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Uncertainties and Gaps in Research on Carbon Capture and Storage in Louisiana

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Center for Progressive Reform

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Introduction

The oil and gas industry has targeted Louisiana as an emerging hub for carbon capture, mainly because of the large concentration of industrial facilities that emit carbon dioxide in the stretch of land between New Orleans and Baton Rouge, aptly titled "Cancer Alley." Louisiana Governor John Bel Edwards and state regulators openly support carbon capture as a way to meet the state's goal of reducing greenhouse gas emissions to net-zero by 2050. While Louisiana must move quickly and aggressively in pursuit of climate change solutions, such expansive deployment of carbon capture includes unknown risks.

Carbon Capture and Storage

Carbon capture and storage (CCS) is a process that captures carbon emissions and stores them underground. Carbon capture and utilization (CCU) is a similar process in which carbon emissions are recovered for further usage. Both are unproven solutions to the climate crisis.

This report reviews peer-reviewed literature pointing to the risks and uncertainties associated with this technology. We conclude that further research on the feasibility, safety, and reliability of carbon capture systems at industrial facilities and plants, carbon dioxide (CO_2) pipelines, and storage options in Louisiana is needed. The report is for advocates, decision-makers, and community leaders facing proposed carbon capture and storage (CCS) and carbon capture and utilization (CCU) projects in their area.

Many of the impacts of CCS and CCU on the environment, health, and society lack sufficient research or have not been studied comprehensively. This is particularly true for CCS and CCU's societal and environmental justice impacts. The economic and cost analyses of CCS operations reveal substantial uncertainty about whether CCS is profitable without certain tax credits and subsidies. Finally, there is uncertainty about the adequacy of federal and Louisiana regulations and oversight of CCS and CCU. Current and proposed CCS projects in Louisiana and the Gulf Coast region must be placed on hold indefinitely, given their substantial risk to local communities and future generations.

Global Carbon Emissions

Carbon capture and storage is an unproven technology that is not guaranteed to succeed in preventing catastrophic warming or other negative environmental impacts associated with carbon emissions. A 2020 study published in *Energy & Environmental Science* finds that carbon capture increases net emissions between the drilling, transporting, processing, and burning of natural gas to power carbon capture equipment and the CO_2 that leaks throughout the CCS process.[1] The Intergovernmental Panel on Climate Change's (IPCC) 2005 report on CCS states that continuous leakage of CO_2 from CCS projects could offset at least some purported climate benefits of CCS.[2] Comprehensive research and modeling of the potential CO_2 leakage from modern CCS systems are necessary to measure this impact fully.

Other studies show that CCS increases plants' power needs by 10-40 percent.[3] The 2020 study found that a gas-powered CCS reduces coal and gas combustion plus CO_2 by a net 11 percent over 20 years and 20 percent over 100 years.[4] When using wind power, CO_2 decreases 37 percent over 20 years and 44 percent over 100 years.[5] However, the study finds that CCS *cannot* reduce the social costs below that of replacing fossil fuels with wind energy. As such, it concludes that CCS increases air pollution and total social costs relative to no capture.[6]

To keep the global average temperature rise to 2 degrees Celsius or less, CCS would need to sequester the CO_2 equivalent of holding more than two-thirds of current proven fossil fuel reserves in the ground, according to a 2015 study published in *International Spectator*.[7] Given CCS's limited ability to reduce carbon emissions, it is uncertain whether it will reduce emissions at that level. To our knowledge, no researchers have studied how the deployment and use of CCS affect national and international dependence on fossil fuels.

Infrastructure

Some companies that have proposed or are planning CCS projects in Louisiana have announced how much CO_2 they intend to store after capture. The Calcasieu Pass LNG Terminal project and the CP2 LNG project, both of which are sited in Cameron Parish, are each expected to capture 500,000 tons of CO_2 per year.[8] The G2 Net-Zero Energy Complex, also slated for Cameron Parish, is projected to capture 4 million tons of CO_2 per year, according to project developers.[9] But to be successful, post-combustion CCS requires the installation of equipment and machinery at each plant, as well as the means to compress and transport the captured carbon and store it indefinitely.[10] Each component carries uncertainties and risks associated with availability, safety, and reliability. Furthermore, little research explores the health and societal impacts of building and operating CCS facilities, from capture to transportation to storage.

Carbon Capture Systems at Plants

Plants that lack carbon capture systems can be retrofitted to allow for installation.[11] In the 2022 Louisiana Climate Action Plan, the Climate Initiatives Task Force estimates that, over the next 15 years, 1,700 to 2,500 jobs per year could be created to operate and complete retrofits for carbon capture projects.[12] However, the plan does not specify precisely how many plants the task force recommends retrofitting.[13] An IPCC assessment found that retrofitting existing plants increases costs and significantly reduces overall efficiency compared to building new power plants with carbon capture systems.[14] The number of retrofits proposed in Louisiana is unclear, as is the potentially high cost of these retrofits.

