Carbon Capture, Utilization, and Storage and Louisiana's Power Sector

Prepared on behalf of the Union of Concerned Scientists (UCS) and the Louisiana Against False Solutions Coalition

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Executive Summary

As a potential decarbonization strategy to aide in the reduction of greenhouse gas emissions within the power and industrial sectors, carbon capture, utilization, and storage (CCUS) must be compared to alternative decarbonization strategies to ensure that surrounding communities are prioritized and not negatively impacted. Louisiana's 2022 State Climate Initiatives Task Force's *Climate Action Plan* assigns a critical role to CCUS in achieving net-zero greenhouse gas emissions statewide by 2050 while reaching 100 percent carbon-free electricity by 2035. According to the Plan, CCUS could reduce emissions by capturing CO_2 to either inject into geologic formations for storage or to use in the extraction of new oil and gas resources. While it may form part of a plan for decarbonization, CCUS emissions reduction potential is limited and does not address the upstream fugitive emissions or environmental and public health impacts from fossil fuel extraction, storage, and transmission.

To fully understand and mitigate the risks associated with CCUS, decision-makers must assess (1) how and to what extent CCUS could negatively impact surrounding communities, (2) what policies, rules and regulations are required to ensure that CCUS deployment is conducted in a safe and responsible manner, and (3) which applications are most appropriate for CCUS versus other decarbonization alternatives. This Applied Economics Clinic (AEC) report assesses viability of CCUS as a decarbonization strategy in Louisiana's power sector, while providing an overview of its associated risks and vulnerabilities with the following key takeaways:

- **CCUS is vulnerable to damage.** CCUS infrastructure is susceptible to land subsidence, damage from water, extreme changes in temperature or pressure, and chemical impurities in the CO_2 mixture, which can be further exacerbated by the impacts of climate change such as sea level rise and extreme weather events. Damages to pipelines, injection wells and other types of CCUS infrastructure can impede functionality through leakages, ruptures, embrittlement, and explosions, among other potential hazards.
- **CCUS poses risks to human health, safety, and the environment.** The vulnerabilities of CCUS infrastructure can lead to several risks to human health, safety, and the environment, including: explosions from pipeline ruptures, exposure to CO_2 plumes from leakages, and compromised drinking water supplies due to CO_2 interacting with groundwater.
- **The emissions reduction potential of CCUS is limited.** Although CCUS technologies are commonly designed to capture 90 percent (or more) of CO_2 emissions released, many examples of CCUS have underperformed and failed to meet this target. Even best-case capture efficiencies of CCUS do not account for upstream fugitive emissions from fossil fuel extraction, storage, and transmission.
- **CCUS is expensive.** Retrofitting all of Louisiana's gas-fired combined cycle units with CCUS (without considering IRA tax credits) would cost $1.0 to $1.2 billion per year, which could double the costs associated with operating gas-fired combined cycle power plants in Louisiana.
- **There are excellent, commercially viable alternatives to CCUS.** Although CCUS may present opportunities to address recalcitrant greenhouse gas emissions, especially in certain hard-to-decarbonize industries, there are better alternatives to choose that are cheaper, safer, and more effective.

To identify the most appropriate role that CCUS could play in Louisiana's decarbonization efforts, decision-makers must take into consideration the technical and economic feasibility, emissions reduction potential, and safety of CCUS infrastructure compared to that of alternative decarbonization strategies.

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About the Applied Economics Clinic

Based in Arlington, Massachusetts, the Applied Economics Clinic (AEC) is a mission-based non-profit consulting group that offers expert services in the areas of energy, environment, consumer protection, and equity from seasoned professionals while providing on-the-job training to the next generation of technical experts.

AEC's non-profit status allows us to provide lower-cost services than most consultancies and when we receive foundation grants, AEC also offers services on a pro bono basis. AEC's clients are primarily public interest organizations—non-profits, government agencies, and green business associations—who work on issues related to AEC's areas of expertise. Our work products include expert testimony, analysis, modeling, policy briefs, and reports, on topics including energy and emissions forecasting, economic assessment of proposed infrastructure plans, and research on cutting-edge, flexible energy system resources.

AEC works proactively to support and promote diversity in our areas of work by providing applied, on-the-job learning experiences to graduate students—and occasionally highly qualified undergraduates—in related fields such as economics, environmental engineering, and political science. Over the past four years, AEC has hosted research assistants from Boston University, Brandeis University, Clark University, Tufts University, and the University of Massachusetts-Amherst. AEC is committed to a just workplace that is diverse, pays a living wage, and is responsive to the needs of its full-time and part-time staff.

Founded by Director and Senior Economist Elizabeth A. Stanton, PhD in 2017, AEC's talented researchers and analysts provide a unique service-minded consulting experience. Dr. Stanton has had two decades of professional experience as a political and environmental economist leading numerous studies on environmental regulation, alternatives to fossil fuel infrastructure, and local and upstream emissions analysis. AEC professional staff includes experts in electric, multi-sector and economic systems modeling, climate and emissions analysis, green technologies, and translating technical information for a general audience. AEC's staff are committed to addressing climate change and environmental injustice in all its forms through diligent, transparent, and comprehensible research and analysis.

I. Overview

Carbon capture, utilization, and storage (CCUS) encompasses processes in which carbon dioxide (CO_2) emissions are captured at their source and transported for use in a variety of applications or injected into geological formations for long-term storage so as to prevent CO_2 from entering the atmosphere.[1] Although CCUS technologies may be presented as a way to reduce greenhouse gas emissions, it is essential that climate and energy planning considers the vulnerabilities of the proposed CCUS infrastructure and the potential for safety issues and environmental contamination resulting from infrastructure damage and accidents, as well as the risks of the perpetuation and potential expansion of the use of fossil fuels.

The State of Louisiana aims to achieve net-zero greenhouse gas emissions statewide by 2050, while reaching 100 percent carbon-free electricity by 2035. As described in the 2022 State Climate Initiatives Task Force's *Climate Action Plan*, Louisiana is planning for CCUS technologies to play a critical role in achieving the State's climate and energy goals.[2] According to the Plan, long-term CCUS infrastructure-buildout would reduce greenhouse gas emissions from the electric and industrial sectors by capturing CO_2 to either inject into geologic formations for storage or for use in facilitating the extraction of new oil and gas resources. Louisiana's *Climate Action Plan* designates fossil gas-fired power plants that employ CCUS as "clean" energy resources if a large majority of greenhouse gas emissions are diverted from entering the atmosphere.[3]

Louisiana's commitment to CCUS deployment and the associated risks posed by CCUS infrastructure increase the urgency for an unbiased examination of regulation and permitting of CCUS pipelines, injection wells, and other infrastructure. As CCUS buildout continues, the outcomes for human health and the environment will depend on who is given regulatory and permitting authority over CCUS infrastructure as well as the institutional capacity of the designated agencies to effectively administer their duties.

The report begins in **Section II** with a description of each component of CCUS. **Section III** documents the vulnerabilities of CCUS infrastructure. **Section IV** presents safety and health concerns with CCUS infrastructure, the viability of CCUS in Louisiana from an emission reduction and economic perspective, and the risks to decarbonization posed by large-scale CCUS deployment. **Section V** examines the role and potential of CCUS deployment for storage in Louisiana, existing and planned CCUS infrastructure, and Louisiana's policies compared to those of other states and the federal government. **Section VI** discusses alternatives to CCUS for meeting electric demand while achieving emission reductions in Louisiana. **Section VII** concludes the report with key takeaways associated with CCUS in Louisiana.

[1] 1) U.S. Department of Energy. n.d. "Carbon Capture, Utilization, and Storage." Available at: https://www.energy.gov/carbon-capture-utilization-storage; 2) UNECE. "Carbon Capture, Use and Storage (CCUS)." Available at: https://unece.org/sustainable-energy/cleaner-electricity-systems/carbon-capture-use-and-storage-ccus

[2] State of Louisiana Climate Initiatives Task Force. 2022. *Climate Action Plan: Climate Initiatives Task Force Recommendations to the Governor.* Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf.

[3] State of Louisiana Climate Initiatives Task Force. 2022. *Climate Action Plan: Climate Initiatives Task Force Recommendations to the Governor.* Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf. p.44; 131.

II. What is Carbon Capture, Utilization, and Storage?

CCUS includes the capture of CO_2 from point sources such as power plants and industrial facilities to prevent it from being emitted into the atmosphere; transport of captured CO_2 in pipelines, ships, trucks, or rail; and either use of captured CO_2 in oil and gas recovery or other applications, or injection into geological formations for long-term storage.

Capture

Several different methods can be used to capture CO_2 at point-source facilities, including:

- **Post-combustion capture:** CO_2 captured at fossil fuel and bioenergy combustion plants by separating it from exhaust emissions,
- **Pre-combustion capture:** Separation of CO_2 from fossil fuels prior to combustion, and
- **Oxy-fuel capture:** Burning fossil fuels using pure oxygen to result in a more concentrated stream of CO_2 to be captured from the resulting flue gases.[4]

Post-combustion capture is the primary method of carbon capture used in existing power plants, while pre-combustion capture is only commercially available for industrial facilities.[5] Pre-combustion capture technologies would be prohibitively costly to retrofit onto an existing facility, which means that it is only economically viable at new facilities.[6] Oxy-fuel capture presents an opportunity to simplify the carbon capture process, but requires further research and development to improve system efficiency and reduce capital costs.[7]

Carbon capture technologies employed at power plants require energy to run (referred to as parasitic load or an energy penalty), which means that the power plant must burn more fuel to generate the same amount of electricity—reducing the power plant's efficiency by at least 10 percent.[8]

In addition to point-source capture technologies, CO_2 can also be extracted from the atmosphere itself through a process known as direct air capture. This report focuses on methods that capture CO_2 from power plants and industrial facilities.

Transport

Captured CO_2 is first treated to remove moisture and other chemicals to prepare it for transport to long-term geological storage sites or utilization applications.[9] CO_2 is commonly transported via pipelines but could also

[4] 1) U.S. Department of Energy. 2022. p.3; 2) Eldardiry, H. and E. Habib. 2018. "Carbon capture and sequestration in power generation: review of impacts and opportunities for water sustainability." *Energy, Sustainability and Society 8(6)*: 1-15. Available at: https://energsustainsoc.biomedcentral.com/track/pdf/10.1186/s13705-018-0146-3.pdf. p.3.

[5] Gonzales, V., A. Krupnick, and L. Dunlap. 2022. "Carbon Capture and Storage 101." Resources for the Future. Available at: https://www.rff.org/publications/explainers/carbon-capture-and-storage-101/

[6] Gonzales, V., A. Krupnick, and L. Dunlap. 2022.

[7] National Energy Technology Laboratory (NETL). "Oxy-combustion." Available at: https://netl.doe.gov/node/7477

[8] Vasudevan, S. S. Farooq, I. Karimi, M. Saeys, M. C. G. Quah, R. Agrawal. 2016. "Energy penalty estimates for CO2 capture: Comparison between fuel types and capture-combustion modes." *Energy.* Available at: https://precaution.org/lib/ccs_energy_penalty_for_coal_vs_natural_gas.2016.pdf.

[9] U.S. Department of Energy. 2022. p.19

be transported in smaller quantities by ship, truck, or rail.[10] The transport of CO_2 through pipelines to storage or utilization sites requires the use of pumps, refrigeration stations, and/or compressors throughout the length of the pipeline.[11]

Once captured and treated, CO_2 is prepared for transport as a gas, liquid, or supercritical fluid depending on the type and method of transport. Supercritical CO_2 is a dense phase "fluid" that has properties between those of a liquid and a gas. In this state, CO_2 is an excellent solvent with no liquid surface tension and can dissolve oil trapped in porous rock making it useful in oil recovery applications.[12] CO_2 destined for storage can be transported as a gas or liquid since the properties of supercritical CO_2 are not needed for sequestration applications.[13] However, storing CO_2 as a supercritical fluid can help reduce the likelihood of leakage by making the CO_2 denser and therefore less likely to contaminate groundwater or move back into the atmosphere.[14] CO_2 can also be transported in liquid form, but it must be chilled slightly below ambient temperatures to assure that it remains in the liquid phase.[15] Gaseous CO_2 can be used for transport but must be kept at low pressures to ensure that it does not spontaneously convert to a liquid, which could cause extensive damage to the pipeline's compressors.[16]

Storage

Carbon storage involves the sequestration of CO_2 via injection—known as geological storage— into geologic formations such as deep saline aquifers (i.e., reservoirs made of porous sedimentary rocks filled with salt water), former oil and gas reservoirs (i.e., orphaned wells or abandoned wells[17]), or un-mineable coal seams.[18] Depending on the specific characteristics (e.g., pressure and temperature) of a given geological formation, CO_2 can be stored as a gas, liquid, or supercritical fluid. In addition to storing CO_2 in land-based geological formations, CO_2 can potentially be stored in marine environments, but this method has yet to be tested at large scale and risks ocean acidification if CO_2 were to leak.[19]

Utilization

Carbon utilization entails the use of captured CO_2 for various commercial purposes, such as enhanced oil recovery, enhanced coal-bed methane recovery, and conversion of CO_2 into various chemicals and fuels.[20] Utilization in the food industry also includes the use of CO_2 as a carbonating agent, preservative, packing gas,

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[10] Global CCS Institute. December 2018. "Fact Sheet: Transporting CO_2." Available at: https://www.globalccsinstitute.com/wp-content/uploads/2018/12/Global-CCS-Institute-Fact-Sheet_Transporting-CO2-1.pdf

[11] U.S. Department of Energy. 2022. p.21

[12] Kuprewicz, R. 2022. Accufacts' Perspectives on the State of Federal Carbon Dioxide Transmission Pipeline Safety Regulations as it Relates to Carbon Capture, Utilization, and Sequestration within the U.S. Prepared for the Pipeline Safety Trust. Available at: https://pstrust.org/wp-content/uploads/2022/03/3-23-22-Final-Accufacts-CO2-Pipeline-Report2.pdf., p. 5.

[13] Kuprewicz, R. 2022. p. 5.

[14] Cuéllar-Franca R.M. and A. Azapagic. 2015. "Carbon capture, storage and utilisation technologies: a critical analysis and comparison of their life cycle environmental impacts." *Journal of CO_2 Utilization 9:* 82-102. Available at: https://www.sciencedirect.com/science/article/pii/S2212982014000626. p.85

[15] Kuprewicz, R. 2022. p. 6.

[16] Ibid, p. 7.

[17] New York Department of Environmental Conservation. "Orphaned and Abandoned Well Plugging." Available at: https://www.dec.ny.gov/energy/111211.html

[18] Taku, Ide, S., S. J. Friedmann, H. J. Herzog. 2006. "CO_2 leakage through existing wells: current technology and regulations." Available at: https://sequestration.mit.edu/pdf/GHGT8_Ide.pdf. p.1

[19] Cuéllar-Franca R.M. and A. Azapagic. 2015. p.86

[20] Ibid, p.86

and solvent for caffeine and flavor extraction processes.[21] CO_2 can be directly utilized in the pharmaceutical industry as a respiratory stimulant or an intermediate in drug production; however, these utilization applications require inputs from processes (for example, ammonia production) that yield high-purity CO_2 from their waste streams.[22] Additional applications of CO_2 include the cultivation of microalgae to produce biofuel using waste streams like flue gas[23] and utilization in greenhouses to increase crop yields.[24]

In enhanced oil and gas recovery (or "tertiary" recovery) CO_2 is injected into the ground to extract crude oil from an oil field or gas from coal deposits that cannot be mined through primary (recovery through natural mechanisms) or secondary (recovery through injection of gas or water) methods.[25] While enhanced coal-bed methane recovery is not commercially available, enhanced oil recovery has been practiced for around 50 years in oil-producing countries including Canada, Norway, and the United States. By injecting different agents (including CO_2, nitrogen, polymers, and surfactants) into reservoirs to release oil trapped in rocks, enhanced oil recovery can extract between 30 to 60 percent of the crude oil reserves that would otherwise be unrecoverable.[26]

CCUS can also be used as a critical component of industrial decarbonization. The United States Department of Energy (DOE) includes CCUS among its four major pillars of industrial decarbonization (along with energy efficiency, electrification, and low-carbon fuels) and defines CCUS technologies as those that could capture CO_2 from a point-source and then send it for other utilization purposes or long-term storage.[27] Industrial decarbonization efforts include: post-combustion chemical absorption of CO_2, development of optimization of advanced CO_2 capture materials that improve the efficiency and cost of capture, and the development of processes to utilize captured CO_2 to manufacture new materials.[28]

III. Vulnerabilities and Risks of CCUS Infrastructure

Each stage of the CCUS process requires extensive infrastructure, from the equipment needed to capture CO_2 at power generation and industrial facilities, to the pipelines for transporting CO_2, to the injection wells for CO_2 storage in geological formations or CO_2 utilization in oil and gas recovery. CCUS infrastructure is susceptible to land subsidence, damage from water, extreme changes in temperature or pressure, and chemical impurities in the CO_2 mixture, which can be further exacerbated by the impacts of climate change such sea level rise and extreme weather events. Damages to CCUS infrastructure, such as pipelines or injection wells, can impede functionality through leakages, ruptures, corrosion, embrittlement, and in rare instances explosions, among other potential hazards. These vulnerabilities can lead to CO_2 leakages into the atmosphere or acidification and compromised drinking water through the interaction of CO_2 with groundwater, posing acute risks to human health, safety, and the environment in surrounding communities, as well as long-term risks to climate. Damage to a pipeline that causes CO_2 to escape results in impacts to the

[21] Ibid.
[22] Ibid.
[23] Styring, P. and D. Jansen. 2011. *Carbon Capture and Utilisation in the green economy*. Centre for Low Carbon Futures. Available at: http://co2chem.co.uk/wp-content/uploads/2012/06/CCU%20in%20the%20green%20economy%20report.pdf.
[24] DutchGreenhouses. "CO_2 Enrichment." Available at: https://www.dutchgreenhouses.com/en/technology/co2-enrichment/#:~:text=CO2%20enrichment%20in%20greenhouses%20allows,the%20yield%20of%20greenhouse%20crops.
[25] Cuéllar-Franca R.M. and A. Azapagic. 2015. p.86
[26] Ibid.
[27] U.S. Department of Energy. 2022. *Industrial Decarbonization Roadmap.* Available at: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap.
[28] Ibid.

surrounding environment and to the health of people who are exposed. A 2022 report by the Pipeline Safety Trust (PST) explains that CO_2 is an asphyxiant and intoxicant that is odorless, colorless, and inflammable, making it hard to observe or avoid.[29] When released as a plume, CO_2 migrates significantly from the pipeline right of way—dramatically increasing the affected area around the pipeline. A sudden phase or temperature change of CO_2 can also create a hazard area and explosive forces (as CO_2 converts to a gas) around the ruptured site that first responders may not be aware of without detection equipment.

Risks of CO_2 transport in pipelines

CO_2 pipelines are the primary method for transporting CO_2 from point sources (e.g., power plants or industrial facilities) to the site of eventual CO_2 storage or utilization.[30] Pipelines differ in terms of the specific phase (i.e., gas, liquid, or supercritical fluid) of CO_2 that is being transported as well as the material the pipeline is made from. Each type of pipeline carries a different risk profile.

Gaseous, liquid, and supercritical fluid CO_2 each have unique infrastructural requirements (such as pipeline diameter, auxiliary equipment, etc.) that affect a pipeline's operational parameters. The operational pressure and temperature of pipelines differ depending on the phase of CO_2 that is being transported, which makes some pipelines more susceptible to damages than others.

