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Working Paper from Stakeholder Discussions on "Collaborative Action to Reduce CO_2 Emissions in Texas"

Expanding Carbon Capture in Texas

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Foreword

Since mid-2019, the Center for Energy Studies at Rice University's Baker Institute for Public Policy has convened a diverse group of stakeholders to explore the deployment of carbon capture utilization and storage (CCUS) technologies in the state of Texas. The working group consists of corporations, industry special interest groups, academic institutions, and non-governmental organizations (NGOs). Funding for the effort was provided by The Cynthia and George Mitchell Foundation and the Oil and Gas Climate Initiative (OGCI).

Each of the working group participating organizations is active in the state of Texas and has an interest in CCUS. The organizations that participated are recognized for their contributions to the working group discussions. Recognition does not convey attribution. Moreover, in no way should recognition for participation be deemed as endorsement or adoption of the recommendations and policy proposals herein. The research and recommendations herein are exclusively attributed to the authors.

Participating Organizations of the CCUS Stakeholder Working Group

Corporations: 8 Rivers; Air Liquide; Baker Hughes; BP; Calpine; Chevron; Dow Inc.; Kinder Morgan; Linde; Natural Resource Partners; NRG Energy; Occidental Petroleum; Phillips 66; Quintana Minerals; Repsol; Schlumberger; Sempra; Shell; Valero

NGOs and Other Groups: Center for Houston's Future; Clean Air Task Force; Environmental Defense Fund; Gas Technology Institute; Greater Houston Partnership; Houston Advanced Research Center; OGCI; Port of Houston; US Business Council for Sustainable Development

Universities and Foundations: Center for Energy Studies at the Baker Institute for Public Policy, Rice University; Cynthia and George Mitchell Foundation; Gulf Coast Carbon Center at the Bureau of Economic Geology, University of Texas at Austin; Kinder Institute for Urban Studies, Rice University

I. Introduction

As the International Energy Agency outlines in one of its flagship reports released in September 2020, expanding the use of carbon capture, utilization or storage (CCUS) is paramount to the success of global efforts to substantially reduce carbon dioxide (CO_2) emissions.[1] The scale of existing global energy infrastructure is massive and heterogeneous, and it supports a broad range of economic activities, health and human services, and lifestyles across multiple geographies. As such, the energy ecosystem is built on a legacy that is difficult to replace, costly to dismantle, and impossible to ignore in discussions about energy transitions. There are multiple options that can and will be leveraged as the world moves to reduce the carbon intensity of energy use, and CCUS is a comprehensive suite of technologies that enables decarbonization through retrofit of existing infrastructure and, longer term, a reimagining of hydrocarbon combustion.

While CO_2 emissions are a problem of the global commons, the state of Texas is particularly well-situated to capture significant economies of scale in the CCUS industry and to take a leading role in the transition to a lower carbon future. Medlock and Miller (2020) applied the principle of comparative advantage to the CCUS industry in Texas, arguing that that Texas has a distinct advantage in developing a full-scale CCUS industry due to several distinct factors: [2]

- the scale of industrial and power sector CO_2 emissions in Texas (24% and 12% of all energy-related CO_2 emissions in the US industrial and power sectors, respectively, as Figure 1 illustrates),
- the importance of energy and chemical industries in Texas (representing 13% of gross state product);
- a rich geologic endowment; and
- a human capital endowment of unsurpassed technical knowledge of the subsurface.

As consumers and investors become increasingly conscious of carbon footprints, addressing CO_2 emissions grows ever more important for the sustainability of the Texas economy.