Pipeline Capacity

It is uncertain whether the existing pipeline infrastructure in Louisiana and bordering states can adequately support CCS. Research published in *Environmental Research Letters* in 2016 on water and climate risks to power generation with CCS found that developing "CCS clusters," where CO_2 is collected from clustered industrial sites, can partially reduce infrastructure needs by pipeline sharing.[15] This approach is improbable in South Louisiana if CCS projects rely on its existing pipeline infrastructure. A 2018 Louisiana

State University (LSU) study found that only 1.4 percent of the area's 5,112 pipeline segments are co-located near both a sink (e.g., appropriate sub-terrain) and a source (e.g., gas-fired powerplant) and could be candidates for CCS repurposing.[16] Only about half of the pipeline segments with information available can carry enough CO_2 to sustain a typical enhanced oil recovery project.[17] Further, researchers noted that repurposing natural gas and crude oil pipelines is a relatively new idea, and only a few such efforts have been successful.[18]

Storage Capacity

The storage capacity of oil and gas reservoirs and saline aquifers, or geological formations made of water-penetrable rocks saturated with salt water, in Louisiana and in general, is uncertain and variable. A 2021 study published in the *International Journal of Greenhouse Gas* adapts a mapping tool for screening CO_2 storage sites in Louisiana and Texas and finds "important variations" between potential storage sites, which include capacity, injectivity, and cost of characterization and development.[19] The U.S. Department of Energy's Office of Fossil Energy estimates the amount of carbon storage resources available nationally in its Carbon Storage Atlas.[20] Table 1 details the latest estimates by type:[21]

Table 1: Carbon Storage Availability Estimates by Type of Storage Facility

	Low Estimate (metric tons)	**Medium Estimate (metric tons)**	**High Estimate (metric tons)**
Saline Formation Storage Resources	151.36	734.55	2,075.23
Unmineable Coal Storage Resources	8.30	12.89	18.91
Oil and Gas Reservoirs	3.12	5.70	8.29
Total	**162.78**	**753.14**	**2,102.43**

Source: Carbon Storage Atlas, U.S. Department of Energy Office of Fossil Fuel Energy

A 2016 study published in *Energy Procedia* maps saline aquifers in Louisiana and makes a low estimate of their storage capacity in terms of tons of CO_2. The estimate ranges as little as just under 500,000 tons for Louisiana's northernmost saline aquifers and 31 million tons for saline aquifers in the southern third of the state.[22] Given the wide range in these estimates, the actual capacity of carbon storage resources in Louisiana is uncertain.

A 2022 study in *Frontiers in Earth Science,* which evaluated different methods for determining the storage capacity for CO_2 in deep saline aquifers, speaks to the indeterminacy of CO_2 storage estimates in general.[23] The study found that "no single, consistent, and broadly available method for estimating CO_2 capacity exists"; that different studies have used methods that are difficult to compare; and that, even where studies used the same manner, the estimates vary widely.[24] The main reasons for these difficulties are different capacity assumptions, algorithms, data quality, and other relevant factors.[25]

The storage capacity of saline aquifers in Louisiana is particularly unclear. A 2018 study from researchers at LSU on CCS in cancer alley, also called the "Louisiana Chemical Corridor," found that deep saline aquifers have a greater estimated storage capacity than oil and gas reservoirs. At the same time, they have more uncertainty regarding their size and structural or stratigraphic traps (when a reservoir bed is closed off by other beds or deformation within the reservoir itself) than oil and gas reservoirs.[26] A 2012 study published in *Energy Economics* assessing the impact of geologic variability on the cost of CO_2 storage in deep saline aquifers supports this finding. According to this research, estimates of saline aquifers' storage capacity vary considerably.[27] The study concludes that the geologic heterogeneity of saline aquifers makes it challenging to pinpoint the cost of CO_2 storage in saline aquifers.[28] While the study provides a model of how to account for the geologic heterogeneity of saline aquifers in cost analysis of storage, it identifies a need for better data and methods to do so.[29]

Environmental, Health, and Social Uncertainties

Existing studies have identified many uncertainties and risks associated with CCS and CCU's impact on the environment, public health, and society. There are risks and uncertainties associated with CO_2 storage and leakage, sinkholes, and methanogenesis (*i.e.*, anaerobic respiration that generates methane as the final product of metabolism and seismic activity). Uncertainties regard leakage that can occur from CO_2 storage sites, including risk factors for leakage, the ability to measure leaks and predict their size, and the environmental and public health impacts of leaks. Little research exists on the long-term environmental, health, and societal implications of carbon storage. Additionally, uncertainty remains about the impact of CCS on water sustainability and freshwater resources as well as on other ecosystems.

