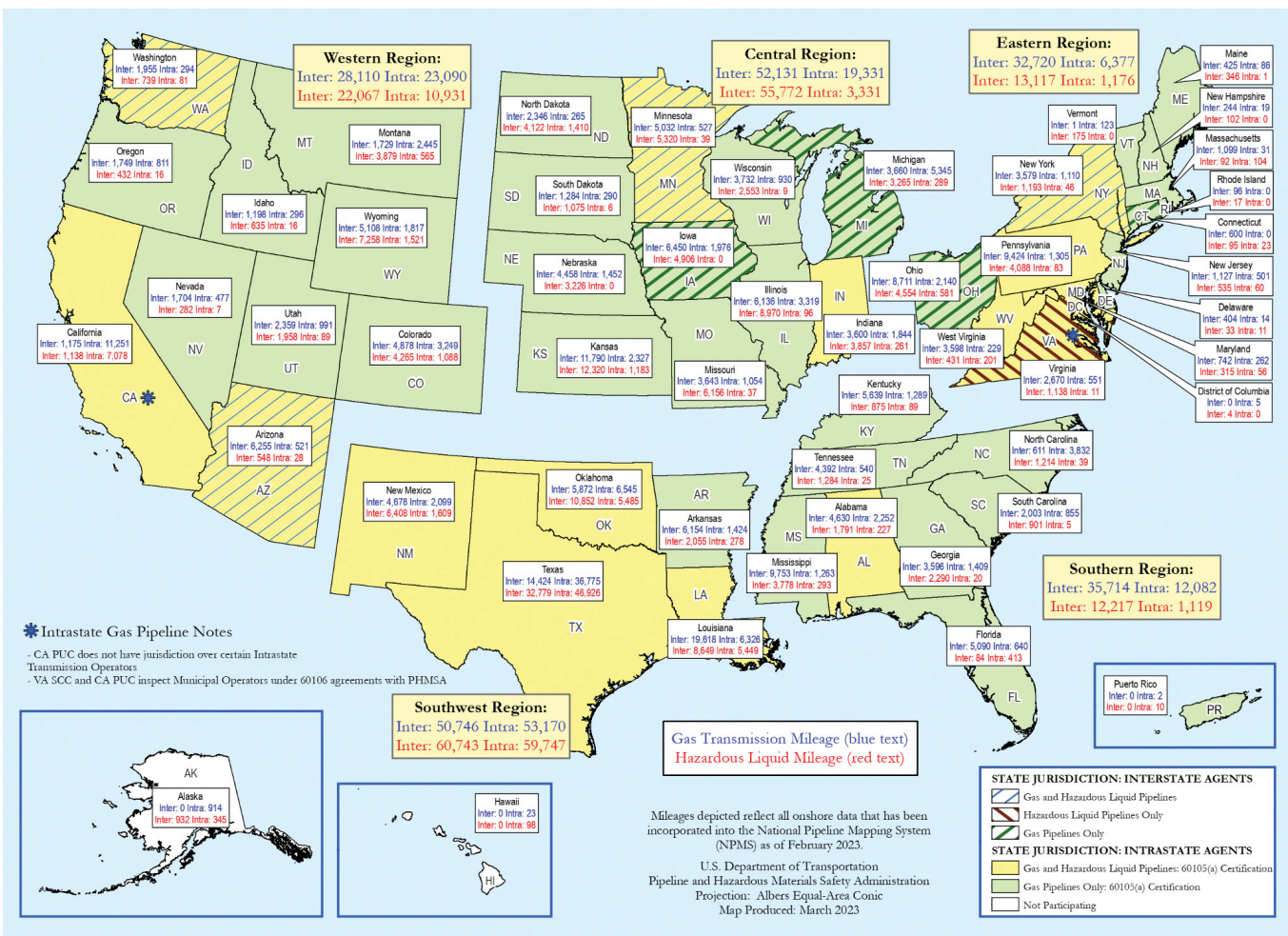
A pipeline interconnection is “a connection point between the transmission company and the receiving party, which may be another pipeline (interstate or intrastate), distribution company, or other customer” (INGAA 2010). Pipeline interconnections, or “interconnects,” can vary in size and complexity depending on the characteristics of the location (e.g., type of connection, equipment involved, etc.).

Unlike natural gas pipelines, which follow FERC guidelines on interconnection (FERC 2021), there appears to be a general lack of guidance regarding the interconnection of CO₂ pipelines. The STB, which regulates non-energy interstate pipelines, requires pipelines under its jurisdiction to have “reasonable, proper, and equal facilities for the interchange of traffic between, and for the receiving, forwarding, and delivering of property to and from, its respective line and a connecting line of a pipeline” (49 U.S.C. 15506). Some states like Louisiana (Louisiana Administrative Code, Title 43, Part XI) and Wyoming Public Service Commission (Wyoming PSC 2023) have enacted more prescriptive intrastate pipeline interconnection guidelines. However, state-level pipeline interconnection guidelines are inconsistent, and in some cases, nonexistent. This lack of guidance can be confusing and impose additional barriers for companies that want to connect sources of CO₂ to trunkline pipelines.

Overview of CO₂ Pipeline Regulation at Federal, State, and Local Levels

The timeline for gaining approval to construct and operate CO₂ pipelines varies significantly based on the jurisdiction(s) where the proposed infrastructure will be sited. FERC and the STB have both rejected jurisdiction over CO₂ pipelines via previous rulings, leaving most economic and siting regulation to state and local entities (Congressional Research Service 2022). As explained below, PHMSA retains jurisdiction over safety regulation for interstate and some intrastate CO₂ pipelines (except in states that have been authorized to act as interstate agents or that have enacted regulations that meet or exceed PHMSA standards for intrastate pipelines; U.S. DOE 2017). In general, states that meet minimum PHMSA standards can participate in a partnership with PHMSA to regulate gas or hazardous liquid pipelines. Safety regulation responsibilities and mileage of pipeline for each state are displayed in **Exhibit 3**.

Exhibit 3. PHMSA Federal/State Cooperative Partnerships



Most CO₂ pipelines currently constructed in the United States are used for EOR operations, which means this infrastructure is mostly located in rural areas near active oil wells. As new incentives and aggressive carbon goals enacted at the federal and state levels increase the economic viability of large-scale CO₂ pipeline infrastructure projects for uses beyond EOR, the range of potential pipeline locations will likely expand to communities that have not been impacted by existing infrastructure (U.S. Executive Office of the President 2021).

With no federal siting and permitting authority, pipeline siting decisions are primarily governed by states except in instances in which pipelines must cross federal lands or use federal funding to aid in construction. Individual state laws govern the form and granularity of siting requirements, but the key factor pipeline developers must consider is accessing public and private ROW and the availability of legal tools to seek ROW access via eminent domain (U.S. DOE 2017).

The process for gaining ROW access can increase in complexity as pipelines cross jurisdictional boundaries. Upon meeting other individual state siting requirements, pipeline operators must negotiate access to the ROW through permits on public land or the purchase of easements to cross private land. In the absence of an agreement, some states provide a legal route for developers to explore and utilize eminent domain.

Comprehensive data on the form and difficulty of multijurisdictional pipeline development is not readily available, as observed by the Council on Environmental Quality (CEQ; U.S. Executive Office of the President 2021). Studying the experience of the large interstate projects currently in progress like the Summit Carbon Solutions, Navigator CO₂, and Wolf Carbon Solutions projects proposed in the Midwest will provide more practical knowledge on the applications of varying state and local requirements.

Following the completion of a CO₂ pipeline, the operator is obligated to conduct maintenance and safety inspections consistent with state-level and PHMSA regulations as well as managing their performance on any terms associated with the permits or agreements governing public and private ROW access.

Federal Responsibilities

PHMSA regulates the safety of pipelines transporting hazardous materials, including CO₂. The Pipeline Safety Reauthorization Act of 1988, which amended the Hazardous Liquid Pipeline Safety Act of 1979, broadened PHMSA's oversight to include CO₂ amid mounting safety concerns associated with large quantities of pressurized CO₂ after the Lake Nyos disaster in Cameroon in 1986 (Krajick 2003). Although this incident was not associated with pipeline infrastructure, the U.S. House of Representatives Energy and Commerce Committee cited the incident, in which CO₂ trapped underneath volcanic Lake Nyos suddenly exploded and killed nearly 1,800 people, as a major reason to broaden PHMSA's regulatory purview (U.S. DOT Research and Special Programs Administration 1991).

Regulatory Treatment of CO₂ Based on Physical State

PHMSA has rulemaking authority for CO₂ pipeline safety regulation under the Pipeline Safety Reauthorization Act of 1988 (Public Law 100-561). In a 1991 rule, PHMSA defined CO₂ as "a fluid consisting of more than 90 percent carbon dioxide molecules compressed to a supercritical state" and has not updated the rule since then despite recognition by PHMSA's predecessor that it has the authority to regulate all forms of CO₂ transport by pipeline. The relatively narrow definition was attributed to the economics of CO₂ transport at the time; supercritical liquid was considered the practical medium for pipeline transmission (U.S. DOT Research and Special Programs Administration 1991). PHMSA stated in the 1991 rule, however, that it would revise the rule if it was "inappropriate" for CO₂ transportation in the future (U.S. DOT Research and Special Programs Administration 1991). Even though CO₂ behaves as a gas or a solid in the form of dry ice when frozen under normal conditions and fluctuations in the state or purity of CO₂ in a pipeline are difficult to monitor over long distances, PHMSA has not updated the 1991 definition.

The Pipeline Safety, Regulatory Certainty, and Jobs Creation Act of 2011 directed U.S. DOT to develop minimum safety standards for the pipeline transportation of CO₂ as a gas. In a 2015 PHMSA study, the agency anticipated that supercritical liquid would remain the most prevalent form of CO₂ transported via pipeline but acknowledged that rule updates would be necessary to implement the statutory mandate (U.S. DOT PHMSA 2015). However, to date, PHMSA has not proposed minimum safety standards for the transport of gaseous CO₂.