Gaseous CO_2 can be transported in pipelines that have larger diameters and operate at lower pressures than their liquid or supercritical fluid counterparts.[31] Investment in new gaseous CO_2 pipelines is not considered likely because of the lower pressure for operation, though specific situations could arise in which larger diameter natural gas pipelines could be repurposed as gaseous CO_2 pipelines.[32]

Due to its density, transporting **supercritical CO_2** (1) requires the use of pumps instead of the compressors needed to move gaseous CO_2 and (2) can be transported in smaller diameter pipes.[33] Supercritical CO_2 pipelines are susceptible to running ductile fractures—pipeline ruptures that extend for long distances when a small crack results in pipeline wall material being unable to handle the extreme internal pressure[34]—that can create enough force to throw tons of material (e.g., pipes, shrapnel, ground covering, etc.) and form large craters along the length of the failed pipeline.[35]

Pipelines—especially those made from carbon steel—that transport **liquid CO_2** are susceptible to ruptures if temperatures are not kept above -20 degrees Fahrenheit.[36] Despite this risk, liquid CO_2 pipelines can handle up to double the volume of flow (density) of supercritical CO_2 pipelines, allowing the transport of more CO_2 in pipelines with smaller diameters.[37] Liquid CO_2 is also less viscous than supercritical CO_2, making it possible for

[29] Kuprewicz, R. 2022. p. 8.
[30] 1) Johnson, G. 2020. *Pipeline Corrosion Issues Related to Carbon Capture, Transportation, and Storage*. Materials Performance. Available at: https://www.materialsperformance.com/articles/material-selection-design/2015/08/pipeline-corrosion-issues-related-to-carbon-capture-transportation-and-storage#:~:text=Sankara%20Papavinasam%3A%20Carbon%20steel%20(CS,which%20is%20corrosive%20to%20CS; 2) Noothout, P., F. Wiersma, O. Hurtado, D. Macdonald, J. Kemper, K. van Alphen. 2014. "CO_2 Pipeline infrastructure – lessons learnt." *Energy Procedia.* Vol 63. Available at: https://www.sciencedirect.com/science/article/pii/S1876610214020864. Pg. 2484.
[31] Ibid, p. 7.
[32] Ibid.
[33] Kuprewicz, R. 2022. p. 5.
[34] Martynov, S., R. Talemi, S. Brown, H. Mahgerefteh. 2017. "Assessment of Fracture Propagation in Pipelines Transporting Impure CO2 Streams." *Energy Procedia.* Available at: https://www.sciencedirect.com/science/article/pii/S1876610217319999. p. 6686-6687.
[35] Kuprewicz, R. 2022, p. 6.
[36] Ibid.
[37] Ibid.

fewer pumps to operate the pipelines.[38]

Corrosion

CO_2 pipelines are primarily constructed of carbon steel, but can be made with alternative materials that are characterized based on their lining, resistance to corrosion, and temperature- and pressure-tolerance.[39] Depending on the material, pipelines may be vulnerable to hydrogen embrittlement, a process in which molecular hydrogen diffuses into the pipeline material and cause small-scale damage to pipelines that can lead to larger ruptures if left unattended (see below for a comparison of the impacts of brittle and ductile fractures in the subsection, "Pipeline Failure").[40] Constructing pipelines with low sulfur content steels can mitigate this problem at an increased cost.[41]

Carbon steel is weldable and durable, but corrosion from seawater and chemical compounds are its primary weaknesses. It generally requires a special coating or lining of some resistant material when used underwater or underground.[42] Carbon steel pipelines are also sensitive to temperature. When not kept within a specific temperature range, pipeline operations can be impacted due to coating deterioration and corrosion.[43]

Other less common CO_2 pipeline materials include stainless steel, which resists oxidation and corrosive substances.[44] Cast iron pipes are corrosion resistant but have a high degree of hardness and friability and so cannot be suitable for facilities that may experience vibration or seismic activity.[45] Galvanized pipe is coated with zinc to provide resistance to rust and is used in drains and conduits.[46] Finally, fiber reinforced plastic can handle pressure and temperature better than regular plastic pipe and is not subject to corrosion.[47] Another alternative to carbon steel is 13Cr steel, a corrosion resistant alloy made of stainless steel, but that material is vulnerable to corrosion from higher concentrations of sulfur dioxide.[48]

According to a 2018 report by the Canadian Association of Petroleum Producers (CAPP), the predominant factor contributing to pipeline failures and leakages is the susceptibility of carbon steel pipelines to corrosion.[49] Although CAPP's 2018 report focuses on carbon steel pipelines carrying water, many of the threats discussed are common to pipelines that carry CO_2. For instance, exposure to water carries risk of aqueous CO_2—which can dissolve in water to create carbonic acid that increases corrosion—a threat to CO_2 pipelines echoed in research published in the journal *Materials Performance*.[50] That same research also shares CAPP's concern over hydrogen sulfide in water that can result in sulfuric acid. Research published in the journal *Materials Performance* and *Hazards* notes a similar problem with the formation of nitric acids in

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38 Ibid.

39 Ibid, p. 11.

40 Bilio, M., S. Brown., M. Fairweather, H. Mahgerefteh. 2009. "CO2 Pipelines Material and Safety Considerations." *Hazards.* Vol. XXI. Available at: https://www.icheme.org/media/9558/xxi-paper-061.pdf. p. 424.

41 Bilio, M., et. al. 2009. p. 424.

42 Jatmoko, F. A., E. Kusruni. 2018. "Analysis of CO_2 transmission pipelines for CO_2 enhanced oil recovery networks: gas field X to oil field Y." E3S Web of Conferences. Vol. 67. Available at: https://www.e3s-conferences.org/articles/e3sconf/pdf/2018/42/e3sconf_i-trec2018_04009.pdf. p. 2.

43 CAPP. 2018. *Mitigation of Internal Corrosion in Carbon Steel Water Pipeline Systems.* Available at: https://www.capp.ca/wp-content/uploads/2020/01/Mitigation_of_internal_corrosion_in_carbon_steel_water_pipeline_systems-326701.pdf. p. 7.

44 Jatmoko, F. A., E. Kusruni. 2018. p. 2.

45 Ibid.

46 Ibid.

47 Ibid.

48 1) Johnson, G. 2020. 2) Corrosion Resistant Alloys. "13 Chrome: UNS S42000/ W.NR. 1.4021." Available at: https://www.cralloys.com/alloys/13-chrome/

49 CAPP. 2018. p. 4.

50 1) CAPP. 2018. p. 4-5; 2) Johnson, G. 2020.

water.[51]

Research in the journal *Hazards* describes the presence of water in CO_2 pipelines as inevitable due to the concentration of water in inlet steam—particularly in post-combustion capture technology.[52] The *Hazards* research also notes that free water can directly attack pipeline materials by acting as an electrolyte[53] and that water in CO_2 pipelines can combine with gas molecules to form gas hydrates, which can block pipelines causing serious operational and safety issues.[54] Mechanisms to prevent the formation of carbonic and sulfuric acid include effective pigging—the use of special projectiles to recover leftover contents in a pipeline[55]—and inhibition programs[56]—the use of chemical compounds to slow down or halt corrosion processes in a pipeline.[57]

The CAPP report also highlights the danger of bad operating practices that can lead to accelerated corrosion, including ineffective pigging and inhibition, intermittent operation, inadequate pipeline suspension, and operating pipelines past the expected life of internal coating.[58]

The most common method of protecting pipelines against external corrosion is cathodic protection, which is a process that controls the corrosion of a metal surface by making it the cathodic side of an electrochemical cell.[59] Other methods include keeping water content in pipelines as low as possible using a dehydration system, though systems producing dry gas (such as hydrogen plants or gas processing plants) may not require it.[60] The CAPP report presents a list of mitigation practices aimed at limiting and detecting corrosion risk, including:[61]

- Use proper materials and components for pipeline construction to prevent corrosion, enable effective isolation of pipeline sections, and facilitate pigging and inspection capability,
- Conduct corrosion assessments, inhibition, and monitoring to prepare and design an effective corrosion mitigation program,
- Develop an inspection program or strategy to assure that the corrosion mitigation program is effective,
- Perform a proper failure analysis to reassess and adjust the corrosion mitigation program,
- Establish repair and rehabilitation protocols to prevent multiple failures and/or reoccurrence, and
- Integrate a leak detection strategy and management of change process allow for proper maintenance of pipeline infrastructure.

Pipeline failure

Pipeline failure is physical damage to the pipeline that prevents its continued use and results in the escape of

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51 1) CAPP. 2018. p. 5; 2) Johnson, G. 2020.; 3) Bilio, M., et. al. p.424.
51 Bilio, M., et. al. p.424.
52 Ibid.
53 Ibid.
54 Ibid, p.425.
55 HPS. "What Pigging Is And How It Works?" Available at: https://www.hps-pigging.com/about-hps/what-is-pigging/
56 CAPP. 2018. p.5.
57 Murthy, T. 2020. "Preventing Internal Corrosion in Oil and Gas Field Pipelines." *Materials Performance.* Available at: https://www.materialsperformance.com/articles/chemical-treatment/2019/04/preventing-internal-corrosion-in-oil-and-gas-field-pipelines
58 CAPP. 2018. p.7.
59 Noothout, P., et al. 2014. p. 2486.
60 Ibid.
61 CAPP. 2018. pp.8-12.

CO_2. Two types of fractures result in pipeline failures: (1) ductile fractures and (2) brittle fractures. A ductile fracture involves significant deformation, where the damage may grow as the stress on the pipeline causes it to continuously fail.[62] Brittle fractures start with small deformations, where the area around the fracture will rapidly lose temperature and weaken the pipeline. Left unchecked, the fracture will grow until a larger and possibly catastrophic failure occurs.[63]

Risks of CO_2 storage and utilization applications

CO_2 storage—whether in oil and gas fields, un-mineable coal seams, or saline reservoirs—is at continual risk of leakage and seepage. For example, CO_2 injected into these storage sites may encounter human-made well bores, which can create conduits for CO_2 to rise to the surface.[64] Leakage problems may also emerge with orphaned, abandoned, or old wells that were left unclosed—or that have open well bores that could provide a fast path for leakage.[65] In most types of storage sites, CO_2 will be a supercritical fluid due to the pressures and temperatures during injection.[66] Since many of the sites are brine bearing (that is, containing a high concentration solution of salt in groundwater), CO_2 will be buoyant during injection and migrate to the top of the storage area, spreading laterally in a plume. Some CO_2 will be trapped through chemical dissolution or mineralization. But un-trapped gases will remain mobile. If oil and gas exploration penetrated the cap rock during extraction, CO_2 could escape through those openings.[67] Even properly plugged wells can leak when carbonic acid forms through the dissolution of CO_2 into geologic storage sites containing brine; this acid can then cause corrosion of the well when it comes in contact with hydrated cements[68]—a product of water reacting with cement.[69]

Underground stored CO_2 can is also susceptible to seepage, which research in the journal *Climate Policy* defines as "CO_2 that migrates from the intended geological storage reservoir to another subsurface zone or back to the atmosphere."[70] Seepage risks may increase as injection proceeds, reservoir pressure increases, and the plume of CO_2 in the storage—be it a well for oil and gas or saline reservoir.[71]

Research published in the journal *Developments in Water Science* suggests that CO_2 storage in salt caverns could be more efficient than other geologic forms of storage—such as wells.[72] However, a cavern filled with supercritical CO_2 will close in until its pressure equalizes with the stress on the salt bed.[73] This inevitably reduces the volume of the cavern resulting in some cavern closure.[74] Storing CO_2 offshore reduces certain

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62 Ibid, p.425.
63 Ibid.
64 Taku Ide, S., et al. 2006. p.1.
65 Ibid.
66 Ibid.
67 Ibid, p.2.
68 Scherer, G.W. et. al. 2005. "Leakage of CO_2 through Abandoned Wells: Role of Corrosion of Cement," *CO_2 Capture and Storage Project, 2.* 823-244. Available at: https://www.researchgate.net/publication/246663624_Leakage_of_CO2_through_abandoned_wells_Role_of_corrosion_of_cement.
69 ScienceDirect. "Hydrated Cement." Available at: https://sequestration.mit.edu/pdf/GHGT8_Ide.pdf
70 Pollak, M., E. J. Wilson. 2009. "Risk governance for geological storage of CO_2 under the Clean Development Mechanism" *climate policy.* Available at: https://www.researchgate.net/publication/236845535_Potential_hazards_of_CO2_leakage_in_storage_systems-Learning_from_natural_systems. p.74.
71 Pollak, M., E. J. Wilson. 2009 p. 75.
72 Bachu, S., 2005. "Underground Injection of Carbon Dioxide in Salt Beds." *Developments in Water Science.* Vol. 52: pp.637-648. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0167564805520495.
73 Ibid.
74 1) Ibid; 2) Shi, J. Q., S. Durucan. 2005. "CO_2 Storage in Caverns and Mines." *Oil & Gas Science and Technology.* Vol. 60, pp.569-571. Available at: https://ogst.ifpenergiesnouvelles.fr/articles/ogst/pdf/2005/03/shi2_vol60n3.pdf. p. 570.

kinds of risks to human health, groundwater, and the atmosphere (as discussed below), but still risks displacing underground water and harming ecosystems (see Table 1 below).[75] Research on naturally occurring CO_2 seepage in Europe found that CO_2-charged groundwater can cause limestone dissolution and form large sinkholes.[76]

Table 1. Seepage risk by reservoir location and type

			Reservoir location and type			
			Onshore		Offshore	
			Oil/Gas	Saline	Oil/Gas	Saline
Seepage risk potential	Impacts	Human health	●	●		
		Ecosystems	●	●	●	●
		Drinking water	●	●		
		Fluid displacement	●	●	●	●
		Atmosphere	●	●		
	Vulnerabilities	Wells	●		●	
		Faults	●	●	●	●
		Geological uncertainty		●		●

Note: "Oil/Gas" refers to oil and gas reservoirs used for CO_2 storage and "Saline" refers to saline reservoirs used for the same purpose. Source: Reproduced from Pollak, M., E. J. Wilson. 2009. "Risk governance for geological storage of CO_2 under the Clean Development Mechanism" climate policy. Available at: https://www.researchgate.net/publication/236845535_Potential_hazards_of_CO2_leakage_in_storage_systems-Learning_from_natural_systems. p. 75.

Research published in the journal, *Nature Communications*, finds that well-regulated storage in regions with moderate well densities has a 50 percent change of leakage rates remaining below 0.0008 percent and that 98 percent of injected CO_2 is retained in subsurface storage over 10,000 years.[77] To be effective, CO_2 must be securely retained for 10,000 years while losing less than 0.01 percent per year of the total amount of gas injected.[78] The High Meadows Environmental Institute found CO_2 leakage rates from shallow aquifers less than 0.001 percent after 50 years; 95 percent of results fell below 0.002 percent.[79]

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[75] Pollak, M., E. J. Wilson. 2009. p. 75.
[76] Beaubien, S.E., S. Lombardi., G. Ciotoli, A. Annuziatellis. 2005. "Potential hazards of CO_2 leakage in storage systems—learning from natural systems." Available at: https://www.researchgate.net/publication/236845535_Potential_hazards_of_CO2_leakage_in_storage_systems-Learning_from_natural_systems.
[77] Alcalde, J. S. Flude, M. Wilkinson, G. Johnson, K. Eldmann, C. Bond, V. Scott, S. Gilfillan, X. Ogaya, R. Haszeldine. 2018. "Estimating geological CO2 storage capacity to deliver on climate mitigation." *nature communications.* Available at: https://www.nature.com/articles/s41467-018-04423-1.
[78] Miocic, J. S. Gilfllan, N. Frank. A. Schroeder-Ritzrau, N. Burnside, R. Haszeldine. 2019. "420,000 year assessment of fault leakage rates shows geological carbon storage is secure." *Scientific reports.* Available at: https://www.nature.com/articles/s41598-018-36974-0
[79] Celia, M. 2015. *Estimating Leakage of CO_2 and Brine Along Abandoned Oil and Gas Wells.* High Meadows Environmental Institute. Available at: https://cmi.princeton.edu/annual-meetings/annual-reports/year-2015/estimating-leakage-of-co2-and-brine-along-abandoned-oil-and-gas-wells/

The Lawrence Berkeley National Laboratory (LBNL) conducted a number of studies on CO_2 leakage from groundwater storage and its impacts on groundwater quality.[80] Between 2007 and 2010, LBNL found that CO_2 from underground sources could reach groundwater, increase its acidity and increase the solubility of inorganic hazardous substances introduced from the CO_2 mixture in the acidified water.[81] The acidified water, with its newly introduced hazardous substances, could subsequently interact with underground drinking water.[82] Two LBNL studies conducted from 2009-2012 and from 2009-2013 found that CO_2 injections into the ground can release metals from sediment due to the pH changes. The latter study found that concentrations of these metals could increase suddenly with the initial injection of CO_2, decrease after the injection ended, and then start increasing again even after the injection was completed.[83] Other research published by LBNL indicates that industrial-scale geological storage of CO_2 in saline aquifers may cause CO_2 and brine leakage from abandoned wells into shallow fresh aquifers.[84]

CO_2 released into the marine environment can negatively impact marine life, according to a 2014 study of offshore enhanced oil recovery in the North Sea.[85] These impacts include acidification of the seawater as well as various CO_2-induced stresses on marine life: calcification, increased mortality, impacts on the reproduction and growth of marine life, reduced biological resilience, diminished nutrient availability, and diminished biodiversity.[86]

IV. Safety and Viability of CCUS Activities

CCUS resources carry numerous safety risks. Exposure to concentrated CO_2 is damaging to human health and—at the highest concentrations—can be deadly. Once released into the atmosphere, CO_2 plumes can spread as a deadly fog—heavier than the surrounding air—which can prevent emergency crews from responding to the site of an accident. Finally, CO_2 released into soils or water can cause acidification and the loss of biodiversity.

In addition, the viability of CCUS as a reliable path to decarbonization of the electric power sector is widely contested. CCUS does not eliminate the release of greenhouse gas emissions from fossil fuel-fired power plants, nor does it address upstream emissions from fossil fuel extraction, storage, and transmission. If captured CO_2 is utilized for enhanced oil and gas recovery, CCUS activities can prolong reliance on fossil fuels—delaying progress towards meeting climate and clean energy targets. Moreover, emission reductions from CCUS are only realized if (1) point-source facilities are able to achieve high CO_2 capture rates and (2) the stored CO_2 remains in geologic storage and without leaks or other unplanned releases.

Risks of CCUS activities to human health, safety, and the environment

Concentrated CO_2 releases have direct health effects on people. According to the Wisconsin Department of

[80] Berkeley Lab. "Potential Impacts of CO_2 Leakage on Groundwater Quality." Available at: https://eesa.lbl.gov/projects/potential-impacts-of-co2-leakage-on-groundwater-quality/
[81] Ibid.
[82] Ibid.
[83] Ibid.
[84] Wang, J., L. Hu, L. Pan, K. Zhang. 2018. *Numerical studies of CO_2 and brine leakage into a shallow aquifer through an open wellbore*. Lawrence Berkeley National Laboratory. Available at: https://escholarship.org/uc/item/3g22z8t4.
[85] Carruthers, K. 2014. *Environmental Impacts of CO_2-EOR.* Available at: https://www.sccs.org.uk/images/expertise/reports/co2-eor-jip/SCCS-CO2-EOR-JIP-WP4-Environmental-Impacts.pdf. p.14.
[86] Ibid, pp.14-19.