CO_2 Transport

Many studies have illustrated the array of environmental, health, and societal risks associated with CO_2 pipeline operation. In a 2010 study published in the *Journal of Hazardous Materials*, researchers conclude that quantifying the risks of transporting CO_2 by pipelines is difficult.[30] The study identified the following gaps in research on the risks associated with CO_2 pipelines:

(1) Whether the release of supercritical CO_2 (i.e., a fluid state of carbon dioxide held at or above its critical temperature and critical pressure from a pipeline) differs significantly from dense liquid release;

(2) The impact of impurities on pipeline operations;

(3) The final human health impact resulting from the release and subsequent dispersion of CO_2 and impurities;

(4) The effect of crosswinds on the dispersion of a CO_2 cloud;

(5) How clogged holes due to dry ice or hydrate formation in the pipeline may influence the release rate at the exit of the channel; and

(6) The impact of rapid cooling of CO_2 on adjacent installations and exposed pipelines.[31]

Using or repurposing metal pipelines for CO_2 transportation risks corrosion. A 2009 report on CO_2 Pipelines Material and Safety Considerations presented at the IChemE Symposium Series: HAZARDS XXI Process Safety and Environmental Protection Conference found that existing examples of CO_2 pipeline usage are limited and identified issues relating to pipeline safety and integrity that require further research.[32]

Regarding the risk of corrosion, the report found that water will inevitably be present in CO_2 pipelines, causing corrosion and hydrate formation.[33] As of 2009, no comparative investigations involving CO_2 in the presence of impurities had been undertaken. This information is essential because several known impurities likely increase corrosion rates and may contribute to hydrogen embrittlement and fast-running brittle or ductile fracture mechanics.[34] In addition, the report found no available data on the supercritical region for CO_2 corrosion. This is important because CO_2 presents uncertainties about understanding water corrosion behavior in pipelines transporting supercritical CO_2.[35]

Pipeline embrittlement occurs when molecular hydrogen in a pipeline seeps into the pipeline material and causes fractures.[36] The 2009 report on *CO_2 Pipelines Material and Safety Considerations* found that embrittlement has been extensively studied in pipelines transporting hydrocarbons, but not those transporting CO_2.[37] The report found that the presence of hydrogen as an impurity within CO_2 can contribute to pipeline embrittlement.[38] It noted pipeline materials such as low-sulfur content steels, which are more expensive than other pipeline materials, could control the risk of hydrogen embrittlement.[39] Future studies of CO_2 pipeline ductile and brittle failures "must entail the development and application of appropriate equations of state and detailed consideration of the interactions between the transported fluid and the materials of containment," researchers wrote.[40]

A 2022 report on CO_2 pipeline safety regulations prepared and published by Accufacts Inc. for the Pipeline Safety Trust finds that combining CO_2 phase and temperature changes can contribute to rupture as CO_2 converts to gas.[41] Specifically, the "unique failure dynamics" of CO_2 pipelines can cause fractures that impact a significantly greater geographic area than hydrocarbon pipelines, the report notes.[42] Given this information, the population of the regions for proposed CO_2 pipelines must be evaluated as a part of the risk analysis. The IPCC's Special Report on Carbon Dioxide Capture and Storage (2005) found that due to the immense health and safety risks associated with CO_2 transportation via pipeline through densely populated regions, there must be attentiveness to "route selection, overpressure protection, leak detection, and other design factors."[43]

Another concern about CO_2 pipeline rupture is the apparent lack of preparedness to respond to such a disaster. In February 2020, a pipeline operated by Denbury, Inc., ruptured in Satartia, Mississippi, hospitalizing 49 residents.[44] A *HuffPost* article on the disaster reported that no sheriffs' deputies, volunteer firefighters, or staff at the two area hospitals had any emergency training in CO_2 leaks.[45] Months after the explosion, residents reported mental fogginess, lung dysfunction, chronic fatigue, and stomach disorders.[46] Commenting on the disaster, Marcelo Korc, chief of the World Health Organization's Climate Change and Environmental Determinants Unit, said that CO_2 exposure studies "do not exist."[47]

A 2021 study published in *Rural Social* finds that environmental justice literature suggests that "minority populations, people with low socio-economic status, and rural communities are disproportionately associated with potentially harmful land uses [such as transmission pipelines]."[48] Satartia, Mississippi, is a rural town with a $25,897 per capita income and a population that is 70 percent Black.[49]