Summary of Recent PHMSA Activities: Rulemaking to Update Standards for CO₂ Pipelines

PHMSA's assumption of regulatory responsibility over supercritical CO₂ pipelines in 1988 was not accompanied by comprehensive rule changes to address the unique characteristics of supercritical CO₂ transport. Supercritical CO₂ was simply added to the regulated substances list using existing standards and procedures for the transport of hazardous substances via pipeline (Pipeline Safety Trust 2022). While there have been updates since 1988, none address CO₂-specific characteristics, despite many updates focusing on industry technical standards incorporated by reference via an expansive list of publications.⁴

For example, PHMSA updated rules in 2019 to impose regular inspection intervals for transmission pipelines impacted by extreme weather, expanded the required use of leak-detecting technology to all transmission pipelines, and required that wherever feasible, pipelines must be converted to a diameter and format that can accommodate in-line inspection devices within 20 years (U.S. DOT PHMSA 2019). Pipeline operators typically choose between three methods for testing pipeline integrity: in-line inspection, pressure testing, and stress corrosion cracking direct assessment. According to PHMSA's estimates, when the rule was updated almost 90 percent of hazardous liquid pipelines in high consequence areas⁵ were already capable of accommodating in-line inspection devices and 90 percent of that subset were actively performing in-line inspections (U.S. DOT PHMSA 2019).

Exhibit 4. Satartia Pipeline Rupture Site



Source: Eller (2022)

4 The complete list of industry standards incorporated by reference can be found in the *Code of Federal Regulations* 49, part 195 §195.3.

5 The definition of high consequence areas (HCAs) is dependent on the material transported in a pipeline but generally refers to locations where a spill would have the most severe negative consequences.

In response to recommendations from the National Transportation Safety Board and the GAO following investigations into high-profile pipeline failures, PHMSA completed a multiyear rulemaking process in 2022 that addressed additional safety requirements for new or replacement sections of onshore hazardous liquid pipelines, including supercritical CO₂ pipelines under its jurisdiction. The rules, which took effect October 5, 2022, set new minimum requirements for installing and spacing rupture-mitigation valves or alternative equivalent technologies that allow for the remote or automatic closure of transmission pipelines upon the identification of a rupture (U.S. DOT PHMSA 2022f).

In 2022, PHMSA took further action to respond to growing concerns about CO₂ pipeline safety, stated an intent to initiate rule changes, and solicited research related to CO₂ transmission pipelines, including:

- Responding to numerous instances of pipeline damage due to earth movement around pipelines located in variable, steep, and rugged terrain, including the Satartia incident (see Exhibit 4), PHMSA issued an advisory bulletin encouraging pipeline owners and operators to monitor geological and environmental conditions, including extreme weather near their pipeline facilities (U.S. DOT PHMSA 2022d).
- Issued a proposed civil fine of approximately \$4 million (the largest ever for a CO₂ pipeline) to Denbury Gulf Coast Pipelines LLC, the operator of the CO₂ pipeline that ruptured in Satartia for a lack of timely notification of the threat, the lack of written procedures for normal and emergency operating conditions, and the failure to conduct routine inspections of the pipeline facilities (U.S. DOT PHMSA 2022a).
- PHMSA issued a notice of funding opportunity on February 28, 2022, for the Competitive Academic Agreement Program for four different pipeline safety research projects. One seeks the creation of a tool or model to calculate the potential impact radius of CO₂ pipeline ruptures similar to the potential impact radius guidelines for natural gas pipeline ruptures articulated in 49 CFR 192.903 (U.S. DOT PHMSA 2022e).
- In May 2022, PHMSA announced that it would initiate a new rulemaking for CO₂ pipelines that includes emergency preparedness and response standards. As of May 2023, PHMSA has not released a notice of proposed rulemaking for new CO₂ specific pipeline regulations (U.S. DOT PHMSA 2022b).
- In April 2023, PHMSA announced a CO₂ Public Meeting held on May 31, 2023. The purpose of the CO₂ Public Meeting was to inform rulemaking decisions by discussing key topics such as public awareness, emergency response and effective communication with emergency responders and the public, dispersion modeling, safety measures to address other constituents besides CO₂ in CO₂ pipelines, leak detection and reporting, and geohazards.

Impacted Areas for CO₂ Pipeline Ruptures

Ruptured CO₂ pipelines present different safety hazards than traditional hazardous materials transported via liquid or gas pipelines. On one hand, CO₂ is not flammable and does not pose a threat of combustion, unlike oil and natural gas. Still, the high pressure at which supercritical CO₂ is transported raises the risk of a ductile fracture compared to other hazardous materials transported by pipeline. A ductile fracture occurs as the result of the pipeline material degrading over time resulting in a catastrophic release of pressure that can split the pipeline over a long distance causing the dispersion of earth and pipeline debris (Kuprewicz 2022a). Further, CO₂ is an odorless and colorless gas that is heavier than oxygen and can quickly spread and settle without detection (Congressional Research Service 2022).

Because CO₂ is undetectable without specialized equipment, the public and first responders are at significant risk of exposure to hazardous levels without warning. At mild levels, CO₂ acts as an intoxicant and can cause illness; moderate to significant exposure can cause death by asphyxiation (U.S. Department of Agriculture 2020). As CO₂ displaces oxygen, it can prevent the operation of gasoline or diesel engines and extinguish pilot lights on gas-powered appliances (Kuprewicz 2022a). CO₂ travels quickly and can settle in low-lying areas,

resulting in a nearly undetectable danger zone. The Satartia incident required evacuation of a quarter-mile radius. Unlike liquids or lighter-weight gases that follow a more predictable route and disperse more quickly when released, CO₂'s impact area is largely dependent on the physical characteristics of the terrain and wind in the vicinity of the rupture (Kuprewicz 2022a).

Overview of Other Federal Responsibilities for Economic and Safety Regulation and Enforcement

Clear federal authority to regulate CO₂ pipelines is currently limited to the safety responsibilities of PHMSA noted above. However, pipeline projects must comply with other federal environmental laws and regulations and may require permits from other federal agencies.

The EPA is responsible for enforcing several regulations that could impact a CO₂ pipeline project and the end use of the transported CO₂. The Clean Water Act and Safe Drinking Water Act give the EPA significant authority to respond to actions that impact surface water and groundwater. CO₂ pipelines must comply with regulations issued under these statutes during the construction process, as the Clean Water Act specifically addresses the discharge of dredge or fill material in wetlands for any pipeline that traverses a body of water. The EPA can also engage pipeline operators through its statutory obligation to monitor and support the enforcement response to a leak or spill impacting water resources governed by each law.

While the end use of CO₂ for a wide range of CCUS applications is beyond this paper's scope, the EPA's broad authority over carbon storage should be noted. The EPA retains significant permitting, monitoring, and enforcement authority through the Clean Air Act and the Safe Drinking Water Act to address the injection of CO₂ below ground. To the extent that transportation of CO₂ is tied to successful storage operations, the EPA's regulatory coverage of pipelines may increase as demand grows.

Developers must use construction practices that protect endangered or threatened species. When a pipeline impacts the habitat of an endangered or threatened species, additional permits may be required. The U.S. Fish and Wildlife Service issues permits to address the "incidental take" of an endangered or threatened species and conducts associated enforcement actions. Addressed in multiple federal laws like the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act, incidental take addresses liability for the foreseen but inadvertent harm of a species. Long linear construction projects like CO₂ pipelines impact a broad range of habitats, an aspect of the construction process that can be targeted for litigation by pipeline opponents.

State and Local Responsibilities

Narrow federal regulation of CO₂ pipelines has forced significant regulatory responsibility onto state and local governments. This has created a legal patchwork that, as explored further below, increases compliance costs for interstate pipeline developers and heightens uncertainty about a project's prospects for success. PHMSA's (and FERC's and the STB's) reluctance to expand its rulemaking authority over CO₂ pipelines has often left state legislatures and utility commissions scrambling to develop the regulatory framework for responsible CO₂ pipeline deployment.

A growing number of states have CO₂-specific pipeline-siting rules or pending legislation to that effect. When a pipeline crosses private land, many states allow developers to invoke the power of eminent domain to condemn private property. As landowner complaints have increased, however, several states have considered legislation to narrow or eliminate eminent domain authority for CO₂ pipeline development. One state—California—has placed a moratorium on all CO₂ pipelines until PHMSA announces the results of the current rulemaking. Unresolved safety concerns, opposition to CCUS as a climate solution, and general NIMBYism around energy infrastructure suggest the scope of eminent domain power for CO₂ pipelines will remain a relevant issue for the foreseeable future.

Appendix A briefly describes each state's treatment of CO₂ pipeline permitting, common-carrier status, and eminent domain. Below is a deeper dive into select states' approaches to CO₂ pipeline regulation.

Texas: Low Bar to Become Common Carrier

The first CO₂ pipelines in the United States were built in the early 1970s to service oil fields in West Texas and eastern New Mexico (Wallace et al. 2015). Today the Permian Basin remains home to the largest network of CO₂ pipelines—approximately 2,000 miles—in the country, and several hundred miles of additional CO₂ pipelines now pass through East Texas (Mack and Muñoz-Patchen 2022). Texas's 50-year history of CO₂ pipeline transmission has yielded (and in turn has been helped by) a pipeline-friendly regulatory regime. Notably, the Texas Railroad Commission (RRC) does not require an operator to obtain a permit before building a CO₂ pipeline—or any pipeline—and the RRC “has no pipeline routing or siting authority” (Texas Railroad Commission n.d.b). Instead, a pipeline owner must self-designate as a “common carrier” that “operates, or manages, wholly or partially, pipelines for the transportation of carbon dioxide or hydrogen in whatever form to or for the public for hire [and], files with the commission a written acceptance of the provisions of this chapter” (Texas Legislature n.d.a). A pipeline common carrier may exercise the right of eminent domain (Texas Legislature n.d.a). The RRC has no role in determining whether a company is actually a common carrier or regulating a company's exercise of its eminent domain power, leaving those questions for the courts (Texas Railroad Commission n.d.a).

In describing the leniency of Texas common-carrier law regarding pipelines, legal experts have noted that “the bar is low” because “the operation of a pipeline in Texas is itself indicative of a public purpose, satisfying the common carrier requirement if there is [only] a reasonable probability of use by the public, even if there are no third-party shippers at the time of construction” (Garofalo and Lewis 2020). The Texas Supreme Court reaffirmed this principle in May 2022, writing, “Evidence establishing a reasonable probability that the pipeline will, at some point after construction, serve even one customer unaffiliated with the pipeline owner satisfies the public use requirement” (Terrance J. Hlavinka ... v. HSC Pipeline Partnership, LLC). The RRC does not require CO₂ pipeline operators to publish their tariffs, making it difficult to discern whether the operator is charging equal rates for service (Garofalo and Lewis 2020).