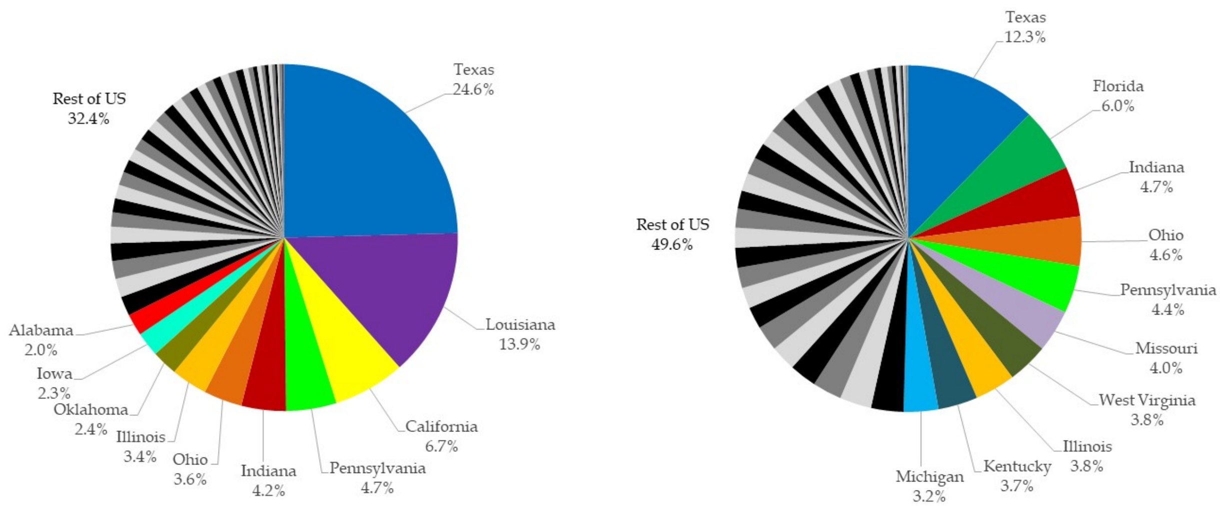
[1] See International Energy Agency, "CCUS in Clean Energy Transitions," September 2020 available online at https://www.iea.org/reports/ccus-in-clean-energy-transitions.

[2] Medlock, III, Kenneth B. and Keily Miller, "Carbon Capture in Texas: Comparative Advantage in a Low Carbon Portfolio," Working Paper, *Baker Institute Center for Energy Studies*, June 2020. Available online at https://www.bakerinstitute.org/research/carbon-capture-texas-comparative-advantage-low-carbon-portfolio/

Figure 1. State Energy-Related Industrial and Power Generation CO_2 Emissions

Industrial
994 Million Metric Tons CO_2

Power Generation
1729 Million Metric Tons CO_2



Note: the ten states with the highest CO_2 emissions in each sector are specifically identified.

Source: EIA, "2017 State energy-related carbon dioxide emissions by sector," May 2020, https://www.eia.gov/environment/emissions/state/

According to a study from the Great Plains Institute (GPI), 9 million tons of CO_2 are already economically feasible for capture in Texas. With today's technology and the availability of the federal tax credit for CO_2 sequestration provided under Section 45Q of the Internal Revenue Code (45Q), a $10-20 per ton reduction in capture costs would increase total economically feasible capture potential in Texas to an estimated 78 million tons of CO_2.[3] According to GPI, CO_2 storage potential in Texas is estimated at nearly 1.4 trillion tons in saline formations and an additional 4.9 billion tons in enhanced oil recovery (EOR) operations.[4]

Significant geologic storage potential, coupled with a wide talent pool well-versed in the operational and technical demands of the subsurface, give Texas an inherent advantage as it positions its nascent CCUS industry for growth.[5] With many of the

[3] Capture costs differ by industry and facility. Where capture costs exceed $40 per ton, it is likely that additional state support or financing will be needed. See Dane McFarlane, "Regional Carbon Capture Deployment: Texas Gulf and Houston Area," *Great Plains Institute*, February 19, 2020.
[4] Abramson et al, "Transport Infrastructure for Carbon Capture and Storage," *Great Plains Institute*, 19, June 2020.
[5] Medlock, III, Kenneth B. and Keily Miller, "Carbon Capture in Texas: Comparative Advantage in a Low Carbon Portfolio," Working Paper, *Baker Institute Center for Energy Studies*, June 2020.

necessary conditions already in place for the development of a CCUS industry, Texas simply needs to marshal the political will and legislative resources to facilitate action.

In the sections that follow, we outline the CCUS value chain and frame its development as a coordination problem, allowing us to highlight the hindering role that legal, regulatory and commercial encumbrances can play. Next, we introduce and discuss six issues that CCUS industry participants, experts and stakeholders have identified as important to address for expansion of CCUS in Texas. We then present potential pathways for growth of CCUS in Texas, accounting for the location of CO_2 sources, existing infrastructure and potential sequestration sites with a distinct accounting for each of the six issues. We follow with a discussion of CO_2 sequestration supply-demand dynamics before providing recommendations and final remarks.