CO_2 Storage

CO_2 Leakage in Oil and Gas Reservoirs. The existing body of research on the environmental, health, and societal impacts of CO_2 storage is minimal, and many studies identify issues needing further investigation. Considering the potential risks associated with CO_2 storage in Louisiana, the historical uses of proposed storage sites should be evaluated. For example, a 2020 study by LSU researchers assessing the economic feasibility of CCS in Louisiana noted that in the late 1970s and early 1980s,

Shell Global operated an enhanced oil recovery project, injecting approximately 44,000 tons of CO_2 into Louisiana's Weeks Island Oil and Gas Field.[50]

Many studies have identified that the presence of wells increases the risk of leakage of CO_2 stored in oil and gas reservoirs. A 2017 study presented at the Carbon Management Technology Conference in Houston outlines a risk-based approach to identify wells with comparatively higher leakage probabilities.[51] The study found that wells have different levels of risk for CO_2 leakage depending on the characteristics of their wellbore[52] (the hole or channel within a well).[53] Wellbores have the most-to-least leakage risk in the following order: wells with no casing, wells with no cement coverage in the storage area, and wells with entirely cemented storage areas.[54] Dry and plugged wells drilled in the 1950s and '60s may only have surface casing installed to protect freshwater aquifers, but well segments passing through deeper storage zones may not have a casing.[55] These wells may pose a particular risk because their deeper storage areas may provide a large flow area for leaking fluids, provided that the wellbore has not collapsed.[56]

The study mentioned several other studies that have identified risks and uncertainties relating to the leakage of CO_2 stored in oil and gas reservoirs. A 2008 study presented at the Society of Petroleum Engineers Symposium on Improved Oil Recovery found that most leakage factors depend on the processes adopted during the well's drilling, completion, and abandonment phases.[57] A 2014 study published in *Energy Procedia* found that some well sections with low-quality cement will not block leaking fluids.[58] A 2020 study on carbon capture and storage in southern Louisiana published in *GeoGulf Transactions* identified that older wells present unique risks and challenges because oil and gas wells were not regulated before the early 1900s.[59] The researchers found that modern standards for cementing practices were not established until 1952, so wells abandoned before then are likely to lack additives needed to set cement properly.[60]

Wells drilled before this time may not have been appropriately abandoned, the study concludes.[61] Further, the study cautions that during World War II, steel casings were often removed from inactive wells for recycling, which makes those wells challenging to locate now.[62] The researchers urge caution when approaching wells with these histories or characteristics and recommend avoiding injection-related pressure changes on such wells.[63] LSU and Louisiana's Department of Natural Resources have created maps of wells in oil and gas reservoirs in Louisiana.[64] However, given the risks associated with the wells' wide range of characteristics, detailed research and evaluation of the wells in oil and gas reservoirs proposed for carbon storage are necessary.

Studies on CO_2 storage in oil and gas reservoirs have identified several other risk factors for leakage. A 2013 study published in *Energy Procedia* identified several risk factors that can increase the chance of leakage, including shallow depth, the presence of CO_2 in the gas phase, and hydrostatic overburden (pressure exerted by all the material above a reference point).[65] A study published in a 2020 issue of the *International Journal of Greenhouse Gas Control* found that faulting processes, which produce a complex fault damage zone impacting oil and gas reservoirs, may result in significant leakage.[66]

Meanwhile, the 2018 study published by Louisiana State University notes that faults are part of geological settings in southern Louisiana; therefore, authors recommend quantifying potential fault-related leakage.[67] This study also expressed concern regarding the tendency of CO_2 to cause asphaltene precipitation, which may alter porosity, permeability, well injectivity, and dynamic storage capacity.[68] According to this study, the effect of asphaltene precipitation on CO_2 storage is still under investigation.[69] Based on this research, proposed storage sites in Louisiana must be evaluated for these leakage risk factors. Although numerous studies have provided models and methods for estimating leakage from carbon storage sites,[70] there has not been a comprehensive study on the leakage potential of all proposed carbon storage sites in Louisiana.