Texas courts have upheld the state's laissez-faire approach to pipeline development, but the Texas Legislature has taken recent steps to reform eminent domain law and improve protections for landowners. In addition to imposing stronger notice and disclosure obligations for pipeline developers, as of January 1, 2022, Texas law requires that the “condemning entity” make a “bona fide offer” to voluntarily acquire property before beginning eminent domain proceedings (Texas Legislature n.d.a). Such an offer must equal or exceed the property value as determined by a certified appraiser and must include a copy of a revised landowner's bill of rights.

Illinois: ICC Gears up to Enforce CO₂ Pipeline Law

Illinois is one of the only Midwestern states with a specific CO₂ pipeline statute, but the law predates the current proliferation of CCUS projects. The state legislature passed the Carbon Dioxide Transportation and Sequestration Act in 2011 (Illinois CO₂ Act) to support Illinois's long-standing coal industry and its efforts to reduce carbon emissions from “clean coal” facilities in the state (Illinois General Assembly n.d.). A significant driving factor behind this legislation was to facilitate the DOE-supported public-private partnership on the FutureGen demonstration project that ultimately did not come to fruition due to capital constraints. However, the Illinois CO₂ Act applies more broadly to pipelines transporting CO₂ “produced ... by any other source that will result in the reduction of carbon emissions from that source.” The act calls for a comprehensive review by the Illinois Commerce Commission (ICC). In addition to standard financial and technical requirements, the act instructs the ICC to consider several factors in determining whether the pipeline is in the public interest, including effects “upon the economy, infrastructure, and public safety” along the route, effects on Illinois's economic development potential, effects on property values, and “any evidence presented by any State or

federal governmental entity as to how the proposed pipeline will affect the security, stability, and reliability of energy” (Illinois General Assembly n.d.).

The Illinois CO₂ Act affords broad eminent domain authority to CO₂ pipeline developers. As an initial matter, the law states that the transportation of CO₂ by pipeline “is declared to be a public use and service, in the public interest, and a benefit to the welfare of Illinois and the people of Illinois,” though, as explained above, the ICC must try to confirm this. The act embeds eminent domain authority within the “certificate of authority” granted to developers to build a pipeline: “A certificate of authority to construct and operate a carbon dioxide pipeline issued by the Commission shall contain and include ... a limited grant of authority to take and acquire an easement in any property or interest in property for the construction, maintenance, or operation of a carbon dioxide pipeline in the manner provided for the exercise of the power of eminent domain under the Eminent Domain Act” (Illinois General Assembly n.d.). Despite providing significant eminent domain power to CO₂ pipeline developers, however, Illinois requires them to use “reasonable and good faith efforts to acquire the easement or property” in question before invoking eminent domain (Illinois General Assembly n.d.). Illinois does not require pipeline operators to be “common carriers.”

Sources familiar with the state’s regulatory process told the authors of this paper that ICC personnel have limited knowledge of CO₂ pipeline operations, which leads to a potential knowledge and resource limitation to conduct the comprehensive review called for by the act. Unless another party intervenes to challenge the developer’s application, they explained, the ICC generally approves the project if the applicant supplies the required information and staff’s review found no issues. Resource and expertise limitations also explained why the ICC should be cautious in attempting to regulate the safety or rates of CO₂ pipelines in operation, they said, with PHMSA and FERC, respectively, best equipped to fill those roles given their long-standing authority over non-CO₂ pipelines. Still, they noted the ICC’s close monitoring of the Navigator Heartland Greenway pipeline (which would store millions of metric tons of ethanol- and fertilizer-based CO₂ underground in Illinois), including a January 2023 recommendation to the presiding administrative law judge that Navigator CO₂ not be permitted to restart the 11-month clock on the ICC’s review by filing an updated application.

In 2023, the Illinois Legislature introduced two bills intended to increase oversight and limit development of CO₂ pipelines pending further safety due diligence, and one bill that provides liability support to CO₂ pipelines. The Safety Moratorium on Carbon Dioxide Pipelines Act would place an immediate moratorium on CO₂ pipelines for two years or until PHMSA finishes its rulemaking process, whichever comes first (Illinois House Bill 3803). This includes any applications already in progress. The Carbon Dioxide Transport and Storage Protections Act would significantly amend the existing Illinois CO₂ Act, including by eliminating the eminent domain authority contained with the certificate of authority. Illinois Senate Bill 2481/House Bill 3119 adds requirements that applicants must meet for certification and removes the ability to receive eminent domain authority. Illinois House Bill 2202 provides the means to obtain pore space for sequestration, requires the creation of the Carbon Dioxide Storage Long-Term Trust Fund that is funded by the sequestration owner/operator, and allows, at completion of a sequestration project, the transfer of the facility to the State of Illinois, who will become the party responsible for all future facility maintenance, liability, and upkeep. All the bills are in the early stages of consideration as of May 2023.

Iowa: Pipeline Epicenter Sees Flurry of Legislation and Litigation

Unlike Illinois, Iowa does not have a separate CO₂ pipeline law but includes “liquified carbon dioxide” under its definition of hazardous liquids (Iowa Legislature n.d.). The Iowa Utilities Board (IUB) has “the authority to implement certain controls over hazardous liquid pipelines ... [and] to approve the location and route of hazardous liquid pipelines, and to grant rights of eminent domain where necessary.” An application for siting approval must include “a general description of the [public and private lands] across which the pipeline will pass,” “the inconvenience or undue injury which may result to property owners as a result of the proposed project,” and “possible use of alternative routes[.]” Further, the applicant “shall hold informational meetings in

each county in which real property or property rights will be affected” at least 30 days prior to filing its petition with the IUB. After the informational meeting, the company may enter private land to conduct surveys “by giving ten days’ written notice by certified mail.”

Iowa gives broad eminent domain authority to pipeline developers. A company granted a permit to build a pipeline “shall be vested with the right of eminent domain, to the extent necessary and as prescribed and approved by the Board” (Iowa Legislature n.d.). Like Illinois, Iowa does not require a pipeline operator to be a common carrier, but “a permit shall not be granted to a pipeline company unless the Board determines that the proposed services will promote the public convenience and necessity” (Iowa Legislature n.d.). At least one pipeline company has argued that CO₂ pipelines are critical to ethanol production and, as a result, Iowa’s economy overall (Kauffman 2022).

Iowa lawmakers have introduced several bills in 2022 and 2023 to eliminate or restrict the use of eminent domain for CO₂ pipelines or to halt application reviews until PHMSA’s rulemaking process concludes. The most procedurally advanced bill—HF 565—passed the Iowa House of Representatives on March 22, 2023, but failed to receive a vote in the Iowa Senate before the 2023 funnel date, meaning that it is dead for 2023. If enacted, HF 565 would have, inter alia, prevented the IUB from granting a company the right of eminent domain unless the company acquires at least 90 percent of the affected route miles through voluntary negotiations. The bill also called for an “interim study” on the application (or use) of eminent domain in Iowa and recommendations to “improve eminent domain policy,” including standards for entering land for surveying and “review of eminent domain public benefit and private-use tests” (Iowa Legislature 2023).

Because Iowa’s ethanol industry is the epicenter of at least three major interstate pipeline projects, it is not surprising that it has become a hotbed of CO₂ pipeline-related litigation. Most of the lawsuits revolve around the role of local government in pipeline-siting decisions. Since October 2022, four counties have passed ordinances imposing requirements on hazardous liquid pipelines, including limitations on developers’ ability to survey land along the approved route. Similar ordinances are under consideration in at least six other counties. In response, developers have also sued to enforce their right to enter and survey private land after the information meetings and with at least ten days’ written notice (Strong 2022).

More significantly, one developer has filed a lawsuit alleging that Story County’s ordinance (which establishes setbacks and other requirements for hazardous materials pipelines) is preempted by the federal Pipeline Safety Act (regarding safety) and Iowa Code Chapter 479B (regarding siting). As to state siting authority, the developer argues that the county ordinance “imposes an additional permitting process ... separate and apart from the standards established by the Iowa Utilities Board,” which effectively “prohibits activity otherwise permitted under state law ‘absent compliance with the additional requirements of local law.’” According to the developer, this renders the county regulation inconsistent with state law and, as such, preempted,” according to Iowa Supreme Court precedent (Kauffman 2022). The outcome of this case has potentially significant consequences for local governments’ ability to influence pipeline development in the face of established state law in Iowa.

Nebraska and Minnesota: Different Approaches to Regulatory Vacuums

Nebraska is one of several U.S. states that provides no state-level regulatory oversight of CO₂ pipelines. Pipeline regulation and oversight is done at the local level in Nebraska. The Nebraska Public Service Commission (Nebraska Commission) has limited siting authority over major oil pipelines (defined as larger than six inches in interior diameter) but has no authority regarding other pipelines in Nebraska, including CO₂ pipelines. The Nebraska Commission did not have purview over major oil pipelines until the passage of the Major Oil Pipeline Siting Act in 2012. As of this writing, no legislation has been introduced relating to CO₂ pipelines during the current session.

As CO₂ pipelines are regulated on the local level, pipeline opponents have encouraged Nebraska counties to adopt muscular regulatory approaches toward CO₂ infrastructure. Landowner advocacy organizations, Bold Nebraska and Nebraska Easement Action Team, have drafted “Model Nebraska County Ordinances for Regulation of Carbon Dioxide Pipelines,” which note that, “in the absence of state legislation routing CO₂ pipelines, the power to determine pipeline location and route falls to Nebraska’s counties” (Bold Nebraska and Nebraska Easement Action Team 2022). The model laws also purport to govern pipeline construction mitigation, pipeline depth, emergency response measures, and abandoned CO₂ pipelines. So far, one county has approved changes to zoning regulations in line with the advocacy groups’ recommendations, with an adjacent county still deliberating (Schindler 2022).

Unlike Iowa, the potential proliferation of county ordinances in Nebraska has not yet triggered legal action by developers. The CEO of Summit Carbon Solutions said in December 2022 that his company had more than 50 percent of the necessary ROWs in Nebraska and was “ahead of schedule” (Dunker 2023). Still, he noted that “a very small percentage” of the necessary land might require use of eminent domain laws. Eminent domain powers for pipeline developers in Nebraska appear confined to “transporting or conveying crude oil, petroleum, gases, or other products thereof,” which arguably does not clearly include or exclude liquid or supercritical CO₂. Bold Nebraska’s founder noted the absence of a state regulatory body and said, “[L]andowners are waiting to see what happens, knowing lots of litigation and moving parts are ahead of us.”