Health Services, high CO_2 levels in the soil can cause cracks in floors and foundations.[87] CO_2 circulating in buildings can cause problems with fresh air circulation. Exposure to higher-than-normal concentrations of CO_2 can cause headaches, dizziness, restlessness, difficulty breathing, sweating, tiredness, increases in heart rates, elevated blood pressure, comas, asphyxia, and convulsions.[88] The average outdoor air level of CO_2 is 400 parts per million (ppm).[89] Drowsiness begins between 1,000 and 2,000 ppm. Headaches, sleepiness, loss of attention, and increased nausea set in between 2,000 and 5,000 ppm. At 40,000 ppm, exposure can result in oxygen deprivation.[90] The Centers for Disease Control and Prevention notes that metal dust—including from magnesium, zirconium, titanium, aluminum, chromium, and manganese—are ignitable and explosive when suspended in CO_2.[91]

CO_2 leaks also create severe safety risks for the surrounding area. On February 22, 2020, heavy rains and a landslide caused a CO_2 pipeline operated by Denbury Gulf Coast Partners in Satartia, Mississippi to rupture and spread a plume of CO_2 into the surrounding area.[92] PHMSA's report on the Satartia pipeline accident notes that super-critical CO_2—the common phase of CO_2 being transported in pipelines—became heavier than the surrounding air when released and began to disperse at ground level.[93] In Satartia, emergency responders had difficulty assessing the risk and location of CO_2 plumes causing them to isolate the affected area by evacuating surrounding communities and shutting down highways.[94]

During a large CO_2 release such as a rupture or a fracture, CO_2 phase changes can happen multiple times, lowering temperature near the pipe failure site and raising the likelihood of dry ice formation; this can fog the air and the ground and can cause temporary restrictions or blockages of the pipe away from the release site. In the event of leaks—which are smaller releases over a period of time—the CO_2-rich clouds may disperse or dissipate.[95] The CO_2 will be heavier than air and the cold dense fog will produce areas of low visibility, eventually becoming transparent if warmed and able to travel considerable distances before settling in low spots and displacing oxygen, which can starve gasoline or diesel-powered equipment—including first responder vehicles. It can cause asphyxiation or death in animals or humans as well as disorientation, confusion, and unconsciousness. Cooling during a CO_2 release can also increase the rate at which CO_2 releases by worsening pipe fractures.[96]

In addition, the injection of CO_2 into geologic storage can induce seismic activity,[97] already a concern with injection activity related to oil and gas production.[98] Injection of CO_2 could induce tremors on pre-existing

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87 Wisconsin Department of Health Services. "Carbon Dioxide." Available at: https://www.dhs.wisconsin.gov/chemical/carbondioxide.htm#:~:text=Exposure%20to%20CO2%20can%20produce,coma%2C%20asphyxia%2C%20and%20convulsions.
88 Ibid.
89 Ibid.
90 Ibid.
91 Centers for Disease Control and Prevention. "Carbon Dioxide." Available at: https://www.cdc.gov/niosh/npg/npgd0103.html.
92 PHMSA. 2022. *Failure Investigation Report – Denbury Gulf Coast Pipelines LLC Pipeline Rupture/Natural Force Damage.* Available at: https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2022-05/Failure%20Investigation%20Report%20-%20Denbury%20Gulf%20Coast%20Pipeline.pdf.
93 Ibid.
94 Ibid, p.2.
95 Kuprewicz, R. 2022. p.8
96 Ibid. p.9.
97 Verdon, J., A. Stork. 2016. "Carbon capture and storage, geomechanics and induced seismic activity." *Journal of Rock Mechanics and Geotechnical Engineering.* Available at: https://www.sciencedirect.com/science/article/pii/S1674775516301196
98 Kaven, J., S. Hickman, A. McGarr, W. Ellsworth. 2015. "Surface monitoring of microseismicity at the Decatur, Illinois, CO_2 sequestration and demonstration site." *Seismological Research Letters.* US Geologic Survey. Available at: https://pubs.er.usgs.gov/publication/70189621

faults or fractures with possible hazards to surface installations or to the integrity of the geologic formation is its use as long-term storage.[99] The U.S. Geologic Survey monitors micro-seismic activity in Decatur, Illinois, the first large-scale injection of supercritical CO_2 in the United States.[100]

Finally, exposure to released or seeping CO_2 can harm soils and water. Research published in the journal, *Environmental Science and Pollution Research,* argues that the effects include a drop in pH (acidification) of ground water, changes to soil microbiology and surrounding vegetation near leakage sites, and the release of metals and metalloids.[101] Elevated levels of CO_2 in the soil can negatively impact crop growth.[102] Leakage of CO_2 into seawater can result in acidification, calcification, impacts on the reproduction and growth of marine life, reduced biological resilience and biodiversity, and diminished nutrient availability.[103]

Emissions reduction potential of CCUS and risks to decarbonization

CCUS's role in the Louisiana's *Climate Action Plan* is a function of its perceived potential to reduce greenhouse gas emissions from the continued use of fossil gas-fired electric generation. The potential of CCUS to successfully meet this goal is not, however, assured. Open questions include: (1) To what extent does CCUS reduce greenhouse gas emissions? and 2) Does reliance on CCUS and continued fossil-gas usage pose any risks to decarbonization efforts in Louisiana?

CCUS infrastructure has not been deployed at scale and the few projects that are currently deployed fail to achieve the capture rates necessary to qualify as "clean generation" in Louisiana and to provide reductions in greenhouse gas emissions from fossil gas generation necessary for decarbonization. Further, the use of CCUS in Louisiana's electric sector would not reduce emissions from gas extraction or other upstream emissions (such as from transportation leaks).

Even under ideal circumstances CCUS technologies are unlikely to capture 100 percent of carbon emissions released by industrial and electric power facilities. Many carbon capture projects are designed to capture at least 90 percent of CO_2 emissions to make it an economically viable investment, but surpassing that goal to achieve a higher capture efficiency would be increasingly difficult and expensive.[104] The *Climate Action Plan* identifies a 90 percent capture efficiency as the threshold above of which fossil gas generation with CCUS will be counted as "clean" generation.[105] The target of attaining at least 90 percent capture efficiency, however, has not been met in practice. Research by the Institute for Energy Economics and Financial Analysis (IEEFA) examines a number of carbon capture facilities and highlights several that have consistently underperformed in emission reduction.[106] Boundary Dam in Canada and Petra Nova in the United States—both coal plants

[99] Ibid.

[100] Ibid.

[101] Gupta, P. G., B. Yadav. 2020. "Leakage of CO_2 from geological storage and its impacts on fresh soil–water systems: a review." *Environmental Science and Pollution Research.* Available at: https://link.springer.com/article/10.1007/s11356-020-08203-7.

[102] Al-Traboulsi, M., S. Sjögersten, C. Black. "Potential impact of CO2 leakage from Carbon Capture and Storage (CCS) systems on growth and yield in maize." *Plant and Soil*. Available at: https://www.scinapse.io/papers/2129514558.

[103] Carruthers, K. 2014. *Environmental Impacts of CO2-EOR*. Available at: https://www.sccs.org.uk/images/expertise/reports/co2-eor-jip/SCCS-CO2-EOR-JIP-WP4-Environmental-Impacts.pdf. p.14.

[104] Moseman, A., H. Herzog. 2021. "How efficient is carbon capture and storage?" MIT Climate Portal. Available at: https://climate.mit.edu/ask-mit/how-efficient-carbon-capture-and-storage#:~:text=Most%20carbon%20capture%20technologies%20aim,to%20capture%20additional%20CO2..

[105] State of Louisiana. 2022. *Climate Action Plan: Climate Initiatives Task Force Recommendations to the Governor.* Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf. p.44; 131.

[106] 1) Schlissel, D., and D, Wamsted. 2022. "Infographic: Carbon capture's methane problem." Available at: https://ieefa.org/resources/infographic-carbon-captures-methane-problem; 2) Robertson, B., M. Mousavian. 2022. *The Carbon Capture Crux: Lessons Learned.* Available at: https://ieefa.org/media/3007/download/. p. 46-47; 77-78.

retrofitted with CCUS—have underperformed on their expected carbon capture efficiency (reported as a "lifetime underperformance" of 50 and 17 percent, respectively).[107] IEEFA estimates that the San Juan Generating Station in New Mexico (a now closed coal plant where CCUS was once proposed) expected to capture 49 to 72 percent of carbon generated compared to the owners' claimed 90 percent carbon capture efficiency for the plant.[108] To put these capture rates into perspective, the CCUS tax credit established in Section 45Q of Title 26 of the U.S. Internal Revenue Code ("45Q tax credit") defines an applicable electric generating unit to have carbon capture equipment that is designed to capture not less than 75 percent of baseline carbon emissions.[109] Depending on how the tax credit is enforced or interpreted, electric generating facilities in Louisiana would receive financial incentives when employing carbon capture technologies that fall short of the state's capture efficiency requirement of 90 percent.

Even best-case capture efficiencies of CCUS do not account for upstream fugitive emissions from fossil fuel extraction, storage, and transmission.[110] For fossil gas, upstream leakage rates have been estimated by U.S. EPA to be 1.4 percent[111] while others analyses suggest leakage rates as high as 2.3 to 8 percent.[112] The resulting fugitive emissions from fossil gas generation are released as methane (CH_4), which has a 100-year global warming potential that is 27 to 30 times greater than that of CO_2 (or a 20-year global warming potential that is over 80 times greater).[113] This means the EPA's low-end estimate of upstream gas leaks (1.4 percent) is equivalent to a loss of an equivalent of 38 to 42 percent downstream CO_2 emissions using the 100-year global warming potential. Even if a fossil fuel-fired power plant with CCUS was able to capture 90 percent of the greenhouse gas emissions that it released, the fugitive emissions from upstream and downstream processes would drastically reduce (or even erase) the emission reduction potential of CCUS technologies for the electric power sector.

In 2021, Louisiana's electric power sector generated 98.7 million MWh of electricity—64.0 million MWh (or 65 percent) of which is attributable to the state's fossil gas-fired power plants with nearly three-quarters (46.7 million MWh) of that generation coming from the state's combined cycle generating units.[114] Research conducted by the National Energy Technology Laboratory (NETL) estimates that the levelized cost of energy of a new fossil gas-fired combined cycle plant with carbon capture is roughly $22 to $26 per MWh more

[107] (1) Robertson, B., M. Mousavian. 2022. *The Carbon Capture Crux: Lessons Learned.* Available at: https://ieefa.org/media/3007/download/. p. 77-78. (2). Robertson, B. 2022. *Carbon Capture: CCS | CCUS | CCU.* Institute for Energy Economics and Financial Analysis. Available at: https://ieefa.org/resources/carbon-capture-ccs-ccus-ccu. p. 15.
[108] Schlissel, D., and D, Wamsted. 2022. "Infographic: Carbon capture's methane problem." Available at: https://ieefa.org/resources/infographic-carbon-captures-methane-problem
[109] 26 U.S.C. § 45Q(e)(2)(A)(i)(II).
[110] Schlissel, D., and D, Wamsted. 2022. "Infographic: Carbon capture's methane problem." Available at: https://ieefa.org/resources/infographic-carbon-captures-methane-problem
[111] U.S. EPA. 1996. *Methane Emissions from the Natural Gas Industry. Volume 8: Equipment Leaks.* Prepared for the Energy Information Administration. Available at: https://www.epa.gov/sites/default/files/2016-08/documents/8_equipmentleaks.pdf. p. iv
[112] (1) Alvarez, R., et al. 2018. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science.* Available at: https://www.science.org/doi/10.1126/science.aar7204 (2) Lin, J., R. Bares, B. Fasoli, M. Garcia, E. Crosman, S. Lyman. 2021. "Declining methane emissions and steady high leakage rates observed over multiple years in a western US oil/gas production basin." *Scientific Reports.* Available at: https://www.nature.com/articles/s41598-021-01721-5
[113] Forster, P., et al. 2021. "Chapter 7: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity." Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07.pdf
[114] U.S. EIA. 2021. *Louisiana State Electricity Profile 2021*. Available at: https://www.eia.gov/electricity/state/louisiana/

expensive than plants without.[115, 116] Based on this cost estimate, retrofitting all of Louisiana's gas-fired combined cycle units with CCUS would cost $1.0 to $1.2 billion per year.[117] Existing gas-fired combined cycle plants costs about $21 to $31 per MWh[118] to operate—or a total of $1.0 and $1.5 billion each year in Louisiana.[119] Based on these rough estimates, CCUS has the potential to double the costs associated with operating gas-fired combined cycle power plants in Louisiana.

It is unclear whether CCUS will effectively reduce Louisiana's net greenhouse gas emissions when deployed at scale over several years. For CCUS to be effective, CO_2 needs to be stored in sites with a sufficiently long lifespan and few if any leaks or unplanned releases.[120] The benefits of CO_2 storage would be negated if stored CO_2 were to escape into the atmosphere.[121]

The existence of CCUS, however, has the potential to create a perverse incentive for continued gas extraction and combustion. The August 2022 Inflation Reduction Act's (IRA) revisions to the 45Q tax credit for CCUS could provide an incentive for emitting facilities to increase their operations (and emissions) which may prolong the operation of otherwise uneconomic plants. To effectively prevent a net increase in emissions to the atmosphere from burning fossil gas, the capture process must not enable more CO_2 emissions than the amount removed across all stages of the CCUS project: obtaining, processing, transporting, and capturing the CO_2.[122] In other words, Louisiana's gas captured through CCUS must not make it possible for gas extraction and fossil generation to outstrip the pace of CCUS infrastructure. Absent more effective CCUS technologies, emissions reductions from gas with CCUS generation are always partial and are simultaneously stimulating greenhouse gas emissions from fossil gas extraction.

Most of the attempts to commercialize CCUS technology have ended in failure, according to 2021 research published in *Environmental Research Letters*.[123] The requisite CCUS infrastructure cannot be installed fast enough to meet net zero climate targets. This risk is further exacerbated by an "energy penalty" whereby fossil-based generation plants must expend some of their generation capacity to run the carbon capture infrastructure, reducing plant efficiency and requiring more fossil gas to generate the same amount of electricity.[124] Research published in the journal *Energy* finds that an energy penalty of between 10 and 15

[115] Schmitt, T. et al. 2022. *Cost and performance baseline for fossil energy plants volume 1: bituminous coal and natural gas to electricity.* National Energy Technology Laboratory (NETL). Available at: https://netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVolume1BituminousCoalAndNaturalGasToElectricity_101422.pdf. p. 16.

[116] All dollar values presented in 2022 dollars, converted (when necessary) using the CPI-U.

[117] To calculate total operational cost of CCUS in Louisiana, we multiplied the per MWh cost differential for gas-fired combined cycle plants with and without CCUS ($22 to $26 per MWh) by Louisiana's generation from gas-fired combined cycle plants in 2021 (46.8 million MWh).

[118] Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/

[119] To calculate total operating costs of gas-fired combined cycle generation without capture technology in Louisiana, we multiply the levelized cost of operating existing gas-fired combined cycle plants ($21 to $31 per MWh) by total gas-fired combined-cycle generation (46.8 million MWh).

[120] Herzog H, Golomb D. 2004. *Carbon Capture and Storage from Fossil Fuel Use. Massachusetts Institute of Technology Laboratory for Energy and the Environment*. Available at: https://sequestration.mit.edu/pdf/enclyclopedia_of_energy_article.pdf. p.1.

[121] Ibid, p.1.

[122] Ibid, p.6.

[123] Abdulla, A., R. Hanna, K. Schell, O. Babacan, and D. Victor. 2021. "Explaining successful and failed investments in U.S. carbon capture and storage using empirical and expert assessments." *Environmental Research Letters.* Available at: https://iopscience.iop.org/article/10.1088/1748-9326/abd19e/pdf.

[124] House, K. Z., C. F. Harvey, M. J. Aziz, and D. Schrag. 2009. "The energy penalty of post-combustion CO2 capture & storage and its implications for retrofitting the U.S. installed base." *Energy & Environmental Science.* Available at: https://pubs.rsc.org/en/content/articlelanding/2009/ee/b811608c.

percent is obtained in fossil gas generation plants.[125,126]

Until Louisiana can provide a detailed plan of how it intends to scale CCUS infrastructure to levels necessary to legitimately support the decarbonization of its electric power sector, CCUS role in Louisiana's *Climate Action Plan* is limited.

V. The Role of CCUS in Louisiana

As jurisdictions around the world work towards achieving greenhouse gas emission reduction targets as well as other climate and clean energy goals, several U.S. states are investigating the use of CCUS to reduce emissions from fossil fuels in hard to decarbonize sectors of the economy. Louisiana is among the states that are actively exploring CCUS technologies and has incorporated CCUS into its 2022 *Climate Action Plan*.[127] According to the U.S. DOE, Louisiana's location on the Gulf Coast affords the state with extensive potential for CO_2 storage—second in the United States only to its neighbor Texas. However, there are barriers to realizing this potential including significant concerns about social and environmental impacts.[128]

As described in its *Climate Action Plan*, Louisiana aims to reach net-zero greenhouse gas emissions by 2050, including reaching 100 percent clean electricity by 2035.[129] In addition to setting targets for the adoption of renewables and other clean energy resources, Louisiana's clean energy goals include equipping gas-fired power plants with carbon capture technologies to remove at least 90 percent of these power plants' emissions.[130] Louisiana's *Climate Action Plan* claims that CCUS is anticipated to play "a critical role in decarbonizing the global economy" and asserts CCUS is a key tool for achieving its own climate and clean energy goals, with reference to Louisiana's "expansive geologic storage potential, highly concentrated industrial corridors, and trained workforce."[131]

Action 5.3 of Louisiana's *Climate Action Plan* aims to "[s]upport the safe and responsible development of carbon capture, utilization, and storage for high-intensity and hard-to-abate emissions."[132] The *Plan* recommends near-term investments into research for siting and impact assessments of CCUS buildout.[133] In addition, Action 26.1 of the *Plan* includes increased near-term investments into the State's Department of Natural Resources (DNR) and Department of Environmental Quality (DEQ) in order to meet the "new and unique set of research and technology" and "monitoring needs" associated with the deployment of CCUS infrastructure. Action 26.1 also supports "increased capacity of DNR and DEQ to monitor potential air quality impacts, leaks at [carbon capture and storage] well sites, complications of underground storage, and

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125 The U.S. Energy Information Administration's 2022 Annual Energy Outlook (AEO) assumes an energy penalty of nearly 11 percent for new gas combined-cycle plants with carbon capture technologies. Source: U.S. Energy Information Administration. March 2022. *Assumptions to the Annual Energy Outlook 2022: Electricity Market Module.* "Table 3. Cost and performance characteristics of new central station electricity generating technologies." Available at: https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf

126 Vasudevan, S. S. Farooq, I. Karimi, M. Saeys, M. C. G. Quah, R. Agrawal. 2016. "Energy penalty estimates for CO2 capture: Comparison between fuel types and capture-combustion modes." *Energy.* Available at: https://precaution.org/lib/ccs_energy_penalty_for_coal_vs_natural_gas.2016.pdf.

127 State of Louisiana. 2022. *Louisiana Climate Action Plan.* Recommendations to the Governor prepared by the Climate Initiatives Task Force. Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf.