Deep Saline Aquifer Storage. Research on CO_2 storage in deep saline aquifers has revealed various risks and uncertainties. A research review published in *Environmental Science and Technology* in 2002 found CO_2 can leak (i.e., vertical migration) by dissolution in shallow aquifer waters.[71] CO_2 can also alter the pH of aquifer waters, which can cause "undesirable changes" in geochemistry, water quality, and ecosystem health,[72] including the mobilization of toxic metals and the leaching of critical biological nutrients, the report cautions.[73] The report adds that another environmental risk is the possible displacement of brines from CO_2 injection into overlying aquifers, which could contaminate potable water supplies.[74] Lastly, the report calls for research on the potential for and consequences of an abrupt release of a large quantity of CO_2 from deep saline aquifers.[75]

A 2008 study published by the University of California Lawrence Berkeley National Laboratory also warns of the risk of brine displacement.[76] The study found when CO_2 is stored in suitable geological structures, pressure changes and brine displacement may affect shallow groundwater resources.[77] A 2015 report published in *Water Resources Research* reviews the research on the viability of CO_2 storage in deep saline aquifers and identifies risk factors for leakage.[78] An important one is a greater risk of leakage if localized zones of high permeability exist in the caprock, which could result in fluid migration into groundwater zones or the atmosphere.[79]

Deep Ocean Floor Storage. The IPCC's 2005 report warns that ocean floor storage of CO_2 can harm the environment, including by altering the local chemical environment of the ocean floor, causing mortality of ocean organisms in areas with high concentrations of CO_2.[80] The report also warns that the long-term effects of CO_2 storage in the ocean on ecosystems over large ocean areas and long times scales have not been studied.[81]

A 2017 literature review published in *Applied Energy* that assesses developments in carbon dioxide storage identifies studies that touch on medium- to long-term storage of CO_2 on the ocean floor.[82] The review identifies a need for research on the effect of air-sea CO_2 exchange on deep ocean storage.[83]

A 2010 study in *Nature Geoscience* on the long-term effectiveness and consequences of CO_2 sequestration found that CO_2 storage would have to last tens of thousands of years to avoid delayed global warming and a significant increase in ocean dead zones — more protracted than what other carbon-climate models project.[84] This study also found that deep-ocean storage causes extreme acidification in the deep sea.[85] According to the National Oceanic and Atmospheric Administration, ocean acidification creates conditions that degrade the shells and skeletons of marine life and could produce toxic algae blooms.[86]

Aside from these two studies, there is still not enough research with a substantial focus on the long-term environmental, health, and societal impacts of deep ocean storage.

General Carbon Storage Uncertainties. Researchers have identified other ways that natural environmental processes and events and human activity can impact CO_2 storage. A 2021 study published in *Nature* researched a process called microbial methanogenesis, in which CO_2 is converted to methane.[87] The researchers studied the Olla Oil Field in La Salle Parish, Louisiana, which was injected with CO_2 in the 1980s for enhanced oil recovery.[88] They found that microbial methanogenesis converted as much as 13 to 19 percent of the injected CO_2 to methane and that an additional 74 percent of the CO_2 dissolved into the groundwater.[89]

Sinkholes also present a risk to storage in salt caverns. In 2012, a sinkhole appeared at a salt cavern in Assumption Parish, Louisiana, where Texas Brine, a Houston-based company, stored oil and gas drilling waste, including radioactive materials.[90]

Seismic activity is a concern as well. The 2018 Louisiana State University study reported that natural earthquakes pose a risk to carbon storage and called for monitoring of natural seismic activity.[91] Additionally, the 2005 IPCC report on CCS found that CO_2 injections can trigger small seismic events.[92]

General Environmental Uncertainties

Much uncertainty remains about CCS's environmental impacts. The 2005 IPCC report on CCS warns that leakage from CO_2 storage sites could kill plants and subsoil animals, contaminate groundwater, and drive up CO_2 concentrations in the air.[93] The effect of CO_2 storage on subsurface microbial populations is not well studied and therefore unknown.[94] The 2022 Louisiana Climate Action Plan, drafted by the state's Climate Initiatives Task Force, recommends an investment in research on utilizing captured carbon and life cycle analyses to understand their overall impact.[95]

There are no comprehensive studies regarding the impact of CCS on water sustainability and freshwater resources. A 2018 report published in *Energy, Sustainability, and Society* examined the effects of CCS on water sustainability.[96] The report finds a need for a complete analysis of the impact of CCS installations on water sustainability in Louisiana.[97] Little or no existing research focuses on the impact of CCS development on wetlands or vice versa[98] or the impact of climate and natural disasters on CCS infrastructure.[99]

There are gaps in existing research on the long-term environmental effects of CCS. A 2008 report published in *Safety Science* on the desirability of CCS from a risk management perspective found a significant lack of information on the long-term impacts of CO_2 storage on the environment.[100] Very little research has focused on the long-term effects of carbon storage since the 2008 report was published.[101]

General Health and Social Uncertainties

The long-term human health impacts of exposure to CO_2 must be researched. The 2005 IPCC report on CCS states that a sudden and significant release with CO_2 concentrations greater than 7-10% "would pose immediate dangers to human life and health."[102] However, the precise impact on human health is uncertain. When commenting on the 2020 CO_2 pipeline rupture in Satartia, Mississippi, Marcelo Korc, Chief of the World Health Organization's Climate Change and Environmental Determinants of Health Unit, said exposure studies on CO_2 "do not exist."[103]