Minnesota presents a notable contrast to Nebraska. Like Nebraska, Minnesota does not have legislative or administrative rules specifically governing CO₂ pipelines, and the definitions of hazardous liquid and hazardous gas do not include CO₂.⁶ In May 2022, the Minnesota Public Utilities Commission (Minnesota Commission) assumed regulatory purview over CO₂ pipelines. The Minnesota Commission unanimously voted that it had “existing authority” to permit the siting of CO₂ pipelines, “including the two multi-state pipelines currently in development” (Minnesota Public Utilities Commission 2022). The commissioners explained that “this decision addresses the growing regional demand to capture carbon dioxide from ethanol plants and transport via pipeline” and “ensure[s] the permitting process for CO₂ pipelines will provide for an orderly review of environmental and socioeconomic impacts when evaluating proposed routes.” In January 2023, the Minnesota Commission formally accepted a developer’s route permit application for what would be the state’s first CO₂ pipeline—but ruled, as part of its decision, that CO₂ pipelines must undergo a full environmental review by the agency, including multiple public comment opportunities (Beach 2023).

One pipeline developer has argued that the Minnesota Commission did not have regulatory authority over CO₂, citing the absence of CO₂ within the definition of nonhazardous liquids (Gunderson 2022). The company also claimed that the Minnesota Legislature might eventually decide the commission does not have authority to regulate CO₂, throwing the company’s previous compliance efforts into question. On the first count, the commission disagreed and noted its experience regulating similar pressurized and temperature-controlled gases in pipelines. On the second count, the Minnesota Commission pointed out that the state legislature would have the opportunity to overrule the commission’s interpretation of its regulatory authority in the 2023 legislative session. On March 8, 2023, legislators introduced House File 2710, which would grant the commission rulemaking authority over CO₂ pipelines.

California: Moratorium on CO₂ Pipelines Pending PHMSA Action; State Agency Recommends Establishing Safety Standards for Siting and Operation of Intrastate Lines

Like Minnesota and Nebraska, California does not have specific CO₂ pipeline rules. Under the California Public Utilities Code, however, “pipeline corporations” that perform services for “the public or any portion thereof” are “public utilities” (Cal. Pub. Util. Code § 216). A pipeline corporation “may condemn any property

⁶ Legislation (HF 2310) enacted in late May 2023 added CO₂ as a gas, liquid, and supercritical state to the definition of “gas” in the Minnesota statute governing pipelines section 216G.02.

necessary for the construction or maintenance of its pipeline.” The term “pipeline corporations” is not defined in the statute, which suggests a CO₂ pipeline that performs services for any portion of the public would qualify. Still, at least one utility has sought clarification from the California Natural Resources Agency (CNRA) that CO₂ pipeline “infrastructure is within the scope of public utility service” (CNRA 2023).

As of January 1, 2023, California has imposed a moratorium on the “utilization” of CO₂ pipelines until PHMSA “has concluded the [ongoing] rulemaking regarding minimum federal safety standards for transportation of carbon dioxide by pipeline” (Cal. Pub. Resources Code § 71465). The law does not distinguish between intra- and interstate pipelines, nor does it appear to restrict the development or construction of CO₂ pipelines; however, the same statute required the CNRA, in consultation with the California Public Utilities Commission, “to provide [by February 1, 2023] a proposal to the Legislature to establish a state framework and standards for the design, operation, siting, and maintenance of intrastate pipelines carrying carbon dioxide fluids (CO₂) of varying composition and phase to minimize the risk posed to public and environmental health and safety.”

In March 2023, CNRA released the required “Proposal to the Legislature for Establishing a State Framework and Standards for Intrastate Pipelines Transporting Carbon Dioxide.” CNRA noted the existing moratorium on CO₂ pipelines and PHMSA’s “estimated” completion date of late 2024 for its rulemaking. However, it expressed concern that tying intrastate CO₂ pipelines to an “unclear” timeframe for PHMSA action “could stall CCUS and carbon removal projects that are critical to meet the State’s statutory 2045 carbon neutrality target.” As a result, CNRA recommended “statutory changes” to “allow for intrastate pipelines transporting CO₂ to proceed in California once either PHMSA or California has adopted safety regulations of these pipelines.” Specifically, CNRA recommended the establishment of “standards regarding how [intrastate] pipelines are designed, sited, operated, and maintained” to “minimize any risks to public health, safety, and the environment.”

At the legislature’s instruction, CNRA’s guidance was limited to protecting “public and environmental health and safety.” The agency did not offer recommendations regarding the economic regulation of CO₂ pipelines or the scope of CO₂ pipeline companies’ eminent domain powers. CNRA recommended its Pipeline Safety Division (located within the Office of the State Fire Marshal) review the safety aspects of pipeline-siting decisions (e.g., potential impact areas from ruptures) but alluded to other “local and State entities” with additional siting authority. CNRA also confined its proposed standards to intrastate pipelines (again, at the legislature’s instruction), noting that PHMSA “maintains regulatory jurisdiction⁷ over interstate pipelines, which encompasses pipelines that travel between states and in federal waters.” This suggests that, unlike intrastate pipelines, interstate pipeline projects would remain subject to the current moratorium regardless of whether the state implements standards sooner. It remains unclear whether California will follow other states in exercising siting authority over interstate pipelines.

Matters of Unclear Jurisdictional Authority

To this point, this report has described the range of regulatory authority exercised by federal, state, and local authorities over CO₂ pipelines. The following subsection highlights areas where authority is notably unclear or, in some cases, absent altogether, and examines the implications for CO₂ pipeline development.

Economic Regulation of CO₂ Pipelines

Unlike safety regulation, which falls under the jurisdiction of PHMSA, for pipelines transporting supercritical CO₂, no federal entity has clear responsibility for the economic regulation of CO₂ transmission pipelines. The two agencies that exercise economic authority over pipelines—FERC (oil and natural gas pipelines) and the STB (all other pipelines)—have issued rulings rejecting regulatory authority over CO₂ pipelines (Congressional Research Service 2008).

7 PHMSA’s regulatory authority is limited to safety regulation; it does not exercise siting authority.

The FERC and STB decisions resulted from requests by Cortez Pipeline Company for declaratory rulings challenging each entity's jurisdiction over a planned CO₂ pipeline from Colorado to Texas. FERC ruled in favor of Cortez in April 1979 by rejecting jurisdiction over CO₂ pipelines. FERC noted that its obligation to protect consumers from unfair natural gas prices under the Natural Gas Policy Act did not extend to the small amount of methane natural gas captured within the production and transport of CO₂, as the methane would not be separated for end use or direct sale.

Following FERC's ruling in its favor, Cortez Pipeline Company approached the Interstate Commerce Commission, the STB's predecessor agency, asking for a similar ruling on Interstate Commerce Commission's responsibilities for addressing financial disputes associated with non-oil or non-natural gas pipelines. Following a formal review, Interstate Commerce Commission determined that it did not have authority over pipelines transporting supercritical CO₂ because CO₂ did not meet their interpretation of the statutory definition of natural or artificial gas (Cortez Pipeline 1980). To date, neither FERC nor the STB has revisited these rulings, which has sidelined federal regulators as CO₂ transportation infrastructure development has expanded.

The role of state utility regulatory commissions in the construction of interstate pipelines is usually confined to initial safety considerations (rather than ongoing operational safety oversight) and siting approval. Some states require companies designated as common carriers to file or otherwise publish rates, but it remains unclear whether those rules would apply to CO₂ pipelines. Indeed, some industry experts contacted for this report admitted they did not know that FERC did not regulate rates for interstate CO₂ pipelines. Precedent exists for state and federal partnership on interstate infrastructure (e.g., interstate electric transmission where FERC sets the rates and public utility commissions address permitting and siting). In the absence of state legislation dictating rate regulation responsibility for CO₂ transport, economic regulation is left to the federal authorities—who have already rejected the responsibility. This gap results in CO₂ pipeline users' reliance on private contracts between CO₂ generators, end users, and pipeline operators, with no clear path for dispute resolution outside of the judicial system.

PHMSA Regulation over Non-Supercritical CO₂

Citing the Code of Federal Regulations, which defines CO₂ only in its 90 percent–concentrated supercritical state, PHMSA has declined authority to regulate pipelines transporting CO₂ in a gaseous state or as a liquid at lower concentrations. The transport of CO₂ in different physical states along the route of an interstate pipeline network raises questions about the scope of PHMSA authority. Current rules do not definitively address whether PHMSA can regulate a pipeline network if any portion includes supercritical transport or if authority is limited to the sections of the network specifically dedicated to supercritical transport (Soraghan 2023).

EJ Concerns

Federal agencies have been charged with integrating the principles of EJ to the greatest extent possible within their individual responsibilities since 1994, when President Bill Clinton issued Executive Order 12898 formalizing expectations for the consideration of environmental impacts on minority and low-income communities (Federal Register 1994). More recently, Executive Order 13985, issued by President Joe Biden in January 2021, directed federal agencies to advance racial equity and support underserved communities by initiating equity action plans (Office of the President 2021).

Due to the lack of a uniform federal siting authority for CO₂ pipelines (e.g., FERC's plan to prioritize EJ and consent-based siting principles in the development of interstate natural gas pipelines and building staff capacity with an EJ focus; FERC 2021), the responsibility for ensuring EJ principles are applied to CO₂ pipeline development is splintered between other permit-issuing entities like the EPA, the U.S. Army Corps of Engineers, and states. The lack of a clear single coordinating authority means that communities impacted by CO₂ pipeline developments must track multiple state and federal processes to effectively communicate concerns or negotiate development parameters.

The BIL codifies several policies expediting federal approval for infrastructure projects, which potentially adds further uncertainty to agency regulatory responsibilities for CO₂ pipelines. The BIL prioritizes interagency communication on overlapping permitting responsibilities and provides several tools for federal agencies to expedite or simplify the review of proposed infrastructure projects. The desire to speed up the deployment of renewable or clean energy infrastructure to fight climate change has resulted in some observers questioning the wisdom of deploying CCUS infrastructure before the regulatory framework is in place to do so safely.

Securing Regulatory Approval for Multijurisdictional Pipelines

Pipeline developers are used to the common challenges of gaining approval from all the government entities along a proposed pipeline route and negotiating for easements and purchases of private property. However, no single entity is responsible for ensuring that CO₂ pipelines broadly comply with multijurisdictional responsibilities. For example, natural gas pipeline developers must secure a certificate of public convenience and necessity from FERC that demonstrates the developer has identified all necessary local, state, and federal permits as well as other due diligence requirements. The absence of a single coordinating entity deprives CO₂ pipeline developers of the security of a project-wide approval and associated land access tools—and removes a layer of regulatory protection for both consumers and residents along the route.