128 U.S. Department of Energy. 2015. *Carbon Storage Atlas (5th Edition).* Available at: https://www.netl.doe.gov/sites/default/files/2018-10/ATLAS-V-2015.pdf

129 State of Louisiana. 2022. p.1, 44

130 Ibid, p.44.

131 Ibid, p.60

132 Ibid.

133 Ibid.

others."[134]

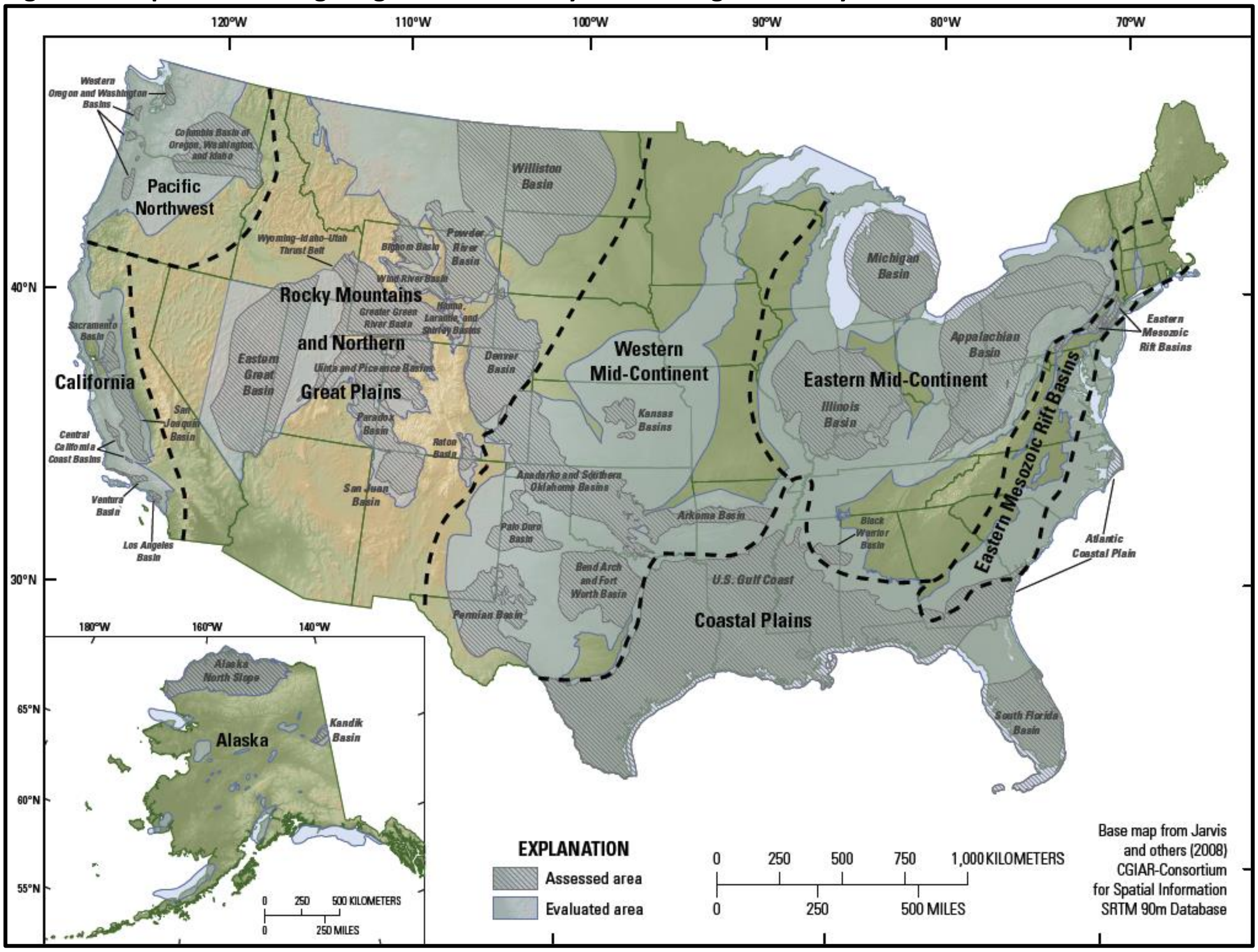
Based on its *Climate Action Plan*, Louisiana is preparing a longer-term CCUS infrastructure buildout. The state's choice to define carbon capture-equipped gas-fired power as a clean energy resource in the *Plan* opens up the possibility of gas-fired power plants—if paired with carbon capture technology—remaining a nontrivial part of Louisiana's electricity grid mix into the future. Several members of the Louisiana Climate Initiatives Task Force expressed dissent regarding the various CCUS-related provisions of the *Plan*, including representatives from the Foundation for Louisiana, Gulf Cost Center for Law and Policy, and Loyola University New Orleans. These members cite the lack of evidence in support of CCUS technologies, the environmental justice concerns of the energy sources employed along with CCUS technologies, and the high costs of CCUS technologies as well as the failure of most projects.[135]

Louisiana's CO_2 storage potential and CCUS infrastructure

According to DOE estimates, Louisiana holds roughly 9 percent of total CO_2 storage potential in North America.[136] The U.S. Gulf Coast region has a high concentration of geological storage resources, including saline formations, former oil and gas reservoirs, and un-mineable coal seams (see Figure 1 below for a map of CO_2 storage regions).

[134] Ibid, p.109-110
[135] Ibid, p.145
[136] U.S. Department of Energy. 2015. pp. 110-111.

Figure 1. Map of CO_2 storage regions assessed by U.S. Geological Survey



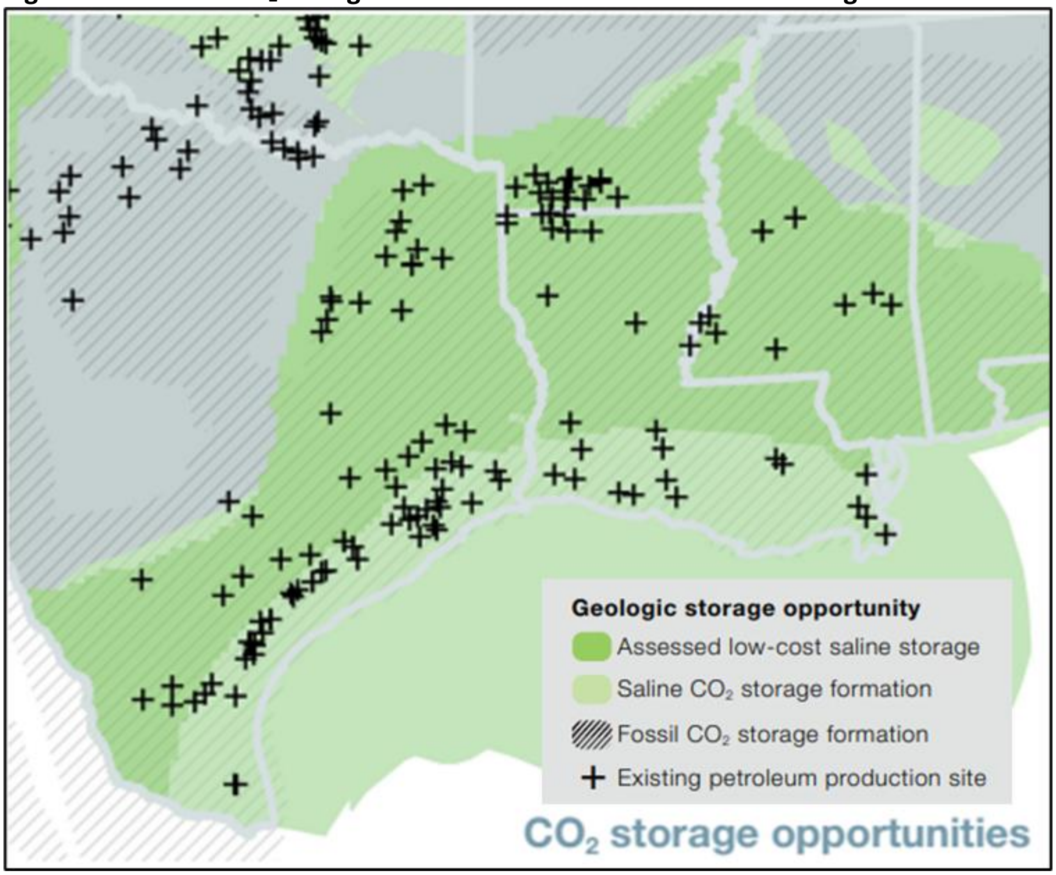
Note: This map only shows the regions assessed by the U.S. Geological Survey for long-term CO_2 storage and does not indicate which regions are deemed most appropriate. The map provides a visual representation of the regions discussed in the report as they relate to Louisiana. Source: Reproduced from USGS. 2013. National Assessment of Geologic Carbon Dioxide Storage Resources—Results. Available at: https://pubs.er.usgs.gov/publication/cir1386. p.4.

A 2013 U.S. Geological Survey conducted by the U.S. Department of the Interior, which examined national geologic CO_2 resources, estimated that the U.S. Gulf Coast region accounts for nearly 65 percent of technically accessible storage potential in the United States.[137] According to the U.S. DOE's latest edition of its *Carbon Storage Atlas*, Louisiana is estimated to have between 163 and 2,100 billion metric tons in total CO_2 storage resource, with over 90 percent of that storage potential coming from saline formations.[138] (For context, that would be enough storage potential to hold 106 to 1,362 years of current CO_2 emissions from the U.S. power sector *or* 32 to 416 years of current economy-wide CO_2 emissions.) In turn, both un-mineable coal seams and oil and natural gas reservoirs constitute less than 10 percent of storage potential.[139] Saline formations are by far the most prevalent storage resource in Louisiana.

[137] USGS. 2013. *National Assessment of Geologic Carbon Dioxide Storage Resources—Results.* Available at: https://pubs.er.usgs.gov/publication/cir1386. p. 6.
[138] U.S. Department of Energy. 2015, p. 110-111.
[139] Ibid.

In its 2022 publication, *An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization*, the Great Plains Institute (GPI) examined several carbon and hydrogen hubs in the United States, including Louisiana (see Figure 2).[140]

Figure 2. Potential CO_2 storage resources in Louisiana and surrounding states



Source: Reproduced from Great Plains Institute. 2022. An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization. Available at: https://scripts.betterenergy.org/CarbonCaptureReady/GPI_Carbon_and_Hydrogen_Hubs_Atlas.pdf. p.42.

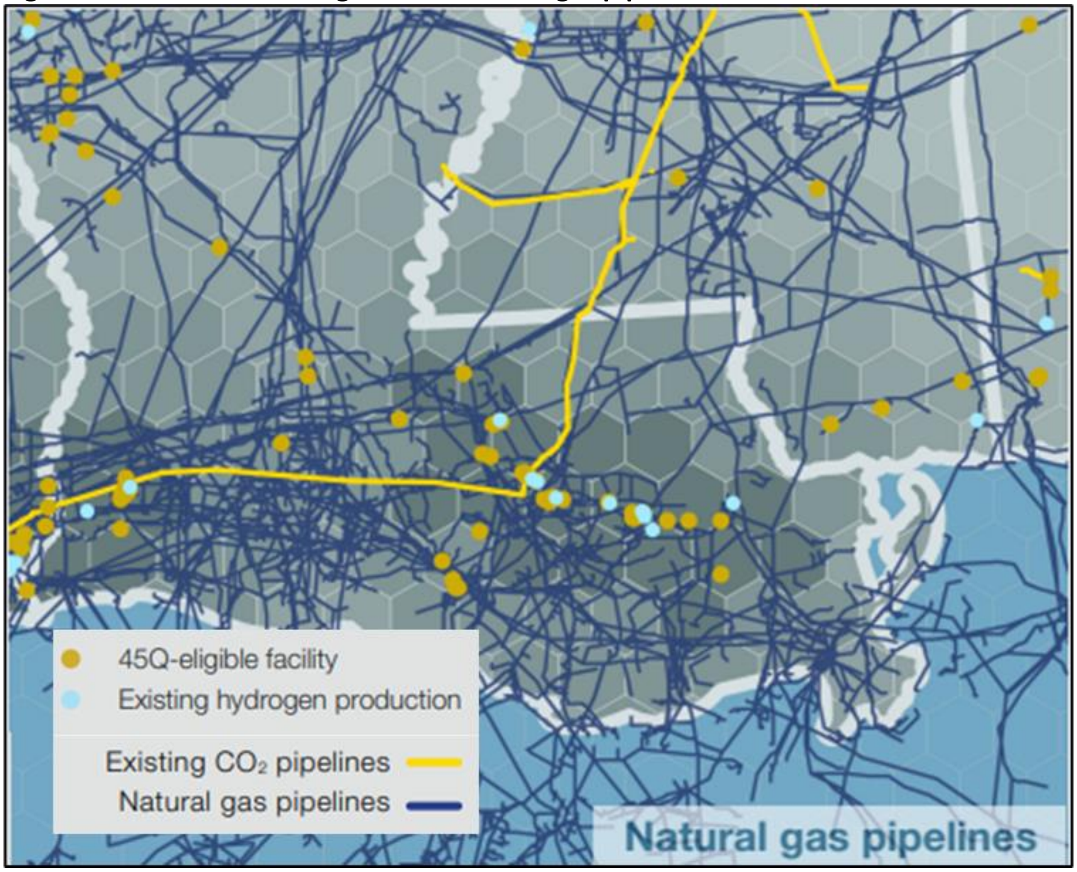
GPI found that Louisiana's industrial and power facilities emit 85.1 million metric tons (MMT) CO_2-equivalents (CO_2e)—86 percent of which are released from facilities that qualify for the federal 45Q tax credit.[141] GPI also estimates that 13.7 MMT CO_2 are capturable on an annual basis in Louisiana within the near- to medium-term.[142] Out of 139 projects nationally, the Clean Air Task Force's database lists 18 projects in Louisiana, two of which are for storage, three for power projects, and the rest for industrial applications.[143]

GPI finds that Louisiana has a CO_2 storage potential of 802 BMT in geologic saline formations with additional storage capacity in other geologic fossil basins, such as former oil and gas reservoirs or coal seams.[144] At

[140] Great Plains Institute. 2022. *An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization*. Available at: https://scripts.betterenergy.org/CarbonCaptureReady/GPI_Carbon_and_Hydrogen_Hubs_Atlas.pdf.
[141] Note that GPI's analysis was released prior to the IRA, which changed components of Section 45Q including increasing the tax credit and loosening its eligibility requirements. Source: Ibid, p. 42.
[142] Ibid, p. 42.
[143] Clean Air Task Force. *US Carbon Capture Activity and Project Table.* Available at: https://www.catf.us/ccsmapus/
[144] Ibid, p. 42.

present, Louisiana's CO_2 transport infrastructure consists of 77 miles of an existing CO_2 pipeline—compared to the state's 4,475 and 5,145 miles of gas and oil pipelines, respectively.[145] The existing CO_2 pipeline runs across the bottom half of Louisiana between its south-western Texas border and Mississippi border north of Baton Rouge (see Figure 3), and is not located near the majority of (pre-IRA) 45Q-eligible facilities in the state.[146]

Figure 3. Louisiana's existing CO_2 and natural gas pipelines



Source: Reproduced from Great Plains Institute. 2022. An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization. Available at: https://scripts.betterenergy.org/CarbonCaptureReady/GPI_Carbon_and_Hydrogen_Hubs_Atlas.pdf. p.42.

Federal incentives for CCUS

In 2011, the Energy Improvement and Extension Act codified Section 45Q of Title 26 of the U.S. Internal Revenue Code, which offers a Federal tax credit for each metric ton of carbon captured and sequestered or utilized ("45Q tax credit").[147] The 45Q tax credit for CCUS was bolstered in the Bipartisan Budget Act of 2018, which broadened the tax credit's eligibility and increased its value.[148] In December 2020, the Consolidated Appropriations Act (Fiscal Year 2021 Omnibus) gave a two-year extension to 45Q tax credits, increasing the

[145] Ibid, p. 43.
[146] Ibid, p. 43.
[147] United States Code. 2011. *Title 26—U.S. Internal Revenue Code, Section 45Q*. Page 252. Available at: https://www.govinfo.gov/content/pkg/USCODE-2011-title26/pdf/USCODE-2011-title26-subtitleA-chap1-subchapA-partIV-subpartD-sec45Q.pdf.
[148] U.S. Department of Energy. 2022. p.9

duration of credits from ten years to twelve years after construction completion date.[149] The Infrastructure Investment and Jobs Act also provided $12.1 billion for large scale pilot projects, demonstration programs, direct air capture competitions, a carbon utilization program, a carbon capture technology program, money for transport and storage, and funds for direct air capture hubs.[150] The 2022 IRA further amends Section 45Q to increase the tax credit for qualified carbon capture facilities,[151] and modifies Section 48C to extend a tax credit to any industrial or manufacturing facility that reduces greenhouse gas emissions by at least 20 percent through CCUS technology.[152]

Prior to the 2022 IRA, the 45Q tax credit allocated $50 per ton of CO_2 captured and stored in saline aquifers and $35 per ton for CO_2 storage in oil and gas formations as well as beneficial utilization of CO_2. The IRA increased this tax credit to $85 per ton and $60 per ton, respectively, for point source capture from industrial and power sites that meet prevailing wage and other labor requirements[153] Power plants are required to capture 75 percent or more of their baseline CO_2 emissions.[154] Direct air capture projects that meet prevailing wage requirements will receive $180 per ton of CO_2 stored in saline aquifers and $130 per ton for EOR or utilization. The IRA also allows direct pay and makes these tax credits transferable, meaning recipients can receive the value of the credit as cash (and are not limited if the credit values exceed their tax liabilities) and can also transfer the value of the credit to other parties through financial markets.[155] Finally, the IRA also allows eligible projects to start construction through 2033 and broadens the definition of eligible facilities by making it easier for projects that capture smaller amounts of CO_2 to qualify.[156]

CCUS facilities are also eligible for several other federal subsidies. For example, the Carbon Dioxide Infrastructure Finance and Innovation Act (CIFIA) is authorized to provide $2.1 billion in credit subsidies for common carrier transportation infrastructure that publishes tariffs and provides services to others for a fee; this program has not yet launched.[157] CIFIA-eligible infrastructure includes pipeline, shipping, rail, or "other forms of infrastructure or equipment to transport or handle CO_2 from anthropogenic sources or ambient air."[158] The U.S. DOE's Title 17 loan guarantee program provides financing for "innovative clean energy projects," which explicitly includes CCUS technologies (post-combustion capture, pre-combustion capture, oxy fuel capture, direct air capture, Class VI wells, and CO_2 hubs) as potential opportunities through which fossil technologies could receive funding.[159] Other incentives include the U.S. DOE Loan Program Office (LPO) financing options, U.S. Department of Agriculture's rural financing, other federal tax credits, and other state and regional policies.[160]

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[149] Public Law 116-260. December 27, 2020. *Consolidated Appropriations Act, 2021*. Available at: https://www.govinfo.gov/content/pkg/PLAW-116publ260/pdf/PLAW-116publ260.pdf. p.3051
[150] Carbon Capture Coalition, I^3, and Regional Carbon Capture Deployment Initiative. *Bipartisan Infrastructure Investment and Jobs Act (H.R. 3684) Carbon Management & Industrial Decarbonization Provisions*. Available at: https://carboncapturecoalition.org/wp-content/uploads/2021/11/Infrastructure-bill_GPI-CM-fact-sheet_final-1.pdf. p.1.
[151] U.S Senate. 117th Congressional Session, H.R. 5376 (2022). *Inflation Reduction Act of 2022*. Available at: https://s3-us-west-2.amazonaws.com/s3-wagtail.biolgicaldiversity.org/documents/inflation_reduction_act_of_2022.pdf. p.291
[152] U.S Senate. 2022. *Inflation Reduction Act of 2022.* p.412-413
[153] Bright, M. 2022. "The Inflation Reduction Act creates a whole new market for carbon capture." Clean Air Task Force. Available at: https://www.catf.us/2022/08/the-inflation-reduction-act-creates-a-whole-new-market-for-carbon-capture/
[154] Ibid.
[155] Ibid.
[156] Ibid.
[157] DeHoratiis, G. 2022. *Building a Bridge to Bankability for CCUS.* DOE Loan Programs Office. Available at: https://netl.doe.gov/sites/default/files/netl-file/22CM_GS_DeHoratiis.pdf. p. 10-11.
[158] Ibid, p. 10.
[159] Ibid, p. 8.
[160] U.S. Department of Energy. 2022. p.10

Louisiana's CCUS regulations, policies, and incentives

Louisiana targets incentives to CCUS technologies and infrastructure under several regulations, policies, and incentives including tax reductions and exemptions for CCUS infrastructure, the assumption of legal liability from CCUS operators, eminent domain provisions for CCUS development, and clarification of regulatory rules governing CCUS.