II. The CCUS Value Chain

A value chain is loosely defined as the steps involved from the development and procurement of raw materials and other product inputs, to manufacture/production, to transport to a market outlet, to final sale/use.[6] The development of a value chain can be viewed as a problem central to coordination theory. One popular example is the prisoner's dilemma.[7] In the case of the prisoner's dilemma, two agents must decide whether to cooperate or act in their own self-interest. If they cooperate, the overall gain is superior to the case where either or both act in their own self-interest. Of course, there is incentive for each agent to act in his or her own self-interest, particularly because there is no prior knowledge of how the other agent will act. In effect, something is needed to tip the scales in favor of coordination, lest a coordination failure may occur yielding an inferior outcome.

Figure 2 indicates three basic components of the CCUS value chain – capture, transport, and use or sequestration.[8] The value proposition at each phase is heavily dependent on each other phase. If one part of the value chain does not move forward, then no part does. In figure 2, each of the agents along the value chain is acting in their own commercial interest. Hence, some signaling needs to occur in the marketplace where agents interact to drive coordination. However, if each agent is confronted with

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[6] See, for example, *Competitive Advantage: Creating and Sustaining Superior Performance* (1985) by Michael E. Porter for a detailed discussion of the value chain concept.

[7] These types of games appear frequently in the economics, sociology and psychology literature. If these types of games are played over and over, the outcome is one in which cooperation becomes the rational outcome specifically because the overall benefit to both players is the superior outcome.

[8] Of course, we could be more specific and address at each phase the subcomponents – such as technology development, project finance, and procurement and installation of equipment – but for the purpose of exposition we will subsume those aspects into the component parts illustrated in figure 2.

barriers to developing their specific part of the value chain, the likelihood of coordination failure increases.

Figure 2. The CCUS Value Chain

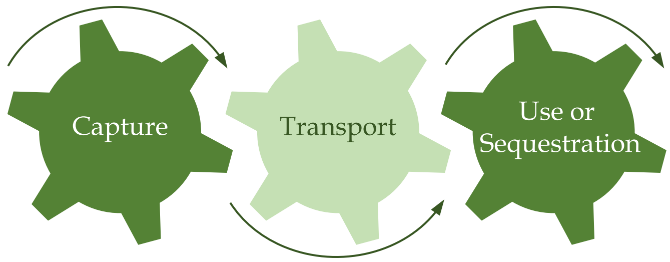


Figure 2 is a very general representation of what is needed for CCUS to occur. It is agnostic to the technology deployed in capture, the type of transport, or whether the captured CO_2 is used in some other process or geologically sequestered. It is very similar to almost any other commodity value chain in that if any single part of the value chain is disrupted or cannot develop due to commercial considerations and/or regulatory/policy burdens, then the entire value chain falls apart. Identifying relevant issues allows the opportunity for them to be appropriately addressed, effectively removing barriers to value chain development.

III. Topics for Consideration in CCUS Value Chain Development

In March 2020, the Center for Energy Studies (CES) at Rice University's Baker Institute collected survey responses from a stakeholder working group comprised of special interest groups, NGOs, academic institutions, and corporations across the energy value chain with an active interest in CCUS.[9] The survey revealed topics that respondents consider important to address, with much of the focus on legal and regulatory issues. Figure 3 presents a heat map of six topic areas that were identified in the survey, including Underground Injection Control (UIC) Class VI primary enforcement authority (i.e.- primacy), pore space access, unitization, eminent domain, liability, and fiscal incentives. To be clear, this list is not meant to be all-inclusive; rather, it captures specific topics that many survey respondents highlighted, each of which is discussed in more detail below.