Multiple unique issues can arise in each community potentially hosting a portion of a proposed construction project. Some states are looking for ways to simplify the development process. Wyoming, through its Pipeline Corridor Initiative (WPCI), has identified approximately 2,000 miles of potential routes for CO₂ pipelines on public and private land across the state. More than half of the routes are located on Bureau of Land Management (BLM)-managed land, so the state has sought and received approval for updates to land and resource management plans from the BLM across the agreed upon routes for future pipeline transmission development (State of Wyoming 2019). Work on the WPCI began more than a decade ago through a partnership between state policymakers, the Wyoming Energy Authority, the University of Wyoming Enhanced Oil Recovery Institute, and oil and gas industry stakeholders in anticipation of future demand for CCUS pipeline infrastructure (State of Wyoming 2019). Although any projects along WPCI-approved routes will still require all applicable federal, state, and local permits and private easements, the WPCI is designed to mitigate opposition to future transmission infrastructure by clearly identifying route corridors and engaging landowners before projects take shape.

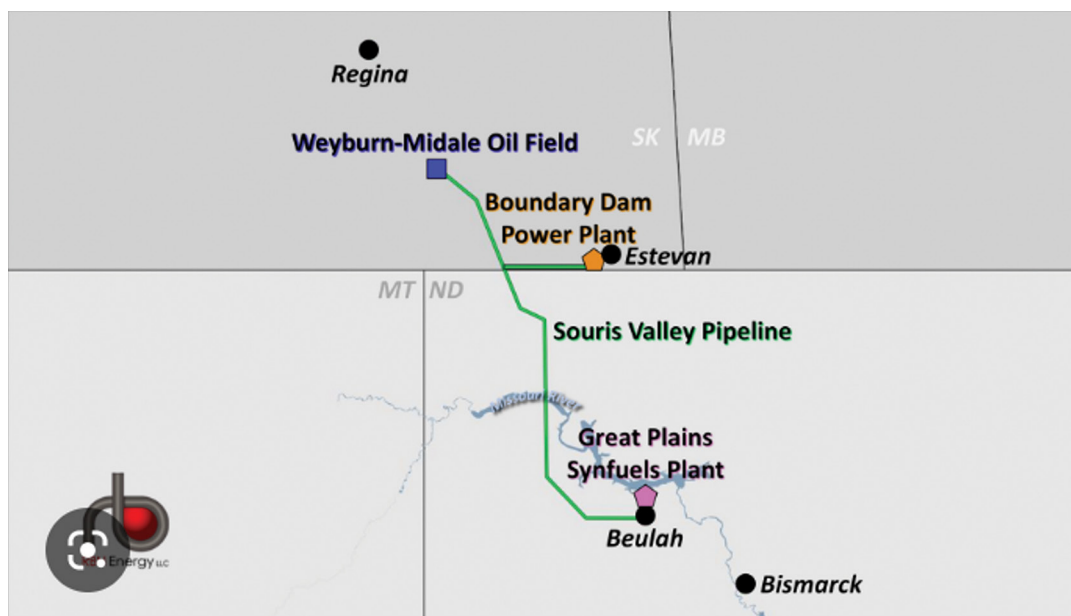
International Approaches to CO₂ Pipeline Regulation

Nearly all the world's CO₂ pipeline infrastructure is in the United States, and most new development is taking place within U.S. borders, likely in response to the resilient U.S. hydrocarbon sector (including ethanol) and generous federal incentives for carbon capture projects. Still, other countries have or are pursuing major CO₂ pipeline projects—and applying different regulatory approaches. In Canada, the province of Alberta reports eight proposed CO₂ transportation projects through 2030, with another six already in use. The largest is the 150-mile Alberta Carbon Trunk Line (ACTL), an integrated, large-scale CCUS system that delivers captured industrial CO₂ emissions for use in EOR and permanent storage in central Alberta. As of April 2022, the ACTL transported 1.6 million metric tons of CO₂ per year, a fraction of its 14.6 million metric ton capacity intended to encourage future interconnections. Because the ACTL does not cross provincial borders, it falls exclusively under Alberta's provincial jurisdiction. The Alberta Energy Regulator has siting and safety authority over all intraprovincial pipelines (except natural gas utility pipelines, which fall under the provincial Alberta Utilities Commission), including CO₂ pipelines (Alberta Energy Regulator 2023).

If a CO₂ pipeline crosses provincial or international borders, the federal Canada Energy Regulator (CER) has exclusive and comprehensive oversight, including pipeline construction and operation, as well as financial and economic aspects. For example, the CER has jurisdiction over the Souris Valley pipeline, which has transported CO₂ from a synthetic natural gas plant in North Dakota to the Weyburn-Midale Oil Field in Saskatchewan since

2000 (Exhibit 5). The CER may also assume jurisdiction over an intrastate pipeline if it determines the pipeline is a component of a larger “federal undertaking” (e.g., a pipeline system that delivers material to the United States). A company must apply for a permit with the CER, which will review the proposed project, including the company’s engagement activities and potential effects on people, property, and the environment. The CER must confirm that the pipeline “is in the public’s interest,” but the pipeline does not need to be a common carrier (CER n.d.b).

Exhibit 5. Souris Valley CO₂ Pipeline Route



Source: RBN Energy (2021)

Under Canadian law, the CER has eminent domain authority for private pipeline projects. If a company is unable to reach a land agreement for access to lands required for an authorized pipeline, it may apply to the CER for a “right of entry order.” To resolve any conflicts between companies and private landowners over ROW, however, the CER has created a no-cost “alternative dispute resolution” (ADR) process (CER n.d.a). The CER’s ADR program—essentially, voluntary mediation with a neutral third party—has a 98 percent success rate in avoiding “a more formal hearing process,” according to the CER.

Outside of Canada, other multi-user CO₂ pipeline networks are in development, including substantial offshore systems in northern Europe (which are outside the scope of this paper). Germany’s largest pipeline company is in the planning stages of a major land-based CO₂ pipeline network that will support the country’s circular CO₂ economy—moving CO₂ from industrial emitters to industrial users and storage sites—and feed into the cross-border Delta Rhine Corridor (summarized in the CO₂ and hydrogen section below). Germany currently has no federal legislation relating to CO₂ transportation or storage. Germany’s economy and climate minister said in January 2023 his country “is working on a carbon management strategy to create legislation for the use of such technologies ... by mid-2023” (AP 2023). The non-governmental German Technical and Scientific Association for Gas and Water (known by its German initials DVGW) has set technical standards for CO₂ pipeline safety and operation—but standards around the siting of CO₂ pipelines are not well developed. For natural gas pipelines, companies typically secure land rights with a land-use agreement and restricted personal easement. If private owners refuse to grant personal restricted easements, private owners may be forced to grant such rights by means of compulsory expropriation proceedings in the German court system (Stuhlmacher and Stappert 2023).

CO₂ and Hydrogen

Hydrogen (H₂) has received significant attention and supportive federal investments from BIL and IRA for its potential as a decarbonization tool. The use of hydrogen as a fuel or energy storage medium for power and/or heat generation and transportation has the potential to produce no GHG emissions, making it an attractive decarbonization option for fossil-intensive processes, particularly in the industrial sector. Although the majority of hydrogen today is produced from natural gas via steam methane reformation and involves GHG emissions at the point of production, DOE is investing in zero-emission hydrogen production from renewable and nuclear generation, which could vastly improve the emissions reduction impacts of hydrogen use. The expansion of “clean hydrogen” faces technical and cost challenges, as well as reliance on a dedicated infrastructure network and/or blending into existing natural gas pipelines to transport hydrogen from production points to end-use customers (U.S. DOE 2022b).

Like CO₂ pipelines, hydrogen pipelines lack clear regulatory guidance at the federal and state levels. No statute expressly provides for federal regulation of the construction or siting of interstate hydrogen pipelines, or their rates or services. Like CO₂, PHMSA currently exercises limited regulatory authority over hydrogen pipeline safety. CO₂ and hydrogen are closely linked because one of the most mature “clean” hydrogen technologies—steam methane reformation with carbon capture, known as “blue hydrogen”—will require CO₂ transportation infrastructure.⁸ Still, a series of different characteristics, including the transportation of hydrogen as a gas, a wider range of uses for hydrogen as an energy product, and a different safety profile compared to CO₂ suggest that regulatory advancements around CO₂ pipelines offer limited lessons for the regulation of hydrogen pipelines.

Unlike CO₂, hydrogen is transported via pipeline as a gas. This increases the likelihood that federal agencies will exercise oversight under existing laws. FERC does not regulate hydrogen pipelines; however, the Natural Gas Act gives FERC jurisdiction over the construction, siting, and economics of “natural or artificial gas” pipelines. As an initial matter, an argument that gaseous hydrogen—the most abundant element in the universe—should fall under a law regulating natural or artificial gas (i.e., all gas) appears to be on solid footing, though legal observers note FERC and reviewing courts have construed the term “natural gas” narrowly. Even if pure hydrogen would not qualify as a “natural gas,” blended hydrogen and natural gas would likely be deemed an “artificial gas.” Although this would foreclose the possibility of FERC jurisdiction over a hydrogen-only pipeline system, it would trigger FERC jurisdiction over the transmission mechanism experts view as most promising because it takes advantage of existing infrastructure.

Hydrogen’s undisputed status as an energy commodity further distinguishes it from CO₂ (Bermudez et al. 2022). Hydrogen already powers certain heavy industry sectors and shows potential uses in other hard-to-abate sectors (e.g., long-range transportation). As a result, hydrogen pipeline proponents can more easily claim that hydrogen’s energy potential constitutes a public use or provides a public benefit, more akin to natural gas or oil than CO₂. Under most state siting regimes, the showing of public use triggers companies’ power of eminent domain. As explored below, legislative action to reclassify CO₂ as an energy product (or at least to clarify that it is not a waste product) could be important to facilitating CO₂ pipeline siting at the state level.

Given specific and long-standing concerns around hydrogen’s flammability compared to natural gas, eminent domain will likely be critical to developing a dedicated and widespread hydrogen transmission network (Kuprewicz 2022b). Commission staff told the authors they expect stronger public opposition to hydrogen pipeline projects than to CO₂ pipeline development. Although CO₂ presents unique safety risks, it is not flammable. Hydrogen, on the other hand, is more flammable, combustible, and energy dense than even natural gas. Such factors contribute to hydrogen igniting in relatively low concentrations in the air and detonating with extreme energy release. Hydrogen molecules (H₂) are smaller than natural gas molecules and more prone to leakage. These concerns cast doubt on assumptions that CO₂ and hydrogen pipelines can simply use the same ROW because landowners are likely to view the relative risks of each pipeline differently.