State Assumption of Long-Term Liability for CCUS (2009 Louisiana Geologic Sequestration of Carbon Dioxide Act): The 2009 Louisiana Geologic Sequestration of Carbon Dioxide Act (House Bill No. 661) authorized the transfer of liability for stored CO_2 to the State, such that ten years after the termination of CO_2 injection at a geologic storage site, the Louisiana Commissioner of Conservation will issue a certificate of completion of injection operations, upon which the storage operator is no longer liable for the storage facility.[161]

Tax Incentives for CCUS (2016 Louisiana House Bill 62): In 2016, Louisiana passed House Bill No. 62 (HB 62), which—along with House Bill No. 61—created a retail tax exemption for the sale of human-made CO_2 used in qualified enhanced oil and gas recovery projects approved by DNR pursuant to Revised Statute 47:633.4.[162]

Tax Incentives for CCUS (The 2009 Geologic Sequestration of Carbon Dioxide Act): Louisiana's Geologic Sequestration of Carbon Dioxide Act allows a 50 percent reduction in taxes on projects using human-made CO_2 specifically for enhanced oil and gas recovery.[163] The Act directly acknowledges CO_2's role as a greenhouse gas and as a commodity. In Section 1102, the Act states that "the geologic storage of carbon dioxide will benefit the citizens of the state and the state's environment by reducing greenhouse gas emissions," and that "carbon dioxide is a valuable commodity to the citizens of the state."[164] The Act establishes a Carbon Dioxide Geologic Storage trust fund, which can be used for site inspection, testing and monitoring, remediation, or well plugging.[165] In addition, the Act grants authority to the State Mineral and Energy Board to "explore for and develop" mineral resources and to enter into operating agreements ensuring the State a portion of revenues from oil, gas, hydrocarbon, and CO_2 storage activities if CO_2 is used in enhanced oil and gas recovery activities.[166]

Pipeline Regulations (Natural Resources and Energy Act of 1973; Louisiana Administrative Code 43-11): The Pipeline Division of the Department of Natural Resources Office of Conservation regulates the use, conservation, and transportation facilities for moving CO_2, fossil gas, and compressed fossil gas within the state; the Pipeline Division is also responsible for conducting safety inspections, enforcing intrastate pipelines, and enforcing damage prevention on pipeline right of ways, and regulating over 400 intrastate pipeline operators.[167] The Natural Resources and Energy Act of 1973 grants regulatory authority over CO_2 pipelines to the Louisiana's Office of Conservation within its Department of Natural Resources in Louisiana Administrative Code Title 43 Part 11, include regulation of transmission, transportation, accident reporting, design,

[161] Louisiana House of Representatives. 2009. *Louisiana Geologic Sequestration of Carbon Dioxide Act*. Available online: http://www.legis.la.gov/legis/ViewDocument.aspx?d=668800&n=HB661%20Act. p.10
[162] Louisiana House of Representatives. 2016. *An Act relative to state sales and use tax*. House Bill No. 62. Available online: https://www.legis.la.gov/legis/ViewDocument.aspx?d=984895. p.23
[163] Louisiana House of Representatives. 2009.
[164] Ibid.
[165] Ibid.
[166] Ibid.
[167] Ring, S. et al. 2021. *Carbon Capture, Utilization, and Sequestration: A State Comparison of Technical and Policy Issues.* Prepared by The Cadmus Group for United States Energy Association. Available at: https://usea.org/sites/default/files/event-/CCUS%20State%20Comparisons%20Report.pdf. p.67

construction, hydrostatic testing, operation, and maintenance.[168] Louisiana Administrative Code 43 Part 13 includes regulations specific to the transportation of gases by pipeline.[169]

Storage Regulations (Proposed Class VI rules): In 2021, Louisiana's Department of Natural Resources Office of Conservation applied to the U.S. EPA for primary enforcement authority over Class VI wells.[170] The Department of Natural Resources' application for Class VI primacy includes draft rules for Class VI wells similar to the federal Class VI rule, including requirements for area of review delineation, permitting, well construction and completion, corrective action, logging, sampling and testing, mechanical integrity, plugging, monitoring, reporting, financial responsibility, post-injection site care, site closure, well emergency, and remedial response.[171]

Injection Regulations (Louisiana Administrative Code 43 Part 19): DNR is responsible for administration, permitting, inspection, and enforcement of activities pertaining to protection of underground sources of drinking water; the Department has primacy for Class I through V wells,[172] and injection activities are regulated under the State's Underground Injection Control program by DNR's Injection and Mining Division.[173] Louisiana Administrative Code 43 Part 19 requires permits for all Class II injection wells, with different requirements for new and existing enhanced oil recovery projects, and contains requirements for enhanced oil recovery permit applications including the inclusion of operator information, map of the area of recovery, lease information, injection formation description, logs, casing, plan for development, and a schematic.[174] DNR may also allow enhanced oil or gas recovery pilot projects for 6 months after the date of initiation of injection. Class II permits are subject to public notice in the official state journal and a public hearing.

Eminent Domain Regulations (Geologic Sequestration of Carbon Dioxide Act)**:** Per the Geologic Sequestration of Carbon Dioxide Act, storage operators have the right to construct or develop facilities and pipelines along, over, across, and under navigable streams and public highways, so long as they do not interfere with traffic.[175] Corporations that pipe or market CO_2 for utilization projects and inject CO_2 for underground storage, may expropriate needed property even if unable to reach a compensatory deal with the property owner.[176] In order to conduct an underground CO_2 storage project, Louisiana law stipulates that the Commissioner must find that the underground reservoir is both suitable and feasible for use, without endangering lives, property, or other formations containing other mineral deposits.[177]

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[168] Louisiana Administrative Code (LAC) Title 43, Part XI, Subpart 4. *NATURAL RESOURCES: Office of Conservation—Pipeline Division: Carbon Dioxide*. Available at: https://www.doa.la.gov/media/tjec23qn/43v09-13.pdf. p.41

[169] LAC Title 43, Part XIII. *NATURAL RESOURCES: Office of Conservation—Pipeline Safety*. Available at: https://www.doa.la.gov/media/tjec23qn/43v09-13.pdf. p.73

[170] Louisiana Department of Natural Resources. May 13, 2021. "Class VI USEPA Primacy Application." Available online: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf.

[171] Ibid.

[172] The U.S. Environmental Protection Agency's Underground Injection Control program classifies six types of injection wells (Class I through Class VI). These wells differ based on what the type, depth, and risks of that injection activity: (I) hazardous and non-hazardous wastes in deep, isolated rock formations; (II) fluids association with oil and gas production; (III) fluids to dissolve and extract minerals; (IV) wells for hazardous or radioactive wastes above drinking water; (V) non-hazardous fluids underground into or above underground sources of drinking water; and (VI) CO_2 into underground geologic formations for long-term storage. Note that the State of Louisiana does not currently regulate Class VI injection wells. Source: U.S. EPA. "Underground Injection Control Well Classes." Available at: https://www.epa.gov/uic/underground-injection-control-well-classes.

[173] LAC Title 43, Part XIX. *NATURAL RESOURCES: Office of Conservation—General Operations*. Available at: https://www.doa.la.gov/media/t3qldhn5/43v19.pdf. p.70

[174] LAC Title 43, Part XIX. *NATURAL RESOURCES: Office of Conservation—General Operations*.

[175] Louisiana House of Representatives. 2009. *Louisiana Geologic Sequestration of Carbon Dioxide Act*.

[176] Louisiana State Legislature. *Revised Statutes 19:2.* Available at: https://legis.la.gov/Legis/Law.aspx?d=81784

[177] Louisiana State Legislature. *Revised Statutes 30:22*. Available at: http://legis.la.gov/legis/Law.aspx?d=87252

Comparison of CCUS regulations in other jurisdictions

Louisiana's CCUS potential and its extensive oil and gas extraction infrastructure makes it unique among states pursuing CCUS. Absent the State's *Climate Action Plan* goal to require 100 percent clean electricity by 2035,[178] however, Louisiana's policies for the promotion of CCUS investment are largely in line with those of other states that have CCUS provisions for state tax benefits or the state assumption of long-term liability. In some cases, Louisiana lacks comparable policies, such as for direct financial assistance to CCUS projects, off-take agreements, or utility cost recovery provisions. Several states provide financial and legal incentives for investment in CCUS infrastructure, including: Kansas, Kentucky, Mississippi, Montana, North Dakota, Texas, and Wyoming.

The North Dakota Pipeline Authority is authorized to make grants, loans, or other forms of financial assistance to support pipeline development, including for CO_2 transport.[179] The Wyoming Energy Authority (formerly the Wyoming Pipeline Authority) can also issue bonds and loans for CO_2 pipeline infrastructure.[180] Texas HB 3732 created a program to finance "advanced clean energy projects" including coal-fired power plants with carbon capture technology, authorizing the State's Energy Conservation Office to award grants and loans to such projects.[181] In comparison, Louisiana has limited facilities for direct financial assistance through loans and its policies emphasize tax incentives with some grant funding for site preparation.

In 2009, North Dakota's SB 2221 created a 20 percent tax credit on the revenues of coal conversion facilities (including electricity generation plants and coal gasification facilities) that utilize carbon capture technology to capture at least 20 percent of their CO_2 emissions.[182] The bill offers an additional 1 percent tax credit for each additional 2 percentage points of CO_2 emissions that are captured above the first 20 percent, up to a maximum credit of 50 percent for a facility capturing 80 percent of its CO_2 emissions.[183] Also in 2009, North Dakota's SB 2034 exempted oil produced from CO_2 enhanced oil recovery from the state's oil extraction tax.[184] In 2015, North Dakota's SB 2318 exempted CO_2 sales, construction materials, or CO_2 transport equipment such as pipelines for enhanced oil recovery from sales, use, and personal property taxes.[185] By contrast, Louisiana allows a 50 percent tax reduction on projects using human-made CO_2 and exempts the sale of CO_2 used in enhanced oil and gas projects. Other states with tax benefits for CCUS include Kansas, Kentucky, Mississippi, Montana, Texas, and Wyoming. Most have some combination of sales tax exemptions, reduced tax rate for users of CO_2 (procured via CCUS and often for enhanced oil recovery), and some partial exemptions to state property or income taxes.

Like Louisiana, four other State governments assume long-term liability for CCUS projects: Kentucky, Montana, North Dakota, and Texas. Kansas HB 2418 specifies that the State bears no liability to pay for

[178] State of Louisiana. 2022. *Louisiana Climate Action Plan.* p.44
[179] North Dakota Century Code Chapter 54-17.7. *Pipeline Authority*. Available online: https://www.ndlegis.gov/cencode/t54c17-7.pdf. p.1-2
[180] Wyoming Statutes Title 37, Chapter 5. Available at: https://wyoleg.gov/statutes/compress/title37.pdf.
[181] Texas House Bill No. 3732. Enacted 2007. *An Act relating to the implementation of advanced clean energy projects and other environmentally protective projects in this state*. Available online: https://capitol.texas.gov/tlodocs/80R/billtext/pdf/HB03732F.pdf#navpanes=0. p.4, 19
[182] North Dakota Senate. Bill No. 2221. Enacted 2009. *An Act relating to a credit against privilege taxes on coal conversion facilities for carbon dioxide capture.* Available online: https://www.ndlegis.gov/assembly/61-2009/bill-text/JAQD0500.pdf. p.2
[183] Ibid.
[184] North Dakota Senate. Bill No. 2034. Enacted 2009. *An Act relating to exemption from oil extraction tax on tertiary recovery projects that use carbon dioxide.* Available online: https://www.ndlegis.gov/assembly/61-2009/bill-text/JAIP0400.pdf. p.1
[185] North Dakota Senate. Bill No. 2318. Enacted 2015. *An Act relating to a sales and use tax exemption and ad valorem tax exemption for carbon dioxide capture equipment used for enhanced oil recovery.* Available online: https://legiscan.com/ND/text/2318/id/1204790. pg.1-2

damages resulting from a leak or discharge of CO_2 from injection wells or underground storage.[186] While Louisiana has a ten-year waiting period before the assumption of liability for CCUS projects, Kentucky transfers liabilities immediately upon project completion,[187] Montana waits fifteen years after the termination of injections.[188] North Dakota also waits ten years. [189]

The Renewable and Clean Portfolio Standard proposed in Louisiana's *Climate Action Plan* counts fossil gas as clean if it is paired with CCUS facilities that can sequester 90 percent of their resulting greenhouse gas emissions. As such, a large percentage of electricity in Louisiana could be powered by fossil fuel generation while still meeting "clean" energy standards. By contrast, Michigan's 2008 Clean, Renewable, and Efficient Energy Act (SB 213) established an integrated Renewable Portfolio Standard (RPS) requiring energy providers to procure 10 percent of their electric sales from renewable energy generation—updated in 2016 HB 438 to 15 percent by 2021—up to 1 percent of which may be met through the use of "advanced cleaner energy systems" including coal-fired facilities that permanently sequester at least 85 percent of CO_2 emissions.[190] In its 2022 *Healthy Climate Plan*, the State of Michigan commits to adopting a renewable energy standard of 50 percent and phasing out coal-fired power plants entirely by 2030.[191] In 2008, Utah SB 202 established a voluntary renewable portfolio goal of 20 percent of "adjusted retail electric sales" from renewable or other qualifying sources by 2025—a threshold that can be reduced with the use of carbon capture technology on coal and gas plants.[192] California set carbon removal or capture targets of 20 million metric tons of CO_2e by 2030 and 100 million metric tons of CO_2e by 2045,[193] and has a protocol in its low carbon fuel standard to allow CCUS projects to qualify.[194]

Assessing CCUS regulatory and permitting authority in Louisiana

The regulation of CCUS activities is not enforced by a single entity, but instead this authority is often spread amongst multiple agencies or sub-agency offices at various levels of government. In Louisiana, the state's CCUS infrastructure is regulated by several agencies at both the state and federal levels (see Table 2 below for a summary description of which agencies have responsibility for aspects of CCUS infrastructure).

[186] Kansas House. Bill No. 2418. Enacted 2010. *An Act pertaining to liability of the state of Kansas*. Available online: https://www.kansas.gov/government/legislative/bills/2010/2418.pdf. p.1

[187] Kentucky House. Bill No. 259. Enacted 2011. *An Act relating to economic development*. Available online: https://apps.legislature.ky.gov/record/11rs/HB259.html.

[188] Montana Senate. Bill No. 498. Enacted 2009. *An Act regulating carbon sequestration*. Available online: https://leg.mt.gov/bills/2009/sesslaws/ch0474.pdf. pg.4-6

[189] North Dakota Senate. Bill No. 2095. Enacted 2009. *An Act relating to the geologic storage of carbon dioxide.* Available online: https://www.ndlegis.gov/assembly/61-2009/bill-text/JQTA0300.pdf. p.5

[190] (1) Michigan Senate. Bill No. 213. Enacted 2008. *Clean, renewable, and efficient energy act*. Available online: http://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0295.pdf. (2) Michigan Senate. Bill No. 438. Enacted 2016. *Clean and renewable energy and energy waste reduction act*. Available online: http://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[191] Michigan Department of Environment, Great Lakes, and Energy. 2022. *MI Healthy Climate Plan*. Available at: https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Offices/OCE/MI-Healthy-Climate-Plan.pdf?rev=d13f4adc2b1d45909bd708cafccbfffa&hash=99437BF2709B9B3471D16FC1EC692588. p.33

[192] Utah Senate. Bill No. 202. Enacted 2008. *Municipal Electric Utility Carbon Emission Reduction Act*. Available online: https://le.utah.gov/~2008/bills/sbillenr/sb0202.pdf

[193] Center for Climate and Energy Solutions. *U.S. State Energy financial Incentives for CCS*. Available at: https://www.c2es.org/document/energy-financial-incentives-for-ccs/

[194] Office of Governor Gavin Newsom. 2022. "California Releases World's First Plan to Achieve Net Zero Carbon Pollution." Available at: https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/.

Table 2. Regulatory authority over CCUS activities

Area	Agency	State or federal?	Contested or unclear authority?
Capture			
Electric power sector	Louisiana Public Service Commission	State	No
Utilization			
Class II injection wells	Louisiana DNR's Injection and Mining Division	State	No
Storage			
Class VI injection wells	U.S. EPA	Federal	No
Class VI injection wells	Louisiana DNR	State	Applying for Primacy from U.S. EPA
Transportation			
Pipelines (intra-state)	Louisiana DNR's Pipeline Division	State	No
Pipelines safety (inter-state)	U.S. Pipeline Hazard and Safety Administration	Federal	No
Pipelines (inter-state)	U.S. Federal Energy Regulatory Commission	Federal	Authority Disclaimed
Pipelines (inter-state)	U.S. Interstate Commerce Commission	Federal	Authority Disclaimed
Pipelines (inter-state)	U.S. DOT's Surface Transportation Board	Federal	Authority Unclear

To mitigate safety, environmental, and human health risks from CCUS, Louisiana must ensure that its relevant agencies and offices have the institutional capacity to effectively regulate, administer, and oversee CCUS activities across the state. For the purposes of regulating CCUS activities at the state-level, AEC has assessed the institutional capacity of a given agency or office as a function of the resources it has (including funds and staffing) as well as its processes, procedures, and authority to issue and enforce regulations related to CCUS activities.[195]

Louisiana's regulatory authority of CCUS infrastructure

Most regulation and oversight of CCUS infrastructure in Louisiana is provided by the state government, with some federal involvement in pipeline safety and the regulation of injection wells for CO_2 storage. CO_2 is regulated by stage, starting with its capture at emitting facilities and ending with its use at injection wells for oil and gas extraction or for storage. In Louisiana, the Department of Natural Resources (DNR) holds regulatory authority over several CCUS activities, including CO_2 transport via intrastate pipelines and CO_2 utilization for enhanced oil and gas recovery. Other CCUS activities are either regulated by other Louisiana

[195] ITC-ILO. "Module 12: Institutional capacity development." In *ITC-ILO Curriculum on "Building modern and effective labour inspection systems."* Available at: https://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/---sro-port_of_spain/documents/genericdocument/wcms_633611.pdf. p.6.

agencies or at the federal level by the U.S. Environmental Protection Agency (EPA) or U.S. Department of Transportation (DOT). Finally, CCUS projects could trigger other federal environmental laws, reviews, or permitting processes: the National Environmental Policy Act, the Clean Water Act, the National Historic Preservation Act, the Endangered Species Act, the Migratory Birds Treaty Act, and the Bald and Golden Eagle Protection Act.[196] Furthermore, certain facilities may need to modify their existing permits to account for the impacts of CCUS technologies.

Carbon capture technologies can be utilized in the industrial and electric power sectors—both of which are regulated by different entities. In the electric power sector, carbon capture activities at fossil fuel-fired power plants are regulated by Louisiana's Public Service Commission as electric utilities must receive approval for any capital investments to ensure that the resulting services are safe, adequate, and reliable, while the rates are just, reasonable, equitable, and efficient.[197] The regulatory authority over carbon capture at industrial facilities is unclear. Power plants and industrial facilities that include CCUS technologies may be required by Louisiana's Department of Environmental Quality to file or change any environmental permits to account for changes in emissions, water usage, and waste products resulting from any changes to a facility's operations and efficiency.