The 2022 Louisiana Climate Action Plan identifies the need to "more comprehensively understand the potential impacts of carbon capture technology and infrastructure on communities, ecosystems, and cultural resources to inform siting and permitting deployment."[104] Similarly, the 2018 report published in *Energy, Sustainability, and Society* recommends that environmental, economic, and societal impacts of CCS deployment should be integrated into future assessments of CCS operations.[105]

Economic Uncertainties

Economic and cost analyses of CCS operations reveal substantial uncertainty about whether CCS is profitable without tax credits or subsidies beyond the IRS 45Q tax credit for CO_2 storage.[106]

The upfront costs for CCS operations vary based on several factors. As previously discussed, retrofitting existing plants with CO_2 capture is more costly than building new plants with the technology.[107] Therefore, the costs of the planned retrofits in the 2022 Louisiana Climate Action Plan are higher than projected.[108]

Another factor the IPCC's 2005 report mentions relates to economies of scale,[109] such as developing CCS clusters where CO_2 can be captured from multiple plants with shared transportation and storage.[110] Uncertainty also surrounds the affordability of building CO_2 pipelines. The 2018 Louisiana State University study estimates that building CO_2 pipelines in Louisiana will cost $830,000 per mile.[111]

Multiple economic analyses conclude that CCS will not be economically feasible in Louisiana. The 2018 Louisiana State University study cites an integrated economic feasibility study that shows that a CCS project in southern Louisiana will not be financially viable even with the IRS 45Q tax credit.[112]

A 2020 study published by the *International Journal of Greenhouse Gas Control* found that CCS would only be economically feasible in Louisiana if income were generated through the IRS 45Q tax credit, enhanced oil recovery, or both.[113] However, the study found that even with the expansion of the IRS 45Q tax credit, the overall profitability of the systems remains unchanged.[114]

A 2020 cost analysis of CCS from U.S. natural gas-fired power plants published in *Environmental Science & Technology* found that even with the IRS 45Q tax credit, a minimum incentive gap of about $38 per ton of sequestered CO_2 remains for the geologic sequestration of CO_2 and $56 per ton of sequestered CO_2 for enhanced oil recovery before accounting for revenue generated from delivered CO_2 contracts.[115]

Articles in the local news media about proposed CCS projects in Louisiana also indicate that the economic viability of these projects likely depends on the receipt of Louisiana's Industrial Tax Exemption Program (ITEP) and investment from the state. In 2021, WRK 89.3 Baton Rouge Radio reported that the Air Products CCS project, proposed for Ascension Parish, is seeking up to an 80 percent abatement through ITEP if local government officials sign off on the project.[116] The article also notes that Air Products will receive a $5 million performance grant from the state to offset infrastructure costs on top of the tax abatement.[117] Similarly, Venture Global LNG will receive an 80 percent property tax abatement for five years on its carbon capture liquified natural gas facility in Cameron Parish, according to the *Livingston Parish News*.[118]

Regulatory Gaps

There is uncertainty about the adequacy of federal and Louisiana regulation and oversight of CCS.

Federal Regulatory Gaps

According to a 2022 report published by Great Plains Institute, Louisiana is still awaiting a decision on its application to the U.S. Environmental Protection Agency (EPA) for Class VI primacy,[119] which would allow Louisiana to administer Class VI well permits needed for storing CO_2 in underground formations.[120] Discussions are ongoing about whether CCS regulation on the state level is subject to the Dormant Commerce Clause, which prohibits states from passing legislation that discriminates against or excessively burdens interstate commerce[121] or that violates the preemption doctrine, which provides that federal law preempts state law when they conflict.[122]

A notable case on the issue of the Dormant Commerce Clause and state regulation of the energy industry is *North Dakota v. Heydinger*.[123] In this 2016 case, the 8th Circuit ruled that provisions in Minnesota law restricting energy imports and exports and projects that would increase Minnesota's statewide carbon dioxide emissions violate the Dormant Commerce Clause.[124] The Dormant Commerce Clause limits the state's authority to regulate commerce.[125] It is uncertain whether this decision will be persuasive in the 5th Circuit, where Louisiana is located.