8 CO₂ pipeline company Wolf Midstream claims its ACTL was a key factor in industrial gas supplier Air Product’s decision in 2021 to locate a \$1.6 billion net-zero hydrogen energy complex in Alberta (Kramer 2022).

Questions for Future Policy and Regulatory Decision-makers

As the preceding sections describe, the evolution of the CCUS market and demand for long-range pipeline transmission capabilities present new challenges for regulators. Below are questions PHMSA, state regulators, and DOE should consider to enhance the effective safety, siting, and economic regulation of CO₂ pipelines at the federal and state levels.

Questions for PHMSA

How should CO₂ be defined in federal regulations to ensure a consistent standard of safety across all state and local jurisdictions?

Currently, PHMSA only has regulations applicable to pipelines transporting CO₂ in a supercritical state with a concentration of at least 90 percent CO₂. This would seem to create significant regulatory gaps over the safety of pipelines that transport CO₂ as a liquid or gas. This lack of clarity is exacerbated in pipeline systems where transport states fluctuate due to natural variations in temperature.

As PHMSA undertakes a significant update to the rules governing CO₂ transmission, a key consideration will be the state and purity at which CO₂ may be transported. In the absence of a more comprehensive definition of CO₂ in federal safety regulations—perhaps as a “fluid” at optimal concentrations to be determined—pipeline operators may shop for development opportunities in jurisdictions with the least restrictive safety regulations, with negative repercussions for a widespread and shared network.

How should the potential impact radius for CO₂ pipeline ruptures be defined to enable pipeline operators to plan for emergencies and coordinate with local first responders?

The current lack of a robust dispersion model and limited practical experiences with the behavior of CO₂ at different states during pipeline ruptures represent significant information gaps that contribute to public safety concerns.

PHMSA has issued grant funding to develop a modeling tool to identify the potential impact radius of CO₂ pipeline ruptures. This tool may not be completed for another two to three years. As the market for CO₂ transmission infrastructure increases, in part due to federal policy and economic incentives intended to hasten CCUS deployment, PHMSA should consider interim guidance on the potential impact radius to aid state regulators who will face the obligation to act on CO₂ pipeline-siting proposals before a robust methodology exists to prepare communities for the public safety concerns associated with CO₂ pipeline ruptures and emergency response.

The inability to detect the presence of CO₂ without visual confirmation of a pipeline leak presents a unique safety challenge for the public and first responders identifying and responding to a safety threat. Current rules require the odorization of combustible gases in many pipeline transport scenarios (CFR 192.625). Because a reliable dispersion modeling tool requires years of development, adding an odorization requirement for CO₂ could ensure that hazardous quantities would be detectable without specialized equipment or training pending more detailed rules and public awareness of the CO₂ transportation infrastructure.

How should impurities be addressed?

CO₂ transported through pipelines will contain some measure of impurities (i.e., no CO₂ pipeline stream is made up of 100 percent pure CO₂). This often depends on the source of the CO₂ and the extent to which a CO₂ stream has been “cleaned.” In general, higher levels of impurities are associated with higher pipeline corrosion rates. Additionally, the presence of non-CO₂ elements in a CO₂ pipeline can impact the CO₂’s critical point (i.e., the temperature and pressure at which it becomes a supercritical fluid), therefore changing the temperature and/or pressure at which a pipeline must operate to maintain a supercritical state. The presence of toxic chemicals like hydrogen sulfide and sulfur dioxide can increase risks to public and environmental health in the event of a leak or rupture.

PHMSA and other regulators should consider the value of setting uniform purity standards for CO₂ transported through open-access pipelines. In the absence of federal or state regulations that establish such standards, individual pipeline operators are left to dictate their own purity standards. This has resulted in a variety of impurity thresholds for pipelines across the country. As the U.S. CO₂ pipeline network expands, clear and consistent purity standards could facilitate the interconnection process and ensure that pipeline operators are transporting CO₂ safely and efficiently.

Questions for State PUCs and Other State-level Regulators

How can states establish clear permitting standards for CO₂ pipelines and confirm authority of state PUCs over permitting and economic regulation?

Several states do not have any laws governing the permitting of CO₂ pipelines. This has led to disparate regulatory processes in states with pending CO₂ pipeline projects, with PUCs in some states (e.g., Minnesota) evaluating route applications based on existing non-CO₂ pipeline standards and others (e.g., Nebraska) declining to broaden their jurisdiction and leaving the process to local governments. A scenario where the state is evaluating route applications based on existing non-CO₂ standards creates uncertainty about the reliability of PUC decisions in the absence of stated authority. In states where local governments are tasked with CO₂ pipeline project evaluations, developers bear the burden of seeking county-by-county permission while facing the prospect that different counties will reach different decisions regarding technical standards. In states that regulate CO₂ pipelines under broader statutes or rules governing additional types of pipelines, companies encounter widely different permitting processes that add to the regulatory burden.

Clear and comprehensive laws governing the permitting process for CO₂ pipelines will streamline the regulatory process for developers and close gaps—especially around safety and environmental sustainability—during construction. Express state authority may also reduce litigation around state versus county control under the doctrine of preemption. Furthermore, legislatures could consider strengthening PUC authority vis-à-vis local governments. For example, South Dakota allows its PUC to supersede zoning and other local land-use controls if the PUC finds “that such rules, or regulation, or ordinances, as applied to the proposed route, are unreasonably restrictive in view of existing technology, factors of cost, or economics, or needs of parties” (SD 49-41B-28).

In states with nonexistent or less-developed CO₂ pipeline regulations, legislatures or PUCs could consider undertaking a benchmarking, or similar analysis, to evaluate other states’ experiences overseeing CO₂ pipelines and identify regulatory best practices.

How should state policies be updated to ensure PUCs have the resources and technical expertise to effectively regulate CO₂ transportation infrastructure?

As more state PUCs face applications from pipeline developers for the creation of new CO₂ pipelines, do they possess the authority to ensure pipeline companies provide a proportional share of the costs to administer CO₂ pipeline regulation? To what extent can charge-back provisions be implemented or modified to ensure the true cost of PUC staff and consultant time on CO₂ pipeline cases is not subsidized by taxpayers?

While many PUCs can recover the costs of regulation from CO₂ pipeline applicants, those that lack an existing state-level siting regime or charge-back authority could find themselves needing to seek greater financial resources from the legislature and ultimately their constituents or customers. In the absence of clear safety methodologies, the applicants who will experience financial gain from a pipeline development should fund the resources to provide for their safe operation. This will ensure commissioners’ review of proposed CO₂ pipelines are not limited by existing internal experience while remaining responsible stewards of public resources.

The unique characteristics of CO₂ present regulatory challenges even when limited to the scope of the current definition of CO₂ in PHMSA’s hazardous liquid transportation rules. Do the resources provided through annual

PHMSA State Pipeline Safety Base Program grants⁹ provide sufficient support to manage CO₂ pipeline inspections and the professional staff with CO₂-specific expertise?

What additional state legislative actions need to occur to increase alignment for interstate CO₂ pipeline projects?

In the absence of FERC or other federal agencies establishing siting and permitting authority over interstate CO₂ pipelines, states could consider several legislative actions to increase alignment for interstate CO₂ pipeline projects.

What kind of common-carrier requirement makes sense for CO₂ pipelines?

The common-carrier requirement in certain states—that a pipeline company provides nondiscriminatory access to services at standard rates—is based on sound policy. Common-carrier requirements encourage an efficient network where producers can access shared infrastructure and not build duplicative lines. In the case of CO₂, a common network would help maximize the number of potential CO₂ producers who otherwise might not build the infrastructure to ship their CO₂ to utilization or storage sites. Still, common-carrier rules present potential obstacles for the fledgling CCUS industry. CO₂ transportation has historically been a private endeavor without a public market, as it is not sold to the public or used as an energy resource. That market is developing, but the number of current CO₂ pipeline users remains low, making it more difficult for a company to prove it actually provides service to third parties—especially at the project-permitting stage.

Adoption of a “Texas-style” approach, embodied in that state’s CO₂ pipeline statute and refined by the Texas Supreme Court, might address these concerns. As explained above, a Texas pipeline satisfies common-carrier requirements if there is a “reasonable probability” of use by the public, even if there are no third-party users at the time of construction. Although the Texas Supreme Court did not specify the evidence required to show a reasonable probability, it noted that the company’s failure to identify “any possible customers” or even know about “any other entity ... near the pipeline route that owned CO₂” meant it failed to establish a reasonable probability of future use (Texas Rice Land Partners, Ltd. V. Denbury Green Pipeline-Texas, LLC).

This formulation arguably strikes a balance between encouraging construction of accessible CO₂ transmission pipelines with a higher likelihood of attracting future CO₂ shippers while not making pipeline permits dependent on the existence of said shippers at the time of construction. Further, common-carrier requirements in one state may have implications for pipeline development in a non-common-carrier state. It is unclear whether a common-carrier state could require a pipeline company to be a common carrier in every state along the route. In the absence of a federal regime, greater state alignment around a flexible common-carrier standard could improve regulatory certainty for interstate CO₂ pipeline developers.

Should more states create alternative dispute resolution mechanisms for CO₂ pipeline-siting disputes?

Ongoing litigation among developers, property owners, and local governments threatens to slow down or halt pipeline development. In April 2023, for example, the Iowa Supreme Court rejected a pipeline surveyor’s motion to dismiss a property owner’s lawsuit claiming the surveyor—working for developer Summit Carbon Solutions—trespassed on his land. After months of appeals, the case is now scheduled for trial in late June. Several other cases are pending in Iowa alone. Like Canada, at least three U.S. states (Missouri, Utah, and Virginia) have ADR programs to resolve siting disputes in energy or transportation contexts, though only one—in Utah—appears to be active. Utah’s Department of Transportation reported a 75 percent reduction in takings-related litigation after routing disputes through the Utah Department of Commerce’s Office of the Property Rights Ombudsman to mediate disputes. States may wish to consider implementing ADR procedures to reduce the cost and time of disputes around pipeline siting.

⁹ PHMSA State Pipeline Safety Base Program grants may fund up to 80 percent of the cost of “...personnel, equipment and activities reasonably required to carry out inspection and enforcement activities of intrastate pipelines facilities” (DOT PHMSA n.d.).