Once captured, CO_2 can be transported in two types of pipelines: (1) intra-state pipelines that transport CO_2 within state boundaries and (2) inter-state pipelines that transport CO_2 between states. In Louisiana, the DNR's Office of Conservation's Pipeline Division holds regulatory authority over the construction, design, and operation of intra-state pipelines, including those that transport CO_2.[198,199] The Pipeline Hazard and Safety Administration (PHMSA) within the U.S. DOT has statutory authority over inter-state CO_2 pipeline safety through its enforcement of regulations on the construction, operation and maintenance, and spill response planning for CO_2 pipelines.[200] However, regulation related to issues outside of safety and accident response is uncertain for inter-state CO_2 pipelines with several federal agencies denying or not claiming regulatory authority over the infrastructure.[201] The Federal Energy Regulatory Commission has specifically denied its own jurisdiction over CO_2 pipelines.[202,203] The U.S. DOT's Surface Transportation Board (STB) is another potential candidate to regulate CO_2 pipelines; but its predecessor, the Interstate Commerce Commission, denied its own jurisdiction over CO_2 pipelines in a 1980 decision over the jurisdictional status of pipelines[204] and STB has

196 Kerschner, S., T. Pullins. 2021. "How US environmental laws and regulations affect carbon capture and storage." White & Case. Available at: https://www.whitecase.com/insight-our-thinking/how-us-environmental-laws-and-regulations-affect-carbon-capture-and-storage
197 Louisiana Public Service Commission. "About the Louisiana Public Service Commission." Available at: https://lpscpubvalence.lpsc.louisiana.gov/portal/lpsc-about-us
198 State of Louisiana Department of Natural Resources. "Office of Conservation". Available at: http://www.dnr.louisiana.gov/index.cfm/page/54
199 LAC Title 43, Part XI. *NATURAL RESOURCES: Office of Conservation—Pipeline Division*. Available at: https://www.doa.la.gov/media/tjec23qn/43v09-13.pdf. pg.41-46
200 Congressional Research Service (CRS). 2022. *Carbon Dioxide Pipelines: Safety Issues*. Available at: https://crsreports.congress.gov/product/pdf/IN/IN11944 p.1
201 Caldwell, C., and C. Kidner. 2021. *Carbon dioxide Pipelines: Regulatory and Commercial Issues in Carbon Capture, Utilization and Sequestration.* Caldwell Bourdreaux Lefler PLLC. Available at: https://www.cblpipelinelaw.com/news/articles/Carbon-Dioxide-Pipelines-Regulatory-Commercial=Issues-Carbon-Capture-Utilization-Sequestration.pdf. p. 9.
202 Ibid, p.10.
203 Nordhaus, R., and E. Pitlick. 2009. "Carbon Dioxide Pipeline Regulation." *Energy Law Journal.* Available at: https://www.eba-net.org/assets/1/6/8-85_-_nordhaus_and_pitlick.pdf. p.88.
204 Power, R., J. Hicks, W. Blogiano. 2022. "Hydrogen Production and Carbon Sequestration May Require the Surface Transportation Board to Clarify Jurisdiction over Carbon Dioxide Pipelines." Venable LLP. Available at: https://www.venable.com/insights/publications/2022/11/hydrogen-production-and-carbon-sequestration

not opined its jurisdiction over CO_2 pipelines.[205]

With regard to storage, U.S. EPA's Underground Injection Control (UIC) Program—mandated by the Safe Water Drinking Act—oversees six classes (I through VI) of injection wells.[206] EPA may grant primary enforcement authority, or "primacy", to state agencies for all or part of the UIC program well classes as directed under Sections 1422 and 1425 of the Safe Water Drinking Act. Section 1422 requires primacy applicants to meet minimum requirements established by the U.S. EPA before transferring primacy and Section 1425 (applicable only to Class II wells) does not set such requirements for transferring primacy if applicants can demonstrate sufficient protection standards of underground sources of drinking water.

The Injection and Mining Division within Louisiana DNR's Office of Conservation was granted primacy over Class I through V injection wells by the U.S. EPA on April 23, 1982,[207] transferring responsibility for the administration, permitting, inspection, and enforcement of activities pertaining to the protection of underground sources of drinking water from injection activities from U.S. EPA to the State of Louisiana.[208] Louisiana received primacy over Class II wells (i.e., injection wells used for enhanced oil and gas recovery) under Section 1425 of the Safe Water Drinking Act. Before an injection well can be constructed in Louisiana, the "storage facility" or desired geologic formation for CO_2 injection and storage must be approved by the Commissioner of DNR's Office of Conservation as required under Louisiana's *Geologic Sequestration of Carbon Dioxide Act* of 2009.[209]

Unlike other injection well classes, Class VI wells in Louisiana (used for the long-term storage of CO_2) remain under the primary enforcement authority of the U.S. EPA. In fact, only two states—North Dakota and Wyoming—have been granted primacy over Class VI injection wells.[210] Louisiana submitted its Class VI primacy application in 2021, which is now in the application evaluation phase pending review by the U.S. EPA.[211] (Arizona, Texas and West Virginia are also seeking primacy over Class VI injection wells but are in the early "pre application activities" phase.[212])

[205] Ibid, p.10-11.

[206] (1) The U.S. EPA's Underground Injection Control program classifies six types of injection wells (Class I through Class VI). These wells differ based on the type, depth, and risks of that injection activity: (I) hazardous and non-hazardous wastes in deep, isolated rock formations; (II) fluids association with oil and gas production; (III) fluids to dissolve and extract minerals; (IV) wells for hazardous or radioactive wastes above drinking water; (V) non-hazardous fluids underground into or above underground sources of drinking water; and (VI) CO_2 into underground geologic formations for long-term storage. Note that the State of Louisiana does not currently regulate Class VI injection wells. Source: U.S. EPA. "Underground Injection Control Well Classes." Available at: https://www.epa.gov/uic/underground-injection-control-well-classes; (2) LAC Title 43, Part XIX. *NATURAL RESOURCES: Office of Conservation—General Operations*. Available at: https://www.doa.la.gov/media/t3qldhn5/43v19.pdf. p.70.

[207] Louisiana DNR. "Office of Conservation: Underground Injection Control (UIC) Section" Available at: http://www.dnr.louisiana.gov/index.cfm/page/141.

[208] U.S. EPA. "Primary Enforcement Authority for the Underground Injection Control Program." Available at: https://www.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program-0.

[209] Louisiana Revised Statutes Chapter 30, Sections 1101-1111. 2009. *Louisiana Geologic Sequestration of Carbon Dioxide Act*. Available online: http://www.legis.la.gov/legis/ViewDocument.aspx?d=668800&n=HB661%20Act.

[210] U.S. EPA. "Primary Enforcement Authority for the Underground Injection Control Program." Available at: https://www.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program-0.

[211] U.S. EPA. "Primary Enforcement Authority for the Underground Injection Control Program." Available at: https://www.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program-0.

[212] U.S. EPA. "Primary Enforcement Authority for the Underground Injection Control Program." Available at: https://www.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program-0.

Assessing the institutional capacity of Louisiana's agencies

Louisiana DNR's Office of Conservation's 2021 application to the U.S. EPA for primacy over Class VI injection wells[213] notes that "[t]his submittal will demonstrate that the Louisiana UIC program with Class VI oversight is at least as stringent as its federal counterpart."[214] The U.S. EPA requires primacy applicants to meet a set of minimum requirements to be eligible for regulatory authority over Class VI injection wells. Louisiana's Class VI primacy application outlines the proposed organizational structure, program funding sources and allocations, and proposed regulations and procedures. Of the regulatory authorities discussed in the previous sub-section, Class VI wells are a major exclusion to the general primacy of state regulation over CCUS in Louisiana. In this section we examine whether the Louisiana DNR has the capability, or "institutional capacity," to effectively run the program by examining its Class VI application in the context of the State's current application for regulatory primacy.

To effectively administer its Class VI program, Louisiana plans to ensure that the staffing at the Office of Conservation has the appropriate education, skills, and in-house experience.[215] Through additional program staff and contractors, DNR will assess and oversee the following aspects of the Class VI program: site characterization, modeling, well construction and testing, finance, risk analysis, policy, enforcement, inspection, and environmental justice matters (see Table 3).[216] Staff will review and approve permit applications while also overseeing compliance monitoring.[217] Third-party contractors will be required to augment DNR's in-house capabilities, particularly for technically intensive tasks such as modeling, risk analysis, and evaluating environmental justice impacts.[218]

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[213] Louisiana DNR. May 13, 2021. "Class VI USEPA Primacy Application." Available online: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf.
[214] Louisiana DNR. May 13, 2021. "Class VI USEPA Primacy Application." Available online: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf. p.2.
[215] State of Louisiana Department of Natural Resources. May 2021. *Class VI USEPA Primacy Application: Underground Injection Control Program*. Submitted by Office of Conservation Injection and Mining Division. Docket No. IMD-2021-02; 1-8. Available at: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf. p.2.
[216] Ibid, p.3.
[217] Ibid, p.2.
[218] Ibid, p.2-3.

Table 3. Areas of competency for Louisiana DNR's Class VI application

Expertise Area	In-House	Contractor
Site characterization, e.g., geologists, hydrogeologists, geochemists, and log analysts/experts to review site characterization data submitted during permitting and throughout the project duration.	✓	
Modeling, e.g., hydrogeologists and environmental/reservoir modelers to evaluate area of review (AoR) delineation computational models during permitting and AoR reevaluations.	✓	✓
Well construction and testing, e.g., well engineers, log analysts/experts, and geologists to review well construction information and operational reports on the performance of Class VI wells and review/evaluate testing and monitoring reports.	✓	
Finance experts to review financial responsibility information during permitting and annual evaluations of financial instruments.	✓	
Risk analysts to evaluate emergency and remedial response scenario probabilities and remediation cost estimates.		✓
Policy/regulatory experts on the UIC Program and the Class VI Rule to evaluate compliance with Class VI Rule requirements.	✓	
Enforcement/compliance, e.g., staff who can initiate and pursue appropriate enforcement actions when permit or rule requirements are violated.	✓	
Inspectors including well engineers or log analysts/experts to inspect wells or witness construction activities, workovers, and/or mechanical integrity tests.	✓	
Environmental justice experts to evaluate the Environmental Justice impact report, ensuring that the report is thorough, contextualized, and agrees with the demographic and environmental data from the EPA-developed EJSCREEN tool.	✓	✓

Reproduced from: State of Louisiana Department of Natural Resources. May 2021. Class VI USEPA Primacy Application: Underground Injection Control Program. Submitted by Office of Conservation Injection and Mining Division. Docket No. IMD-2021-02; 1-8. Available at: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf. p.3.

To adequately support and develop the Class VI program, Louisiana must appropriate sufficient funds for program oversight and operation. In its primacy application, DNR's Office of Conservation estimates that the Class VI program would cost $345,000 in the first year and $1.135 million in the second year (in 2021 dollars), with a majority of these costs needed to fund seven staff positions (see Table 4 below for the proposed budget allocation).[219] To cover the costs of the Class VI program, DNR anticipates receiving funds from a variety of sources, including: the Louisiana Carbon Dioxide Geologic Storage Trust Fund, UIC grants from the U.S. EPA, and the Louisiana General Fund.[220] They also anticipate raising funds from fees, including: application fees, annual site regulatory fees, and tonnage fees charged per metric ton of CO_2.[221]

[219] Ibid, p.4.
[220] Ibid, p.4.
[221] Ibid, p.4.

Table 4. Proposed allocation of Louisiana DNR's Class VI program budget

Activity	Percent of budget
Permit application reviews and permit issuance.	30%
Project oversight/review of operating data and testing and monitoring data and reports.	35%
Inspections/witnessing construction or tests.	5%
Data management.	5%
Enforcement/compliance-related activities.	10%
Program oversight/administration.	15%

Reproduced from: State of Louisiana Department of Natural Resources. May 2021. Class VI USEPA Primacy Application: Underground Injection Control Program. Submitted by Office of Conservation Injection and Mining Division. Docket No. IMD-2021-02; 1-8. Available at: http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/ClassVIPrimacyApplicationstamped.pdf. p.5.

To ensure that DNR's Office of Conservation can mitigate the impacts of Class VI injection wells, Louisiana must propose regulations and application procedures that catch potential problems with proposed projects before final approval is granted and deployment begins. In its primacy application, Louisiana outlines how it will review permit applications, what information will be required of applicants, and how the rules of the Class VI program will be monitored and enforced. For instance, staff will perform a technical review of data submitted with a permit application for impacts on health, safety, and public welfare.[222] The owner or operator of the project will be required to conduct an environmental justice review of the project and staff will use an EPA-developed environmental justice tool to evaluate the project site.[223] A cost-benefit analysis will also be required to evaluate the overall impact of each project.[224] Finally, if a project is approved, Louisiana's Office of Conservation will conduct compliance monitoring and site inspections, including tests on the mechanical integrity of well equipment.[225]

Louisiana must ensure that DNR's Office of Conservation has the institutional capacity to effectively administer and carry out the regulatory responsibilities of the Class VI program. Institutional capacity includes whether DNR has sufficient resources (e.g., funding, staffing) to support the program and whether the program has the necessary regulations and procedures to ensure protection of human health, safety, and the environment. To this end, Louisiana does not include language in its application specifying that human health, safety, and the environment are priorities for oversight in a manner similar to the language in Wyoming's application. Wyoming's Class VI primacy application—which was approved by the U.S. EPA in 2020[226]—defined its own scope to specifically include human health, safety, and the environment as areas of regulatory

[222] Ibid, p.5.
[223] Ibid, p.6.
[224] Ibid, p.6.
[225] Ibid, p.8-9.
[226] Wyoming Department of Environmental Quality. "Class VI: Primacy." Available at: https://deq.wyoming.gov/water-quality/groundwater/uic/class-vi/.

focus in addition to the protection of underground drinking water.[227]

VI. Alternatives to CCUS in Louisiana

The combustion of fuels for power generation and industrial operations—whether fossil-based or not—will continue to pose a number of public health and safety risks to surrounding communities. Even when paired with CCUS, combustion-based fuel usage on its own does not provide sufficient emission reductions for Louisiana to achieve its net zero target. On the other hand, building and transportation electrification together with renewable energy resources, energy storage and demand-side management (e.g., demand response and energy efficiency) offer a viable and cost-effective strategy for total decarbonization. Deep emission reductions in Louisiana's electric power and industrial sectors will require choosing multiple strategies among different alternatives. Comparing these decarbonization alternatives—together with CCUS—sheds light on how useful and effective they can be in decarbonizing Louisiana's electric power and industrial sectors. This section of the report presents alternative grid resources for decarbonizing Louisiana's electric power sector, assessing each based on its feasibility, emissions reduction potential, costs, and safety attributes (see Figure 4 below) as well as discusses the potential decarbonization alternatives in the industrial sector.

[227] Wyoming Department of Environmental Quality. 2020. *WYOMING CLASS VI UNDERGROUND INJECTION CONTROL PROGRAM (1422) DESCRIPTION*. Available at: https://downloads.regulations.gov/EPA-HQ-OW-2020-0123-0003/content.pdf. p. 6; 30.

Figure 4. AEC Grid Resources Assessment for Louisiana

	Feasibility	Emissions	Costs	Safety
Energy Efficiency Good	**Good** Large-scale potential	**Good** Reduces energy use and emissions	**Good** \$14 to \$55/MWh	**Good** No major safety risks
Demand Response Good	**Good** Large-scale potential	**No Grade** May cut emissions from peak consumption	**Good** \$33/kW-year	**Good** No major safety risks
Wind Good	**Good** Large-scale potential	**Good** Zero emissions	**Good** \$28 to \$54/MWh and \$90/MWh (offshore)	**Good** No major safety issues
Solar Good	**Good** Large-scale potential	**Good** Zero emissions	**Good** \$30 to \$44/MWh (utility-scale)	**Good** Upstream health risks from materials
Battery Storage Good	**Good** Large-scale storage growth anticipated	**No Grade** May cut emissions from peak consumption	**Good** \$59 to \$348/kW-year	**Good** Safety risks are uncommon
Geothermal Weak	**Poor** Not commercially available	**Good** Zero emissions	**Weak** \$57 to \$705/MWh	**Weak** Seismic activity, drilling accidents
CCUS + Fossil Gas Weak	**Poor** Difficult to scale up	**Weak** CCUS capture 90% before counting leaks	**Weak** \$76 to \$80/MWh	**Weak** Leaks, pipeline ruptures, CO_2 exposure
RNG Generation Weak	**Weak** Diverse feedstocks, supply constraints	**Weak** Upstream methane leakage	**Weak** \$77 to \$484/MWh	**Poor** Health and environmental risks
Green Hydrogen Weak	**Poor** Not commercially viable, difficult to scale up	**Weak** Indirect emission of greenhouse gases	**Weak** \$305 to \$620/MWh, expected to decrease	**Poor** Dangerous health consequences of leaks
New Nuclear Poor	**Poor** Commercial viability and permitting constraints	**Good** Zero emission source of generation	**Poor** \$131 to \$204/MWh \$90 to \$100/MWh (SMRs)	**Poor** Waste storage, accident potential

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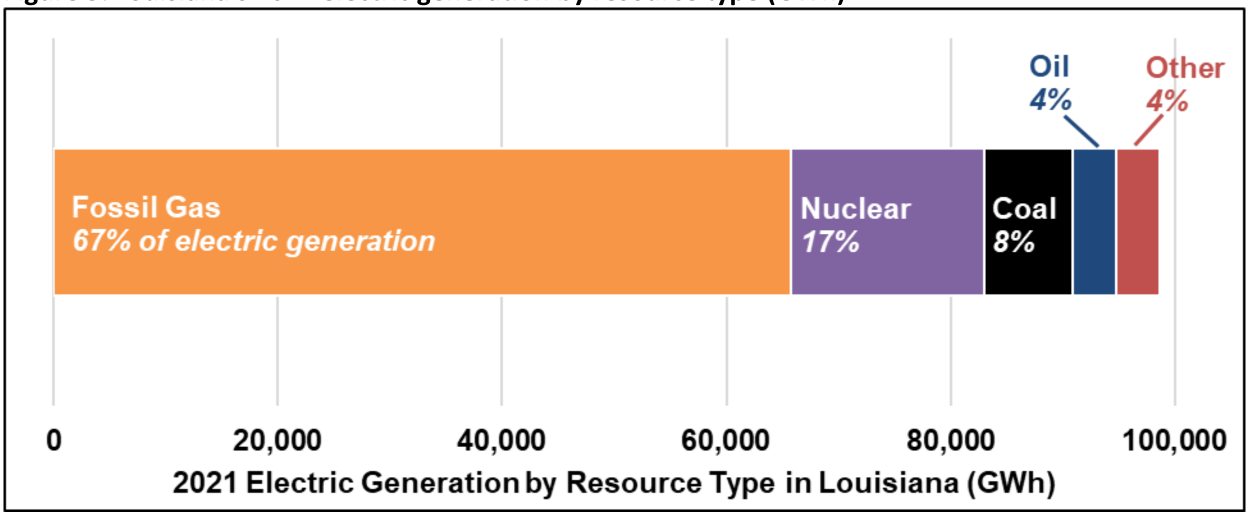
Note: All dollar values are presented in 2022 dollars, converted (when necessary) using CPI-U.