An article published by the Environmental Law Institute in 2016 notes that the regulation of CO_2 pipelines is currently left to the states.[126] However, the 2022 Accufacts report on the state of federal CO_2 pipeline safety regulations states that the Pipeline Safety Act "expressly prohibits state and local regulation that interferes with or supplements federal safety standards for interstate pipelines."[127]

This report also finds that the Pipeline and Hazardous Materials Safety Administration (PHMSA), an agency of the U.S. Department of Transportation, does not regulate pipelines transporting CO_2 as a gas, liquid, or in a supercritical state at concentrations less than 90 percent.[128] Additionally, federal pipeline safety regulations do not provide a methodology for assessing the hazard zone for CO_2 pipelines and do not require pipeline operators to sufficiently address this risk in the event of a pipeline rupture.[129] A 2022 Accufacts report prepared for the Pipeline Safety Trust on the under-regulation of CO_2 pipelines supports these concerns, finding that existing federal regulations do not allow for the safe transportation of CO_2 via pipeline.[130] The report calls on the U.S. Department of Transportation and PHMSA specifically to update and strengthen regulations of CO_2 pipelines as quickly as possible.[131]

State Regulatory Gaps

There is tremendous uncertainty and doubt about the adequacy of state-level regulation and regulatory practices of CCS in Louisiana. In 2020, Louisiana's state legislative auditor evaluated whether the Louisiana Department of Natural Resources Office of Conservation (OC) had implemented recommendations from a 2014 performance audit on the OC's regulation of oil and gas wells and management of orphaned wells.[132] The audit found (1) that OC did not always conduct required re-inspections of wells cited for significant violations; (2) the number of abandoned wells has increased; and (3) resources for plugging abandoned wells were insufficient.[133]

These problems were echoed in the 2022 Louisiana Climate Action Plan, which recommends the following:

- An increase in the resources and staffing capacity of relevant state agencies before the permitting of any CCS projects;[134]

- That internal audits of these agencies be completed before permitting CCS projects to ensure they are adequately funded and prepared to "assess, monitor, and make regulatory determinations for the specific project;"[135] and

- That existing permitting and facility siting practices be updated to align with Louisiana's emissions reduction goals because the current process is complex and disjointed.[136]

Louisiana House Bill 549, which absolves companies from reporting natural gas leaks of less than 1,000 pounds unless they cause hospitalization or death, took effect in August 2021.[137] It is uncertain whether this law will apply to leaks associated with CCS. A July 2021 article from the *Energy News Network* reports that the oil and gas industry pushed for less regulation and notes that the Louisiana state police, which oversees pipeline safety, have frequently lowered or dismissed fines against pipeline companies operating in the state.[138]

Conclusion

This report finds many risks associated with CCU and CCS identified by current research and spotlights many vital gaps in the research on this technology. The uncertainty and lack of research surrounding many potential risks leave advocates, decision-makers, and community leaders facing proposed CCS and CCU projects unequipped to fully understand the risks and consequences that may be associated with these projects. Without comprehensive research finding carbon capture processes to be safe and reliable, proposed projects in Louisiana and the Gulf Coast region should be halted indefinitely.

See the appendix for our recommended studies and specific research questions worth further exploration.

Appendix

Specific Research Questions Worth Further Exploration and Recommended Studies

1. Risk of CCS contributing to local and global environmental challenges and uncertainty of the extent of this risk
    1. How could the deployment and use of CCS contribute to dependence on fossil fuels in Louisiana and more broadly?

2. Risks and uncertainties related to CCS infrastructure
    1. What is the total cost of retrofitting power plants and industrial plants in Louisiana with CCS? What are the health, environmental, and societal risks and costs of making these retrofits?
    2. Can natural gas and crude oil pipelines be successfully repurposed for CO_2 transport in Louisiana? If so, what are the health, environmental, and societal risks and costs of this?
    3. What is the actual carbon storage capacity of oil and gas reservoirs in Louisiana?
    4. What is the actual carbon storage capacity of saline aquifers in Louisiana?
    5. What methods can be used to account for the geological heterogeneity of saline aquifers in cost analyses of storage in Louisiana?

3. Environmental, public health, and societal risks and uncertainties associated with CO_2 transport
    1. This study identified several areas where further research is needed:
        1. Comparative investigations involving CO_2 in the presence of impurities to better understand the effect of impurities on corrosion rates and hydrogen embrittlement.
        2. Studies of CO_2 pipeline ductile and brittle failures that entail the development and application of appropriate equations of state and detailed consideration of the interactions between the transported fluid and the materials of containment.
        3. Studies providing data on CO_2- corrosion in the supercritical region of CO_2 pipelines. This is important because CO_2 presents

uncertainties relating to the understanding of CO_2- water corrosion behavior to pipelines transporting supercritical CO_2.

4. Studies on pipeline embrittlement in CO_2 pipelines. In particular, future studies of CO_2 pipeline ductile and brittle failures "must entail the development and application of appropriate equations of state and detailed consideration of the interactions between the transported fluid and the materials of containment."