Questions for DOE

DOE currently manages multiple significant resources intended to spur CCUS growth. Specifically for CO₂ pipelines, they address access to capital for large-capacity, common-carrier CO₂ transport projects through the Loan Programs Office (LPO) Carbon Dioxide Transportation Infrastructure, Finance, and Innovation (CIFIA) program (U.S. DOE LPO n.d.). CIFIA helps companies overcome barriers to deployment such as “high capital costs, short-term demand and utilization uncertainty, and chicken-and-egg challenges” (U.S. DOE LPO n.d.). The DOE Office of Clean Energy Demonstrations, which is tasked with accelerating the deployment of clean energy technologies funded via the BIL, is working to distribute more than \$3 billion in grant funding to support carbon capture demonstration projects (\$2.5 billion) and large-scale carbon capture pilots (\$937 million; U.S. DOE Office of Clean Energy Demonstrations n.d.).

How can DOE ensure its research, development, deployment, and diffusions programs encourage a collaborative approach to multijurisdictional regulation?

Given that detailed PHMSA safety guidance could still be years away, DOE could consider structuring its funding opportunities to prioritize the selection of applicants for CCUS projects that demonstrate a commitment to innovative and thorough safety procedures. Recognizing that the CIFIA program requires adherence to current PHMSA safety policy, elevating key safety components within opportunity scoring criteria could encourage developers to prioritize the development of innovative safety strategies in concert with technologies that are economically feasible. Specifically, the inclusion of route-specific strategies to measure CO₂ pipeline rupture impact zones and emergency communications protocols inclusive of each community and regulatory authority impacted by a proposed project would afford DOE the ability to demonstrate the value it places on pipeline safety in the absence of updated PHMSA regulations.

How should the CIFIA program define common-carrier requirements in the absence of consistent common-carrier rules?

The CIFIA program guide defines a common carrier as a “transportation infrastructure operator or owner that publishes a publicly available Tariff containing the just and reasonable rates, terms, and conditions of nondiscriminatory service, and holds itself out to provide transportation services to the public for a fee.” The guide does not state when a tariff must be published, but the website clarifies that it must be published “by project completion.” As part of the financial details required, loan applicants must provide a “description of how the Tariff rate will be determined and applied in a nondiscriminatory fashion.”

Perhaps in response to the dearth of CO₂ tariff regulation at the state level, the guide reads, “[i]f an applicable regulatory body (e.g., a state PUC or pipeline safety commission) has not made a determination that a Project Tariff contains just and reasonable rates, terms, and conditions of nondiscriminatory service, DOE will evaluate a project’s satisfaction of this eligibility requirement on a case-by-case basis” (U.S. DOE 2022a, 7).

The lack of consistent common-carrier rules suggests that CIFIA’s thorough definition of common carrier and robust tariff requirements are wise. As discussed above, the existing patchwork could lead to situations where companies favor routes without common-carrier requirements to avoid the risk that a line permitted in one (non-common carrier) state would be prohibited in a state that requires CO₂ pipelines to share access. By linking financial assistance to a stringent definition of common carrier, DOE increases the likelihood that CIFIA-supported projects will meet a given state’s common-carrier requirements. CIFIA may consider removing deference to applicable regulatory bodies, whose method of evaluating common-carrier status may be less rigorous.

Conclusion

The uncertainty around CO₂ pipeline regulation across all levels of government jeopardizes the development of an interconnected, accessible, and nationwide CO₂ pipeline network. Federal regulations provide a baseline for pipeline safety and environmental protection, but significant gaps remain. PHMSA does not exercise jurisdiction over pipelines transporting CO₂ as a gas or liquid or in concentrations below 90 percent, nor does it provide guidance on emergency response measures in the event of a leak or rupture. PHMSA is developing a new rulemaking to bolster its supervision of CO₂ pipelines, but the announcement is not expected until at least 2024. On the economic front, there is currently no federal oversight to ensure that CO₂ pipelines are accessible and affordable to CO₂ shippers in a way that facilitates the widespread deployment of CCUS technologies and advances emissions reduction goals.

In the absence of comprehensive federal rules, individual states are left to fill the void. Not surprisingly, the result has been a patchwork of safety, environmental, and economic regulation that has encouraged development in some states but discouraged it in others. At best, these myriad laws increase the regulatory burden of building the thousands of miles of additional CO₂ pipelines needed to support CCUS. At worst, they could be inadequate—both to protect public safety as some projects barrel forward and to encourage the strategic development needed to transport ever-increasing amounts of captured CO₂ in an environmentally and economically beneficial way. Local governments have understandably attempted to address citizen concerns by hardening zoning and other regulations under their purview—but such atomized oversight threatens emissions reduction goals by extending construction timelines or killing projects altogether.

Federal agencies can help lead research efforts to address the public's rising concerns over CO₂ pipeline safety and pave the way for trusted, comprehensive, and efficient regulation. The lack of information about critical facts (e.g., how far CO₂ can disperse in dangerous concentrations), or best practices regarding emergency response, has led to public protests, litigation, and—enacted in California, and under consideration elsewhere—a moratorium on the operation of CO₂ pipelines pending the conclusion of PHMSA's rulemaking. A comprehensive risk assessment of CO₂ pipelines could help identify and quantify the potential hazards associated with their operation. Developing better methods to detect and mitigate leaks could help CO₂ pipelines operate more safely. Improving knowledge in these areas would help regulators and industry stakeholders better understand the risks and take steps to mitigate them while reassuring the public. Indeed, such information could help DOE's CIFIA program identify and encourage the community benefit plans most likely to address resident concerns and ensure project success.

NARUC and other national organizations that convene state authorities can play a pivotal role in supporting state entities in developing a coordinated approach to CO₂ pipeline regulation. Apart from advocating for comprehensive federal oversight over the permitting, safety, and rates of CO₂ pipelines—likely the optimal approach given the national scope of U.S. CCUS ambitions and divergent state views—helping state legislative and regulatory bodies coalesce around core principles—or even a model statute—that support uniform and predictable rules for pipeline developers while protecting public safety is critical. States like California, Indiana, Texas, and others have pursued interesting strategies that separately, or in combination, could create a common path forward. Ultimately, a collaborative approach among federal and state regulators, industry stakeholders, and the public will be essential to creating a safe and accessible CO₂ pipeline system that helps achieve a sustainable energy future.

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Appendix A: State Common-Carrier Requirements and Eminent Domain for CO₂ Pipelines

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
AL	Alabama Public Service Commission	No	No	Yes ¹	Unclear. Depends on a pipeline developer's ability to prove a CO ₂ pipeline is an exercise in "internal improvement or public utility."	In 2022, Alabama statute was updated to declare that "the underground storage of carbon oxides, ammonia, hydrogen, nitrogen and noble gases is in the public interest for this state and is for a public purpose." ²
AK	Regulatory Commission of Alaska	No	Yes ³	Unclear. Alaska prohibits the transfer of private property to another private entity for "economic development purposes," but waives this provision if the property is transferred to a common carrier. ⁴	Unclear. Eminent domain is limited to pipelines transmitting "natural or artificial gas or oil or any liquid or gaseous hydrocarbons." ⁵	Legislation was introduced in January 2023 to create a regulatory framework for CCUS development projects and authorize carbon offset programs on state land. (HBs 49–50 and SBs 48–49) ⁶
AZ	Arizona Corporation Commission	No	No	No	Yes. Arizona authorizes the use of eminent domain for "pipelines to carry petroleum, petroleum products or any other liquid." ⁷	During the 2022 regular session, legislation was introduced but failed to receive a vote to create a Carbon Capture Task Force to evaluate the use of CCUS in Arizona (HB 2666). ⁸
AR	Arkansas Public Service Commission	No	Yes ⁹	Yes. All pipelines in Arkansas are considered common carriers or public utilities. ¹⁰	Unclear. Pipelines moving mineral oil, petroleum, or natural gas may exercise eminent domain. ¹¹	In February 2023, Arkansas enacted legislation updating its underground storage law to include "carbon oxides, ammonia, hydrogen, nitrogen, or noble gas" (Act 140). ¹²

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
CA	California Public Utilities Commission	No	Yes ¹³	Yes. To exercise eminent domain, a pipeline must be a public utility. Any pipeline company providing services "to the public or any portion thereof" for compensation is a public utility. ¹⁴	No. California law prohibits the transport of CO ₂ via pipeline pending the promulgation of minimum CO ₂ safety standards by PHMSA. ¹⁵	Several new policies were enacted in 2022 related to the CCUS industry.
CO	Colorado Public Utilities Commission	No	No	Yes ¹⁶	Unclear. Colorado provides eminent domain authority for "pipeline companies" that transport power, "water, air, or gas." ¹⁷	The Colorado CCUS Task Force (created in 2021) released recommendations in February 2022 that included the recommendation for state legislative action to establish siting authority of CO ₂ pipelines and outreach to neighboring states to develop a regional CO ₂ pipeline strategy. ¹⁸
CT	Connecticut Siting Council	No	Yes ¹⁹	Unclear. A "certificate of environmental compatibility and public need" is required to use eminent domain. ²⁰	Unclear. "A person engaged in the transmission of electric power or fuel in the state may acquire real property, and exercise any right of eminent domain." ²¹	N/A
DE	Delaware Public Service Commission	No	No	No	No	N/A
FL	Florida Public Service Commission	No	Yes ²²	Yes ²³	Unclear. Operators of petroleum and natural gas pipelines may exercise eminent domain. ^{24, 25}	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
GA	Georgia Public Service Commission	No	Yes ^{26, 27}	No	Unclear. There are several statutes that address an entity's ability to exercise eminent domain that could potentially cover a CO ₂ pipeline. ²⁸	N/A
HI	Hawai'i Public Utilities Commission	No	Yes ²⁹	No	No	N/A
ID	Idaho Public Utilities Commission	No	No	Yes. Eminent domain is only available for public use infrastructure. ³⁰	Unclear. Idaho statute specifies authority for gas and petroleum pipelines. ³¹	N/A
IL	Illinois Commerce Commission	Yes ³²	Yes ³³	No. However, the commission must consider public interest in the approval of pipeline permits. ³⁴	Yes ³⁵	Proposed legislation in 2023 would place a moratorium on the commission issuing a Certificate of Public Authority for CO ₂ pipelines until PHMSA adopts revised safety standards (HB 3803). ³⁶ Another 2023 proposal would direct a portion of taxes received from hydraulic fracturing within the state of Illinois to a new Carbon Dioxide Pipeline Fund for use by the commission to "supervise and regulate" the CO ₂ pipeline industry (HB1143 House Amendment 001). ³⁷
IN	Indiana Department of Natural Resources (authority to construct)/ Indiana Public Utilities Commission (safety)	Yes ³⁸	Yes ³⁹	No	Yes ⁴⁰	Legislation proposed in January 2023 would require CCUS projects, including pipelines, to receive approval from the applicable local government legislative body for projects within its borders (SB 247). ⁴¹