Louisiana's *Climate Action Plan* proposes to label fossil-gas-fired power plants as "clean generation" if paired with CCUS technologies designed to capture 90 percent of the resulting greenhouse gas emissions.[228] In 2021, fossil gas-fired power plants accounted for nearly 67 percent (or 65,752 GWh) of Louisiana's annual net generation (98,715 GWh) (see Figure 5).[229] Nuclear generation accounted for 17.5 percent (or 17,249 GWh) of Louisiana's net generation, while commercial-scale solar accounted for only 0.1 percent (or 146 GWh).[230]

Figure 5. Louisiana's 2021 electric generation by resource type (GWh)



Source: U.S. EIA. 2021. Louisiana State Electricity Profile 2021. Available at: https://www.eia.gov/electricity/state/louisiana/

Energy efficiency

Energy efficiency avoids the use of electric generators and can even make the construction of new generating resources unnecessary. Examples of energy saving measures include weatherization upgrades to homes and businesses, insulation, heat pumps, LED lights, and programs incentivizing changes to consumer behavior.[231] Once installed, energy efficiency measures save consumers money, costing between \$14 to \$55 per MWh of energy saved compared to levelized cost ranges of \$49 to \$80 per MWh for producing combined cycle fossil gas generation, \$28 to \$54 per MWh for producing wind generation, and \$30 to \$44 per MWh for utility-scale solar generation (not including incentives).[232] Other benefits of energy efficiency include reducing emissions from fossil fuel generation, increasing the resilience of communities against harms like air pollution and their associated health impacts, and minimizing load congestion on the grid (thereby reducing the need to invest in additional power plants and transmission and distribution lines).[233] Research published in 2017 by NREL found that Louisiana's single family homes can save \$465.6 million per year on their utility bills from energy

[228] State of Louisiana. 2022. *Climate Action Plan: Climate Initiatives Task Force Recommendations to the Governor.* Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf. p.44; 131.
[229] U.S. EIA. October 2022. "State-level generation and fuel consumption data – Annual." Available at: https://www.eia.gov/electricity/data.php#generation
[230] Ibid.
[231] Ibid.
[232] 1) *ACEEE. 2021. The Cost of Saving Electricity for the Largest U.S. Utilities: Ratepayer-Funded Efficiency Programs in 2018.* Available at: https://www.aceee.org/sites/default/files/pdfs/cost_of_saving_electricity_final_6-22-21.pdf. p. 9. 2) Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/. p. 2.
[233] Office of Energy Efficiency & Renewable Energy. "Energy Efficiency." U.S. Department of Energy. Available at: https://www.energy.gov/eere/energy-efficiency

efficiency, equivalent to 3.8 billion kWh per year in electricity.[234] The top four contributors to the Louisiana energy efficiency savings are (in order from highest to lowest): the installation of high efficiency heat pumps, insulation, smart thermostats, and attic insulation.[235]

- **Feasibility Grade: Good.** Louisiana has high potential for continued savings from energy efficiency.
- **Emissions Grade: Good.** Lowering energy consumption reduces grid emissions.
- **Costs Grade: Good.** Energy efficiency is the least expensive "grid resource", and can lower consumer energy bills.
- **Safety Grade: Good.** Energy efficiency has no major safety issues.
- **Overall Grade: Good.**

Demand response

Demand response programs enable consumers to reduce or shift their electric use away from peak periods in response to financial incentives.[236] The result is a reduced need for capacity resources (often gas combined turbines) required to provide reliability for peak electric demand. Demand response does not reduce the total amount of electricity used in a year, but it does have the potential to reduce emissions, especially in regions where dirtier resources—such as oil and older gas power plants—are run to serve peak needs. Demand response peak shifting programs include financial incentives giving to commercial and industrial facilities, special rates given to large consumers who agree to reduce demand during peak events, and direct load control programs that allow power companies to control appliances (for example, air conditioning or refrigeration) during peak periods.[237] The additional benefits of demand response programs include avoided fuel use by lowering demand in peak periods, avoiding generator startups and shutdowns,[238] preventing blackouts,[239] and increasing energy system resilience. Finally, demand response can create cost savings for participating customers both by reducing electric consumption at expensive peak times and preventing price spikes during periods of grid stress.[240]

The primary benefit of avoiding peak energy usage is to render investment in new peaking generation unnecessary. Louisiana State University's Center for Energy Studies argues that demand response technologies are particularly applicable to the state's industrial sector due to forecasted growth in peak load in the coming decades.[241] A study by the consulting firm ICF on Entergy Louisiana's demand response potential estimated savings of 4.0 to 5.3 percent of peak electricity demand by 2038 and offset peak demand growth by between 41 to 55 percent.[242] NREL modelling estimates cost savings from peak demand response

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[234] Wilson, E. 2017. *Louisiana: Residential Energy Efficiency Potential.* NREL. Available at: https://www.nrel.gov/docs/fy18osti/68812.pdf. p. 1.
[235] Ibid, p. 1.
[236] Office of Electricity. "Demand Response." Department of Energy. Available at: https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/demand-response
[237] Ibid.
[238] Hummon, M.. 2014. *Value of Demand Response: Quantities from Production Cost Modeling.* NREL. Available at: https://www.nrel.gov/docs/fy14osti/61815.pdf. p.10.
[239] 1) Safdar, M., G. A. Hussain, and M. Lehtonen. 2019. "Costs of Demand Response from Residential Customers' Perspective." *energies.* Available at: https://www.mdpi.com/1996-1073/12/9/1617/htm; 2) Tarufelli, B. 2020. *Foundations for an Intelligent Energy Future: Demand Response Potential in Louisiana.* LSU Center for Energy Studies. Available at: https://www.lsu.edu/ces/publications/2020/demand-response-potential-in-louisiana-df.pdf. p. 2-3.
[240] Tarufelli, B. 2020. *Foundations for an Intelligent Energy Future: Demand Response Potential in Louisiana.* LSU Center for Energy Studies. Available at: https://www.lsu.edu/ces/publications/2020/demand-response-potential-in-louisiana-df.pdf. p.3.
[241] Ibid, p. 6.
[242] ICF. 2018. *Entergy Louisiana: Analysis of Long-Term Achievable Demand Response Potential.* Available at: https://cdn.entergy-louisiana.com/userfiles/content/irp/2019/Draft_ELL_DR_Potential_Study_Report_w_Appendices.pdf. p.1.

capacity to be $33 per kW-year;[243] for comparison, Net CONE (the cost of new fossil gas capacity resources) for Louisiana is $84 to $94 per kW-year.[244]

- **Feasibility Grade: Good.** Louisiana has high potential for utilizing demand response programs to reduce peak grid stress.
- **Emissions Grade: No grade**. Demand response may reduce emissions under particular circumstances.
- **Costs Grade: Good.** Costs are well below Net CONE in MISO's Zone 9 (Louisiana and Eastern Texas).
- **Safety Grade: Good.** Demand response has no major safety issues.
- **Overall Grade: Good.**

Wind

Wind energy (offshore and onshore) has no major safety issues and does not produce greenhouse gas emissions. Wind energy is a developed technology and is commercially viable. However, the costs and potential for deployment in Louisiana differs among onshore and offshore installations. Onshore wind energy is less expensive than geothermal and new nuclear in Louisiana, but more costly than solar: The levelized cost of onshore wind is $28 to $54 per MWh.[245] According to NREL's *Annual Technology Baseline* (which was last updated before the IRA expanded incentives), the costs of onshore wind are expected to decrease substantially.[246] A 2012 analysis by NREL indicates that Louisiana has technical potential for 935 GWh of onshore wind.[247]

In contrast, offshore wind is $90 per MWh, on average nationwide.[248] The BOEM 2020 analysis estimates the Gulf of Mexico's offshore wind cost between $79 to $192 per MWh, with the lowest costs available near the Western Louisiana coast.[249] These costs make offshore wind more expensive than energy efficiency, onshore wind, and solar generation. It is comparable in cost to cheaper battery storage and CCUS at fossil gas plants, but still cheaper than new nuclear and geothermal. According to NREL's 2022 *Annual Technology Baseline* the costs of offshore wind are also expected to decrease substantially.[250] Research published by the Rocky Mountain Institute predicts that the IRA will accelerate the decline in wind costs.[251] A 2020 study by the U.S. Bureau of Ocean Management (BOEM) estimates Louisiana's offshore wind potential to be approximately 220 GW—nine times the state's 2021 summer peak capacity.[252]

- **Feasibility Grade: Good.** Wind power is widespread, commercially viable, and can be scaled.

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[243] Hummon, M. 2014. *Value of Demand Response: Quantities from Production Cost Modeling.* NREL. Available at: https://www.nrel.gov/docs/fy14osti/61815.pdf. p. 12.
[244] Resource Adequacy Subcommittee. 2022. "MISO Cost of New Entry (CONE) Planning Year 2023/2024." MISO. Available at: https://cdn.misoenergy.org/20221012%20RASC%20Item%2004c%20CONE%20Update626542.pdf. p. 11.
[245] Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf. p. 2.
[246] NREL. 2022 *Annual Technology Baseline.* Available at: https://atb.nrel.gov/electricity/2022/definitions#capex
[247] Lopez, A. B. Roberts, D. Heimiller, N. Blair, and G. Porro. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL. Available at: https://www.nrel.gov/docs/fy12osti/51946.pdf. p. 14-15.
[248] Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf. p. 2.
[249] Bureau of Ocean Energy Management. 2020. *Offshore Wind in the US Gulf of Mexico: Regional Economic Modeling and Site-Specific Analyses.* OCS Study BOEM 2020-018. Available at: https://espis.boem.gov/final%20reports/BOEM_2020-018.pdf. p. 31.
[250] NREL. 2022 *Annual Technology Baseline.* Available at: https://atb.nrel.gov/electricity/2022/
[251] Shwisberg, L. 2022. "The Business Case for New Gas is Shrinking." RMI. Available at: https://rmi.org/business-case-for-new-gas-is-shrinking/
[252] Bureau of Ocean Energy Management. 2020. *Survey and Assessment of the Ocean Renewable Energy Resources in the US Gulf of Mexico.* OCS Study BOEM 2020-17. Available at: https://espis.boem.gov/final%20reports/BOEM_2020-017.pdf. p.27.

- **Emissions Grade: Good.** Wind is zero emissions generation.
- **Costs Grade: Good.** New wind resources are less expensive than geothermal and new nuclear but more expensive than commercial-scale solar.
- **Safety Grade: Good.** Wind generation has no major safety issues.
- **Overall Grade: Good.**

Solar

NREL estimates Louisiana's technical potential for urban commercial-scale (sometimes called "utility-scale") solar, rural commercial-scale solar, and rooftop photovoltaics respectively as: 55,669 GWh, 4,114,605 GWh, 14,368 GWh.[253] (For context, Louisiana's 2021 annual generation was 98,715 GWh.[254]) At present, there are supply chain challenges with new solar development in the United States; key inputs (polysilicon, ingots, wafers) are not being produced in sufficient quantity and manufacturing sites often rely on imported parts and materials.[255] However, these supply issues are unlikely to persist over the long term as market developments and industrial policies address these problems. In particular, the IRA contains significant incentives to expand domestic manufacturing and lower the costs of producing solar capacity; the Solar Energy Industries Association believes the law will help achieve 50 GW of domestic solar manufacturing capacity by 2030.[256] Levelized cost for all types of utility-scale solar ranges from $30 to $44 per MWh, while rooftop photovoltaics and community solar costs have a higher and wider range: from $64 to $239 per MWh (not including incentives).[257] According to NREL's 2022 *Annual Technology Baseline* the costs of solar were expected to decrease substantially.[258] Research from the Rocky Mountain Institute projects solar costs to fall faster with the passage of the IRA.[259]

- **Feasibility Grade: Good.** Solar power is widespread, commercially viable, and can be scaled.
- **Emissions Grade: Good.** Solar is zero emissions generation
- **Costs Grade: Good.** Commercial-scale solar resources are less expensive than every other form of zero emissions generation.
- **Safety Grade: Good.** Solar has issues with sourcing upstream materials.
- **Overall Grade: Good.**

Battery storage

Batteries, or energy storage, improve the reliability of the electric grid by storing energy that can later be dispatched during outages or periods of high electric demand. Battery storage paired with solar or wind generation can act as a zero-emission resource for both generation and meeting peak capacity. Like demand

[253] Lopez, A. B. Roberts, D. Heimiller, N. Blair, and G. Porro. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL. Available at: https://www.nrel.gov/docs/fy12osti/51946.pdf. p. 10-12.
[254] U.S. EIA. October 2022. "State-level generation and fuel consumption data – Annual." Available at: https://www.eia.gov/electricity/data.php#generation
[255] Solar Technologies Office. "Solar Photovoltaics Supply Chain Review. Department of Energy. Available at: https://www.energy.gov/eere/solar/solar-photovoltaics-supply-chain-review-report.
[256] SEIA. 2022. *Catalyzing American Solar Manufacturing.* Available at: https://seia.org/sites/default/files/2022-08/SEIA%20Manufacturing%20Roadmap%202022_2.pdf
[257] Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/. p. 2.
[258] NREL. 2022 *Annual Technology Baseline.* Available at: https://atb.nrel.gov/electricity/2022/
[259] Shwisberg, L. 2022. "The Business Case for New Gas is Shrinking." RMI. Available at: https://rmi.org/business-case-for-new-gas-is-shrinking/

response, energy storage shifts peak without reducing annual electric generation and only reduces greenhouse gas emissions under particular circumstances. In its 2022 *Storage Future Study,* NREL estimates new U.S.-wide storage deployment—consisting of 2-, 4-, 6-, 8-, and 10-hour batteries as well as 12-hour pumped storage—ranges from 100 to 650 GW of capacity between 2020 and 2050, [260] up from 23 GW in 2020.[261] Levelized costs of commercial-scale battery storage range from $59 to $348 per kW-year depending on the duration (e.g. 1, 2, or 4 hours)—hybrid systems with battery storage and solar PV cost between $178 to $320 kW-year but provide both capacity and generation services.[262] Net CONE in MISO's Zone 9 (Louisiana and Eastern Texas) is $84 to $94 per kW-year, falling in the middle of the range of commercial-scale battery storage costs.[263] NREL anticipated continued declines in battery costs of multiple durations without accounting for the effects of the IRA.[264] Battery storage is subject to some uncommon, but possible, safety risks including uncontrollable self-heating of battery cells and the release of flammable and toxic gases.[265] Lithium-ion batteries depend on complex supply chains for several metallic resources such as lithium and cobalt, which are vulnerable to disruption at the mining , refining, and manufacturing stages.[266]

- **Feasibility Grade: Good.** Battery storage is a scalable technology and is projected to play a significant role in integrating high levels of wind and solar.
- **Emissions Grade: No grade.**
- **Costs Grade: Good.** Battery storage costs vary widely with a range that extends both above and below Net CONE in MISO's Zone 9 (Louisiana and Eastern Texas), but are projected to fall significantly over time as deployment continues to increase.
- **Safety Grade: Good.** Batteries' safety risks are uncommon, but can include uncontrollable self-heating, release of gases, and fires.
- **Overall Grade: Good.**

Geothermal

Most of the geothermal potential in Louisiana requires the development of enhanced geothermal systems (EGS) which converts underground heat into electric power by generating steam. EGS systems use human-made reservoirs to access heat where there is little natural escape to the surface.[267] Injection wells allow water to be added to human-made fractures underground in order to release steam.[268] While a 2012 analysis by NREL estimated that Louisiana's technical potential for EGS is several times the size of its total electric

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[260] Blair, N., C. Augustine, W. Cole, P. Denholm, W. Frazier, M. Geocaris, J. Jorgenson, K. McCabe, K. Pdkaminer, A. Prasanna, B. Sigrin. 2022. *Storage Futures Study: Key Learnings for the Coming Decades.* NREL. Available at: https://www.nrel.gov/docs/fy22osti/81779.pdf. p.3.
[261] Blair, N., C. Augustine, W. Cole, P. Denholm, W. Frazier, M. Geocaris, J. Jorgenson, K. McCabe, K. Pdkaminer, A. Prasanna, B. Sigrin. 2022. *Storage Futures Study: Key Learnings for the Coming Decades.* NREL. Available at: https://www.nrel.gov/docs/fy22osti/81779.pdf. p.3.
[262] Lazard. 2021. *Lazard's Levelized Cost of Storage Analysis—Version 7.0.* Available at: https://www.lazard.com/media/451882/lazards-levelized-cost-of-storage-version-70-vf.pdf
[263] Resource Adequacy Subcommittee. 2022. "MISO Cost of New Entry (CONE) Planning Year 2023/2024." MISO. Available at: https://cdn.misoenergy.org/20221012%20RASC%20Item%2004c%20CONE%20Update626542.pdf. p. 11.
[264] NREL. 2022 *Annual Technology Baseline*. Available at: https://atb.nrel.gov/electricity/2022/utility-scale_battery_storage
[265] National Fire Protection Association. 2021. "Battery Energy Storage Hazards and Failure Modes." Available at: https://www.nfpa.org/News-and-Research/Publications-and-media/Blogs-Landing-Page/NFPA-Today/Blog-Posts/2021/12/03/Battery-Energy-Storage-Hazards-and-Failure-Modes.
[266] Sun, X. H. Hao, P. Hartmann, Z. Liu, F. Zhao. 2019. "Supply risks of lithium-ion battery materials: An entire supply chain estimation." *Materials Today Energy.* Available at: https://www.sciencedirect.com/science/article/abs/pii/S2468606919302035.
[267] Geothermal Technologies Office. *What is an Enhanced Geothermal System (EGS)?* U.S. Department of Energy. Available at: https://www1.eere.energy.gov/geothermal/pdfs/egs_basics.pdf. p.1.
[268] Ibid.

demand,[269] EGS technology is still at the trial-phase in the United States.[270,271,272]

Geothermal projects are capital intensive and may involve lengthy administrative processes for licenses and permits.[273] An 2014 EGS-specific study published in the *Journal of Renewable and Sustainable Energy* estimated the levelized cost of EGS to be between $57 and $705 per MWh, a wide variation showing the sensitivity of modeling results to variations in engineering assumptions.[274] Risks from geothermal generation include: spills or mismanagement of drilling and geothermal fluids, air emissions from drilling activities, blowouts or pipeline failure, and the depletion of water reservoirs used to operate geothermal generation.[275] In addition, EGS is linked to enhanced seismic activity around drilling sites.[276]

- **Feasibility Grade: Poor.** EGS (the only type viable in Louisiana) are not yet commercially viable.
- **Emissions Grade: Good.** Zero emission generation.
- **Costs Grade: Weak.** Costs varying from low to extremely high depending on engineering assumptions.
- **Safety Grade: Weak.** Seismic activity and other safety issues can emerge from the use of injection wells and the depletion of nearby water sources.
- **Overall Grade: Weak.**

CCUS and fossil gas

When used in conjunction with fossil gas generation, CCUS is a limited aid to decarbonizing the grid: (1) Carbon capture technologies do not capture all the CO_2 emitted by a power plant—today's commercially viable systems aim for 90 percent efficiency or higher; the remaining 10 percent still ends up in the Earth's atmosphere. (2) Energy is also expended to operate the CCUS system, reducing plant efficiency (that is, more fossil gas is needed to produce the same amount of electricity) and, therefore, increasing emissions from gas combustion. Furthermore, (3) CCUS infrastructure is vulnerable to leaks that spread plumes of hazardous CO_2 across the surrounding area, as well as the seepage of CO_2 underground into water. The National Energy Technology Laboratory's 2022 estimates put the cost of a new natural gas combined cycle plant with CCUS infrastructure at $76 to $80 per MWh.[277]

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[269] Lopez, A. B. Roberts, D. Heimiller, N. Blair, and G. Porro. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL. Available at: https://www.nrel.gov/docs/fy12osti/51946.pdf. p. 17-18.

[270] Robins, J., A. Kolker, F. Flores-Espino, W. Pettitt, B. Schmidt, K. Beckers, H. Pauling, B. Anderson. 2021. *2021 U.S. Geothermal Power Production and District Heating Market Report.* NREL. Available at: https://www.nrel.gov/docs/fy21osti/78291.pdf. p. 38.

[271] IRENA. 2017. *Geothermal Power: Technology Brief.* Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Aug/IRENA_Geothermal_Power_2017.pdf. p. 5.

[272] Patel, S. 2022. "Large-Scale Enhanced Geothermal System Trial Successfully Completed." *Power.* Available at: https://www.powermag.com/large-scale-enhanced-geothermal-system-trial-successfully-completed/.

[273] Ibid, p. 5; 12.