2. Does a release of supercritical CO_2 from a pipeline differ significantly from a dense liquid release?
3. What is the impact of impurities on CO_2 pipeline operation?
4. What is the final human health impact resulting from the release and subsequent dispersion of CO_2 and impurities from a CO_2 pipeline?
5. What is the effect of crosswinds on the dispersion of a CO_2 cloud upon release from a CO_2 pipeline?
6. How may the clogging of holes due to dry ice and/or hydrate formation in the pipeline influence the release rate at the exit of CO_2 pipelines?
7. What is the impact of rapid cooling of CO_2 on adjacent installations and/or exposed pipelines?
8. What are the risks associated with CO_2 transportation via pipeline through densely populated areas in Louisiana?
9. How prepared are local emergency responders and healthcare providers in Louisiana to respond to a CO_2 pipeline rupture?

4. Environmental, public health, and societal risks and uncertainties associated with CO_2 storage
   1. Based on research reviewing the leakage risks associated with CO_2 storage in oil and gas reservoirs in Louisiana, there is a need for a comprehensive study into the leakage potential of all proposed carbon storage sites in Louisiana.
   2. What are the historic uses of proposed CO_2 storage sites in Louisiana?
   3. What are the characteristics of the wellbores of wells in oil and gas reservoirs proposed for CO_2 storage in Louisiana? What do these characteristics mean for storage effectiveness and safety?

4. What processes were used during the drilling, completion, and abandonment phases of wells in oil and gas reservoirs proposed for CO_2 storage in Louisiana? What do these processes mean for storage effectiveness and safety?
5. What is the quality of cement in wells sections in wells in oil and gas reservoirs proposed for CO_2 storage in Louisiana?
6. How old are the wells in oil and gas reservoirs proposed for CO_2 storage in Louisiana?
7. What is the depth of at which CO_2 would be stored in oil and gas reservoirs in Louisiana?
8. Will CO_2 be stored in the gas phase in oil and gas reservoirs in Louisiana?
9. What is the hydrostatic overburden pressure associated with CO_2 storage in oil and gas reservoirs in Louisiana?
10. What are the faulting processes in oil and gas reservoirs in Louisiana proposed for CO_2 storage?
11. What is the risk of CO_2 causing asphaltene precipitation from CO_2 storage in oil and gas reservoirs in Louisiana?
12. What is the potential for an abrupt release of a large quantity of CO_2 from deep saline aquifers in Louisiana? What are the consequences of this?
13. How might brine displacement from deep saline aquifer storage of CO_2 affect groundwater resources in Louisiana?
14. Do localized zones of high permeability exist in the proposed CO2 storage areas in Louisiana, potentially resulting in fluid migration into groundwater zones or the atmosphere?
15. What are the long-term effects of CO_2 storage in the ocean on ecosystems over large ocean areas and long times scales?
16. What is the effect of air-sea CO_2 exchange on deep ocean storage?
17. What are the long-term environmental, health, and societal impacts of CO_2 deep ocean storage?
18. What are the long-term environmental impacts of CO_2 storage in Louisiana?
19. Will stored CO_2 be converted into methane and will CO_2 be dissolved into groundwater via microbial methogenesis? If so, what quantity will be

converted into methane and what quantity will be dissolved into groundwater?

20. What is the risk of sink holes in salt caverns proposed for CO_2 storage in Louisiana?
21. What risk do natural earthquakes pose to CO_2 storage in Louisiana?
22. What is the risk of CO_2 injections triggering seismic events in Louisiana?
23. What is the effect of CO_2 storage on subsurface microbial populations?

5. Uncertainties on the environmental, health, and societal impacts of CCS in general
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        1. A full analysis of the impact of CCS installations on water sustainability in Louisiana.
        2. That environmental, economic, and societal impacts of CCS deployment be integrated into future assessments of CCS operations.
    2. What is the impact on wetlands of CCS development in Louisiana? What is the impact on CCS development of wetlands in Louisiana?
    3. What are the long-term environmental impacts of CCS in Louisiana?
    4. What are the long-term health impacts of exposure to CO_2 from a CO_2 pipeline rupture?

6. Uncertainties about the economic viability of CCS
    1. What is the cost of retrofitting plants with CCS infrastructure in Louisiana?
    2. What is the potential for utilizing economies of scale for CCS in Louisiana?

7. Regulatory gaps and unknowns
    1. Does Louisiana HB 549, which absolves companies from reporting natural gas leaks of less than 1,000 pounds unless they cause hospitalization or death, apply to leaks associated with CCS?

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