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
IA	Iowa Public Utilities Board	Yes ⁴²	Yes ⁴³	No	Yes ⁴⁴	Legislation was proposed in 2023 to block eminent domain for CO ₂ pipelines that had not secured voluntary easements for 90 percent of their route. House File 565 failed to receive action from the Iowa Senate prior to the 2023 “funnel” date, meaning it will not be considered any further this year. ⁴⁵
KS	Kansas Corporation Commission	No	No	Yes ⁴⁶	Unclear. Eminent domain statute includes pipeline companies; does not define the type of material to be transported. ⁴⁷	N/A
KY	Kentucky Public Service Commission	Yes ⁴⁸	Yes ⁴⁹	No. However, Kentucky statute declares CO ₂ pipelines to be a public use. ⁵⁰	Yes ⁵¹	N/A
LA	Louisiana Conservation Commission	Yes ⁵²	Yes ⁵³	No	Yes ⁵⁴	N/A
ME	Maine Public Utilities Commission	No	No	No	Unclear. Maine grants eminent domain authority to entities “engaged in the generation, transmission or distribution of telephone, gas, electric, water, sewer or other utility products or services.” ⁵⁵	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
MD	Maryland Public Service Commission	Yes ⁵⁶	No	Yes ⁵⁷	Unclear. The statute covers the transmission of natural, artificial, or a mixture of natural and artificial gases. ⁵⁸	N/A
MA	Energy Facilities Siting Board and Department of Telecommunications and Energy	No	No	No. Pipeline operators must demonstrate that a transmission line serves public convenience and is in the public interest but does not explicitly require it to be a common carrier. ⁵⁹	Unlikely. Massachusetts statute grants eminent domain authority to oil and natural gas pipelines specifically. ⁶⁰	N/A
MI	Michigan Public Service Commission	Yes ⁶¹	Yes ⁶²	Yes ⁶³	Yes ⁶⁴	N/A
MN	Minnesota Public Utilities Commission	No. However, the PUC issued a ruling in 2022 claiming authority over CO ₂ pipelines. ⁶⁵	Yes ⁶⁶	Unclear. The transport of petroleum, natural gas, and other hydrocarbons as a common carrier is considered in the public interest. ⁶⁷	No	House File 2310 signed by Governor Tim Walz on May 24, 2023, added CO ₂ (as a gas, liquid, or in a supercritical state) to the Minnesota statute governing pipelines (section 216G.02). ⁶⁸
MS	Mississippi State Oil and Gas Board and Mississippi Public Service Commission	No	Yes ⁶⁹	No	Yes. For the limited purpose of EOR. ⁷⁰	N/A
MO	Missouri Public Service Commission	No	No	No	Yes. A private utility company, public utility, rural electric cooperative, municipally owned utility, pipeline, railroad, or common carrier shall have the power of eminent domain. ⁷¹	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
MT	Montana Public Service Commission	Yes ⁷²	Yes ⁷³	Yes ⁷⁴	Yes ⁷⁵	N/A
NE	N/A	No	No	No	Unclear	The 2021 Geologic Storage of Carbon Dioxide Act declared CO ₂ storage to be “in the public interest” and gave the Nebraska PSC the authority to regulate carbon “storage facilities,” but specifically excluded pipelines from that definition. ⁷⁶
NV	Public Utilities Commission of Nevada	No	Yes	Likely. Petroleum and natural gas pipelines are automatically considered “common carriers,” and pipelines are considered “public uses.” ⁷⁷	Unclear. Pipelines for “petroleum, petroleum products, and natural gas, whether interstate or intrastate” may use eminent domain. ⁷⁸	N/A
NH	New Hampshire Department of Energy and New Hampshire Public Utilities Commission	No	Yes ⁷⁹	Yes	No. Natural gas and oil pipelines “may institute condemnation proceedings” if unable to acquire necessary lands. ⁸⁰	N/A
NJ	New Jersey Board of Public Utilities	No	Yes	No. N.J. Stat. Sec. 48-10-1 distinguishes between “pipeline companies” and “pipeline utilities,” both of which may use eminent domain. ⁸¹	Unclear. “Pipeline companies” is not specifically defined.	Bill A3162 would restrict the use of eminent domain by private pipeline companies to those demonstrating the pipeline is in the public interest and agreeing to regulation by the Board of Public Utilities. ⁸²
NM	New Mexico Public Regulation Commission	Yes ⁸³	Yes ⁸⁴	No	Yes ⁸⁵	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
NY	New York Public Service Commission	No	Yes ⁸⁶	No	Unclear. New York law provides eminent domain authority for gas corporations that supply artificial or natural gas for public use. ⁸⁷	N/A
NC	North Carolina Utilities Commission	No	Yes ⁸⁸	Yes. Pipeline companies must provide services “for the public” to use eminent domain. ⁸⁹	Yes. Eminent domain law covers “natural gas, gasoline, crude oil, coal in suspension, or other fluid substances.” ⁹⁰	On March 27, 2023, legislators proposed a constitutional amendment to prohibit the taking of private property by eminent domain “except for a public use.” ⁹¹
ND	North Dakota Public Service Commission	No	Yes ⁹²	Yes ⁹³	Yes ⁹⁴	Legislators introduced several bills in 2022 and 2023 to restrict pipeline companies’ eminent domain power. As of April 2023, all bills have failed to advance. ⁹⁵
OH	Ohio Public Utilities Commission	No	No	Yes ⁹⁶	Unclear. The eminent domain statute grants authority for pipelines that transport natural or artificial gas. ⁹⁷	N/A
OK	Oklahoma Corporation Commission	No	Yes ⁹⁸	Yes. Oil and natural gas transmission pipelines must operate as common carriers to exercise eminent domain authority. ⁹⁹	Unclear. There is no express statutory authority for eminent domain for CO ₂ pipelines. However, Okla. Stat. tit. 27A § 3-5-101 states that CO ₂ storage is “in the public interest” and notes that CO ₂ transportation “is expected to increase.” ¹⁰⁰	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
OR	Oregon Public Utility Commission	No	Yes ¹⁰¹	Yes ¹⁰²	Unclear. Pipeline companies distribute “fluids, including petroleum products, or natural gases and those organized for constructing, laying, maintaining or operating pipelines, which are engaged, or which propose to engage in, the transportation of such fluids or natural gases.” ¹⁰³	N/A
PA	Pennsylvania Public Utility Commission	No	No	Yes. Pipeline operators must be classified as a public utility to exercise eminent domain. ¹⁰⁴	Yes ¹⁰⁵	N/A
RI	Rhode Island Public Utilities Commission	No	Yes ¹⁰⁶	Yes. Pipeline companies are included in the definition of “public utilities,” which have the power of eminent domain. ¹⁰⁷	Likely. The term “pipeline company” is not defined or otherwise restricted to specific types of pipelines. ¹⁰⁸	N/A
SC	Public Service Commission of South Carolina; South Carolina Office of Regulatory Staff (ORS), Pipeline Safety Department	No	No	Yes. However, only natural gas companies qualify as “public utilities.” ¹⁰⁹	No. Only natural gas companies are authorized to exercise eminent domain. ¹¹⁰	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
SD	South Dakota Public Utilities Commission	Yes ^{111,112}	Yes ¹¹³	Yes ¹¹⁴	Yes ¹¹⁵	There are currently two pieces of legislation before the South Dakota Legislature that could impact CO ₂ infrastructure. HB 1133 excludes transmission for the purpose of geologic storage from common-carrier status and associated eminent domain authority. HB 1178 would require applicants for a CO ₂ pipeline to wait for approval pending PHMSA CO ₂ pipeline rulemaking. ^{116, 117}
TN	Tennessee Public Utility Commission	No	No	Yes ¹¹⁸	Unclear. A “pipeline corporation” may exercise the right of eminent domain. The definition of “pipeline corporation” is not limited to a specific material transported. ¹¹⁹	N/A
TX	Texas Railroad Commission	Yes ¹²⁰	Yes ¹²¹	Yes ¹²²	Yes ¹²³	N/A
UT	Utah Public Service Commission	No	No	No	Unlikely. Only natural gas, oil, and coal pipelines are granted eminent domain authority in the statute. ¹²⁴	N/A
VT	Vermont Public Utility Commission; Department of Public Service	No	Yes ¹²⁵	Yes ¹²⁶	Unclear. A transmission facility, energy storage facility, or generation facility can exercise eminent domain. ¹²⁷	N/A

State	Pipeline regulatory authority	CO ₂ pipelines identified in statute?	General permitting requirements for pipelines?	Does a pipeline company need to be a common carrier or public utility to exercise eminent domain authority?	Can CO ₂ pipeline companies exercise eminent domain authority?	Recent or pending actions
VA	Virginia State Corporation Commission	No	Yes ¹²⁸	No	Unclear	In January 2022, the Virginia Carbon Sequestration Task Force that was created by a statute in 2021 released its recommendations, which included increases in support for existing forestry programming and the exploration of new carbon market incentives like tax credits. The focus of the task force was on natural sequestration but did demonstrate increased state government interest in CO ₂ mitigation policies. ¹²⁹
WA	Washington Utilities and Transportation Commission	Yes ¹³⁰	Yes ¹³¹	Yes ¹³²	Unlikely. Only oil or natural gas common-carrier pipelines may exercise eminent domain authority. ¹³³	N/A
WV	West Virginia Public Service Commission	No	No	No	Unclear. Pipelines that transport “petroleum oil, natural gas, manufactured gas, and all mixtures and combinations thereof” may exercise eminent domain. ¹³⁴	House Bill 4491 was signed into law on March 1, 2022. The legislation created a permitting process and regulatory framework for carbon sequestration but explicitly excludes pipelines. ¹³⁵
WI	Wisconsin Public Service Commission	No	No	No	Unlikely. Only oil and natural gas pipelines may exercise eminent domain. ¹³⁶	N/A
WY	Wyoming Public Service Commission	No	Yes ¹³⁷	No	Yes. All pipelines may exercise eminent domain. ¹³⁸	N/A

Appendix A – Endnotes

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