[274] Beckers, K., M. Lukawski B. Anderson, M Moore, and J. Tester. 2014. "Levelized costs of electricity and direct-use heat from Enhanced Geothermal Systems." *Journal of Renewable and sustainable Energy.* Available at: https://aip.scitation.org/doi/10.1063/1.4865575.

[275] 1) International Finance Corporation and the World Bank Group. 2007. *Environmental, Health, and Safety Guidelines for Geothermal Power Generation.* Available at: https://www.ifc.org/wps/wcm/connect/afad6488-c478-45d8-bd2e-dc2f86b7e18a/Final%2B-%2BGeothermal%2BPower%2BGeneration.pdf?MOD=AJPERES&CVID=nPtgOhC&id=1323161975166. p. 2-5. 2) Hanson, P. 2019. "Risk Mitigation for Geothermal Development." Geoenergy Marketing Services. Available at: https://www.geoenergymarketing.com/energy-blog/risk-mitigation-for-geothermal-development/.

[276] Hanson, P. 2019. "Risk Mitigation for Geothermal Development." Geoenergy Marketing Services. Available at: https://www.geoenergymarketing.com/energy-blog/risk-mitigation-for-geothermal-development/.

[277] Schmitt, T. et al. 2022. *Cost and performance baseline for fossil energy plants volume 1: bituminous coal and natural gas to electricity.* National Energy Technology Laboratory (NETL). Available at: https://netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVolume1BituminousCoalAndNaturalGasToElectricity_101422.pdf. p. 16.

- **Feasibility Grade: Poor.** There are no U.S. examples of active commercial-scale CCUS technology on fossil gas generation.
- **Emissions Grade: Weak.** Emissions reductions are incomplete due to low efficiencies of capture technologies, upstream emissions, and leakages in the transportation infrastructure.
- **Costs Grade: Weak.** Capture and retrofitting of plants is an expensive addition to the cost of fossil gas generation.
- **Safety Grade: Weak.** CCUS technology endangers surrounding community health and safety due to the danger of ruptures and CO_2 exposure.
- **Overall Grade: Weak.**

RNG-fired generation

Renewable natural gas (RNG)—sometimes called upgraded biogas—is produced from "renewable" source materials converted into a gas that can be burned in place of fossil gas for electric generation. Source materials for making RNG include biomass feedstocks like agricultural and municipal waste, forest residues, or energy crops. In addition, RNG can be produced using several processes including anaerobic digestion and thermal gasification.[278] The most likely forms of biogas will derive methane from landfills, wastewater treatment plants, and manure digesters. Due to the wide range of possible feedstock sources and production processes, net emissions from RNG combustion can be positive or negative, ranging from -389 to +52 kg CO_2e per Btu.[279] RNG is methane—a much more potent greenhouse gas than CO_2—and its transport in pipelines can result in substantial leakage that offsets or even negates potential emission reductions from its use.[280] Moreover, supply constraints call into question the widespread viability and affordability of RNG as a fuel source, prices for which can vary anywhere from \$77 to \$484 per MWh;[281] the greater the demand for RNG feedstocks, the higher the price. Beyond the costs of RNG as a fuel itself, its use entails several other risks common to all forms of methane—including worse indoor air quality, tree mortality near leak sites, and the risk of large-scale fires or explosions.[282]

- **Feasibility Grade: Weak.** RNG has a diverse set of feedstocks, but its production processes can face supply constraints.
- **Emissions Grade: Weak.** Upstream leakages limit the emissions reduction potential but emission

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[278] Stifel Equity Research. 2021. *Energy & Power—Biofuels: Renewable Natural Gas.* Available at: https://www.rngcoalition.com/data-resources-2. p. 24

[279] ICF. December 2019. *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment*. An American Gas Foundation Study. p. 72. Available at: https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-ReportFINAL-12-18-19.pdf

[280] Gasper, R. and Searchinger, T. 2018. *The production and use of renewable natural gas as a climate strategy in the United States.* World Resources Institute (WRI). Available at: https://www.wri.org/research/production-and-use-waste-derived-renewable-natural-gasclimate-strategy-united-states

[281] AEC calculated a Louisiana-specific heat rate for gas-fired power plants (9.733 MMBtu per MWh) using EIA data (Form 923) on fuel usage (6.6 million MMBtu) and electricity generation (680,000 MWh), which were then used to convert the cost of RNG (\$8 to \$50 per MMBtu) from dollars per MMBtu to dollars per MWh. Source: 1) ICF. March 2020. *Study on the Use of Biofuels (Renewable Natural Gas) in the Greater Washington,D.C. Metropolitan Area*. Prepared for Washington Gas Light Company. Available at: https://edocket.dcpsc.org/public/search/details/fc1142/597; 2) US Energy Information Administration. 2021. *Form EIA-923*. Available at: https://www.eia.gov/electricity/data/eia923/

[282] (1) Campbell, R. 2020. *Structure Fires in Schools*. National Fire Protection Association. Available at: https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Structure-fires-in-schools; (2) Glick D., Plautz, J. 2018. "The rising risks of the West's latest gas boom." *High Country News*. Available at: https://www.hcn.org/issues/50.18/energy-industry-how-site-workers-and-firefighters-responding-to-a-2017-naturalgas-explosion-in-windsor-colorado-narrowly-avoided-disaster; (3) U.S. EPA. n.d. "Introduction to Indoor Air Quality." Available at: https://www.epa.gov/indoor-air-qualityiaq/introduction-indoor-air-quality; (4) Gas Leaks Allies. n.d. *Gas Leaks Kill Trees*. Available at: https://www.wellesleyma.gov/DocumentCenter/View/9596/Gas-Leaks-Kill-Trees-PDF.

benefits depend on the feedstock used.

- **Costs Grade: Weak.** Highly variable and more expensive than all other alternative grid resources.
- **Safety Grade: Poor.** Numerous health, safety and co-pollutant risks.
- **Overall Grade: Weak.**

Green hydrogen

While green hydrogen may present a viable alternative in the industrial sector, this assessment reviews green hydrogen's viability within the power sector compared to other power-sector alternatives. Hydrogen gas can be added to fossil gas or RNG fuel used to produce electricity. Renewable electricity—instead of being used by customers—can be used to produce green hydrogen that can reduce the amount of fossil gas in pipeline distribution by up to 15 percent. [283] Green hydrogen—hydrogen produced from the electrolysis of water using energy generated from solar or wind energy—can be considered compatible with states' clean energy mandates but its use for electric generation is less efficient (that is, energy is lost) compared to more direct uses of renewable electricity. Without equipment upgrades, green hydrogen presents risks of explosions and leaks.[284] In addition, combusting green hydrogen (as opposed to using it in a fuel cell) can release significant nitrogen oxides (NO_x) emissions—an indirect greenhouse gas, on par with natural gas combustion, or worse.[285] At present, the only domestic sources of green hydrogen are demonstration projects; its production has not been demonstrated at scale. Global prices of generation from green hydrogen (calculated as if green hydrogen could be used independent as a fuel for electric generation) range from $305 to $620 per MWh.[286] Both the IRA and the Infrastructure, Investment and Jobs Act, however, are expected to aid the deployment of nascent hydrogen technologies, potentially lowering costs.[287] That said, a 2022 report by Resources for the Future noted that hydrogen produced by electrolysis in particular may have difficulty achieving cost competitiveness in the short run even with these investment incentives due to both the price of direct renewable electricity purchases and parasitic load.[288]

- **Feasibility Grade: Poor.** Difficult to scale green hydrogen production for use as independent fuel.
- **Emissions Grade: Weak.** Green hydrogen can result in indirect emissions of NO_x, which produce the greenhouse gas ozone once in the atmosphere.
- **Costs Grade: Weak.** More expensive than all other alternative grid resources.
- **Safety Grade: Poor.** Operational risks without upgrades.
- **Overall Grade: Weak.**

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[283] Melaina, MW. et al. March 2013. *Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues*. NREL. Available at: https://www.nrel.gov/docs/fy13osti/51995.pdf. p. 31.

[284] St. John, J. November 30, 2020. "Green Hydrogen in Natural Gas Pipelines: Decarbonization Solution or Pipe Dream?" Greentech Media. Available at: https://www.greentechmedia.com/articles/read/green-hydrogen-in-naturalgas-pipelines-decarbonization-solution-or-pipe-dream

[285] Forster, P. et. al. 2018.; 2) J.M.K.C. Donev et al. 2021. "Energy Education - Greenhouse gas." Available at: https://energyeducation.ca/encyclopedia/Greenhouse_gas

[286] AEC calculated a Louisiana-specific heat rate for gas-fired power plants (9.733 MMBtu per MWh) using EIA data (Form 923) on fuel usage (6.6 million MMBtu) and electricity generation (680,000 MWh), which were then used to convert the cost of green hydrogen ($31 to $64 per MMBtu) from dollars per MMBtu to dollars per MWh. Source: 1) Lazard. October 2021. *Lazard's Levelized Cost of Hydrogen Analysis*. Version 2.0. Available at: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/; 2) US Energy Information Administration. 2021. *Form EIA-923*. Available at: https://www.eia.gov/electricity/data/eia923/.

[287] Krupnick, A., and A. Bergman. 2022. *Incentives for Clean Hydrogen Production in the Inflation Reduction Act.* Resources for the Future. Available at: https://www.rff.org/publications/reports/incentives-for-clean-hydrogen-production-in-the-inflation-reduction-act/

[288] Ibid.

New nuclear

Potential new nuclear generation includes small modular reactors (SMRS)—a type of light-water design,[289] newer models of conventional light water reactors, and advanced non-light-water reactor designs cooled by sodium, molten salt, or high-temperature gas.[290] SMRs "modular" character refers to the ability to standardize their design and manufacture more so than a conventional nuclear plant.[291] However, SMRs in particular have not yet been deployed at scale. NuScale—the company that received the first approval of an SMR design by the U.S. Nuclear Regulatory Commission—plans for its first design go operational in 2029.[292] The development of new nuclear reactors is also hindered by lengthy development, licensing, permitting, and approval times.[293]

New conventional reactors' levelized cost is estimated at $140 to $220 per MWh, higher than utility-scale solar, wind, geothermal, coal, and gas combined cycle.[294] SMRs cost estimates for the NuScale project are $90 to $100 per MWh.[295] In contrast, extending the life of conventional nuclear plants is considerably cheaper than building a new plant, and may be cost competitive with solar and wind projects.[296] In 2019, the International Energy Agency (IEA) suggests that investments to extend the lifetime of existing nuclear could cost less than both new nuclear and new renewables.[297]

Existing and new nuclear generation do not release greenhouse gas emissions; there are, however, important safety concerns. Conventional nuclear generation and SMRs contain radioactive materials that, if released through accident, natural disaster or violent act can pose significant radiological risk to the surrounding area, the environment, and to human health. Certain alternative reactor designs can pose more safety, proliferation, and environmental risks than the current reactor fleet.[298] Mining of uranium can produce solid and liquid radioactive wastes, which must be stored at specifically designed disposal sites.[299] Both miners and

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289 Lyman, E.. 2021.*"Advanced" Isn't Always Better."* Union of Concerned Scientists. Available at: https://www.ucsusa.org/sites/default/files/2021-05/ucs-rpt-AR-3.21-web_Mayrev.pdf

290 Due to their relative size, SMRs require less capital investment and can be sited in more locations than larger, conventional reactors. The International Atomic Energy Agency classifies SMRs as having a power capacity of up to 300 MW per unit, one third of conventional reactors. Sources: (1) Liou, J. 2021. "What are Small Modular Reactors (SMRs)?" Available at: https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs#:~:text=Small%20modular%20reactors%20(SMRs)%20are,of%20traditional%20nuclear%20power%20reactors. (2) Office of Nuclear Energy. "Advanced Small Modular Reactors (SMRs)." Available at: https://www.energy.gov/ne/advanced-small-modular-reactors-smrs.

291 Office of Nuclear Energy. "Benefits of small Modular Reactors." Available at: https://www.energy.gov/ne/benefits-small-modular-reactors-smrs.

292 Levitan, D. 2020. "First U.S. Small Nuclear Reactor Design Is Approved." *Scientific American*. Available at: https://www.scientificamerican.com/article/first-u-s-small-nuclear-reactor-design-is-https://www.utilitydive.com/news/challenge-from-renewables-forces-nuclear-industry-to-look-beyond-electricit/620072/approved/#:~:text=NuScale's%20SMR%2C%20developed%20with%20the,than%201%2C000%20megawatts%20(MW).

293 Good, A. 2022. "Costs, permitting hurdles dampen potential for new nuclear capacity." *S&P Global*. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/co[…]g-hurdles-dampen-potential-for-new-nuclear-capacity-69550774

294 Lazard. October 2021. *Lazard's Levelized Cost of Energy Analysis*. Version 15.0. Available at: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/. p. 2.

295 Walton, R. 2022. "Rising steel prices, interest rates could push NuScale Utah project cost to $100/MWh, but support remains." *Utility Dive.* Available at: https://www.utilitydive.com/news/nuscale-nuclear-reactor-smr-uamps-rising-steel-prices-interest-rates/636619/

296 IEA. 2019. *Nuclear Power in a Clean Energy System.* Available at: https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

297 Ibid.

298 Lyman, E. 2021. *"Advanced" Isn't Always Better.* Union of Concerned Scientists. Available at: https://www.ucsusa.org/resources/advanced-isnt-always-better

299 EPA. "Radioactive Waste from Uranium Mining and Milling." Available at: https://www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling.

surrounding communities can be exposed to radon if precautions are not taken or if excessive gas is vented.[300] The United States also lacks a permanent long-term storage for nuclear waste[301]—and commercial plants generally store waste on-site.[302]

- **Feasibility: Poor.** SMRs are not commercially available and advanced nuclear technologies face significant delays and barriers in permitting. Extending the life of existing generation is possible.
- **Emissions: Good.** Nuclear generation does not produce greenhouse gases.
- **Costs: Poor.** New nuclear generation is expensive relative to other zero emission resources.
- **Safety: Poor.** Nuclear generation presents substantial risks from catastrophic accidents and waste storage.
- **Overall: Poor**

Alternatives to CCUS in the Industrial Sector

Louisiana's industrial sector accounted for 66 percent of the state's total greenhouse gas emissions compared to 19 and 13 percent for the transportation and electric power sectors, respectively. Industry in Louisiana represents a disproportionately large share of total emissions compared to the rest of the United States: 66 percent of total economy-wide emissions in Louisiana versus 17 percent for the United States as a whole.[303] Louisiana's *Climate Action Plan* presents four strategies for decarbonizing the state's industrial sector: (1) monitor, inventory, certify, and support industrial decarbonization; (2) improve efficiencies in and modernization of industrial processes and facilities; (3) accelerate industrial electrification, switching to low- or no-carbon fuels and low- or no-carbon feedstocks; and (4) promote reduced carbon materials.[304] Each of these strategies to decarbonize Louisiana's industrial sector follows U.S. DOE's guidance by considering opportunities for energy efficiency, industrial electrification, the use of low- and no-carbon fuels and feedstocks, as well as CCUS technologies.[305] However, Louisiana's *Climate Action Plan* puts less of a near-term emphasis on CCUS deployment in the industrial sector than it does for the electric sector, stating that for the industrial sector, investments in further research and impact assessments are needed to assure that CCUS is deployed in a safe and responsible manner.

Energy efficiency, electrification, and fuel switching are alternative decarbonization strategies that Louisiana can employ in the near-term to reduce greenhouse gas emissions its industrial sector. **Energy efficiency** is reduction of energy consumption, which in turn reduces emissions from fossil fuel consumption.[306] Examples of industrial sector energy efficiency include energy management approaches to optimize industrial system performance, management and optimization of thermal heat in manufacturing processes, and the use of

[300] EPA. "Radioactive Waste from Uranium Mining and Milling." Available at: https://www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling.
[301] Holt, M. 2021. *Civilian Nuclear Waste Disposal.* Congressional Research Service. Available at: https://sgp.fas.org/crs/misc/RL33461.pdf.
[302] Congressional Research Service. 2019. *Nuclear Waste Storage Sites in the United States.* Available at: https://crsreports.congress.gov/product/pdf/IF/IF11201/4.
[303] State of Louisiana. 2022. *Louisiana Climate Action Plan.* Recommendations to the Governor prepared by the Climate Initiatives Task Force. Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf. p.11
[304] State of Louisiana. 2022. *Louisiana Climate Action Plan.* Recommendations to the Governor prepared by the Climate Initiatives Task Force. Available at: https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf. p.52
[305] U.S. Department of Energy. 2022. *Industrial Decarbonization Roadmap.* Available at: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap.
[306] U.S. Department of Energy. 2022. *Industrial Decarbonization Roadmap.* Available at: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap.

smart technologies and data analytics to increase energy productivity.[307] **Industrial electrification** paired with reducing emissions from electric generation can replace direct fuel use to power industrial processes. Examples include electrification of process heating, electrification of high temperature range processes, and replacing thermally-driven processes with electrochemical processes.[308] **The use of low- and no-carbon fuel and feedstocks** to reduce emissions from combustion in industrial processes by substituting the low- or no-carbon fuels for fossil fuels currently in use. Examples include fuel-flexible processes the integration of hydrogen fuels and feedstocks, and the use of biofuels and bio-feedstocks.[309]

CCUS present opportunities for decarbonizing the industrial sector to address hard-to-abate, recalcitrant emissions that remain after other decarbonization strategies are employed.

VII. Key Takeaways for CCUS in Louisiana

Louisiana's commitment to CCUS deployment and the associated risks posed by CCUS infrastructure increase the urgency for an unbiased examination of regulation and permitting of CCUS pipelines, injection wells, and other infrastructure. To fully understand and mitigate the risks associated with CCUS, decision-makers must assess (1) how and to what extent CCUS could negatively impact surrounding communities, (2) what policies, rules and regulations are required to ensure that CCUS deployment is conducted in a safe and responsible manner, and (3) which applications are most appropriate for CCUS versus other decarbonization alternatives. Based on the information presented in this report, the key takeaways to consider are as follows:

- **CCUS is vulnerable to damage.** CCUS infrastructure is susceptible to land subsidence, damage from water, extreme changes in temperature or pressure, and chemical impurities in the CO_2 mixture, which can be further exacerbated by the impacts of climate change such as sea level rise and extreme weather events. Damages to pipelines, injection wells and other types of CCUS infrastructure can impede functionality through leakages, ruptures, embrittlement, and explosions, among other potential hazards.
- **CCUS poses risks to human health, safety, and the environment.** The vulnerabilities of CCUS infrastructure can lead to several risks to human health, safety, and the environment, including: explosions from pipeline ruptures, exposure to CO_2 plumes from leakages, and compromised drinking water supplies due to CO_2 interacting with groundwater.
- **The emissions reduction potential of CCUS is limited.** Although CCUS technologies are commonly designed to capture 90 percent (or more) of CO_2 emissions released, many examples of CCUS have underperformed and failed to meet this target. Even best-case capture efficiencies of CCUS do not account for upstream fugitive emissions from fossil fuel extraction, storage, and transmission.
- **CCUS is expensive.** Retrofitting all of Louisiana's gas-fired combined cycle units with CCUS (without considering IRA tax credits) would cost $1.0 to $1.2 billion per year, which could double the costs associated with operating gas-fired combined cycle power plants in Louisiana.
- **There are excellent, commercially viable alternatives to CCUS.** Although CCUS may present opportunities to address recalcitrant greenhouse gas emissions, especially in certain hard-to-decarbonize

[307] Ibid.
[308] Ibid.
[309] Ibid.

industries, there are better alternatives to choose that are cheaper, safer, and more effective.

To identify the most appropriate role that CCUS could play in Louisiana's decarbonization efforts, decision-makers must take into consideration the technical and economic feasibility, emissions reduction potential, and safety of CCUS infrastructure compared to that of alternative decarbonization strategies.