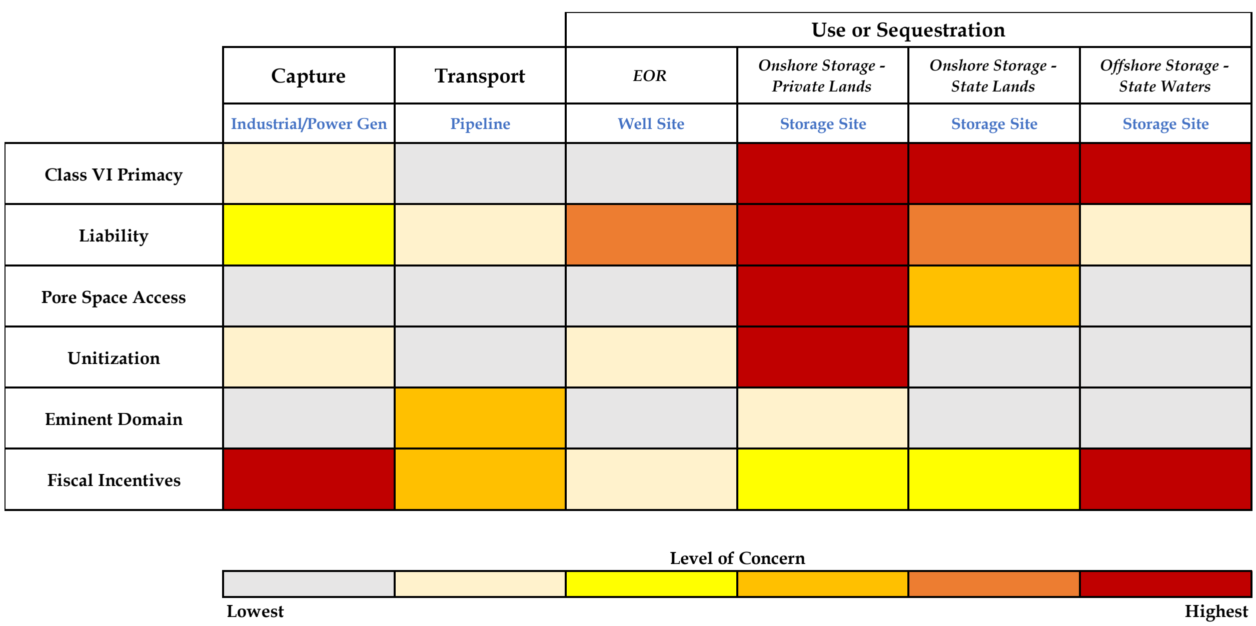
For each activity along the value chain, which is shown horizontally in figure 3 (capture, transport, use or sequestration, the last of which is divided into four types –

[9] Survey results are available in Medlock, Kenneth B. and Keily Miller, "Carbon Capture in Texas: Comparative Advantage in a Low Carbon Portfolio," Working Paper, *Baker Institute Center for Energy Studies*, June 2020. https://www.bakerinstitute.org/research/carbon-capture-texas-comparative-advantage-low-carbon-portfolio/

enhanced oil recovery (EOR), onshore storage in the subsurface on privately-owned lands, onshore storage in the subsurface on state-owned lands, and offshore storage in the subsurface in state waters), an assessment of the level of concern associated with each of the six topic areas, shown vertically, is denoted by color, with darker colors denoting greater concern.

Moving horizontally across figure 3, we see that UIC Class VI primacy tops the list for storage site operators, as Class VI permitting is critical for project finance, DOE loan program support, and full value chain development. In general, respondents expressed varying levels of concern for each of the topics as they affect different parts of the CCUS value chain (capture, transport and use or sequestration). Notably, the resolution of liability entered at virtually every level, to varying extents, as did the addressment of commercial certainty through fiscal incentives. Among the remaining topics, pore space access, particularly on privately-owned lands, was noted, although it was recognized as a matter that could potentially be resolved via contract negotiations between storage site owners/operators and private landowners. On state-owned lands, survey respondents viewed the administration of offshore pore space access as addressed. Finally, it should be recognized that there are cross-cutting aspects for the topics identified in figure 3, insomuch as addressing one (e.g.- pore space access) will affect another (e.g.- unitization).

Figure 3. CCUS Heat Map for Texas



Topic #1: UIC Class VI Primacy

The US Environmental Protection Agency (EPA) oversees UIC program requirements that are in place to protect underground sources of drinking water.[10] CO_2 injection already occurs in Texas for EOR, and it is sourced from naturally occurring formations and industrial activities such as natural gas processing. This type of injection well requires a UIC Class II permit, which is obtained from the Texas Railroad Commission (RRC).[11] When CO_2 injection is to occur for the primary purpose of permanent storage in an underground formation, the injection well requires a UIC Class VI permit from the EPA. States can apply to obtain primacy over Class VI wells, which could, if properly staffed and funded, reduce the time to permit and execute a storage operation. While Texas has primacy for UIC Class I-V wells, it does not yet have primacy for UIC Class VI wells for permanent storage of CO_2.

The issue of primacy is repeatedly named as one of the most important priorities that, if addressed, could advance the CCUS industry in Texas. In a survey administered by the CES in January 2020, two-thirds of survey respondents said the first or second most impactful action to advance CCUS in Texas would be to "enact legislation that directs a state agency to request primacy from the US Environmental Protection Agency (EPA), act as the lead permitting agency for CO_2 injection, and clarify jurisdiction for permitting sequestration sites so that a unifying authority exists to streamline the approval process."[12] Moreover, 80% of respondents ranked it as the first or second most *feasible* policy action available for advancing the CCUS industry in Texas, indicating this may be proverbial "low-hanging fruit."

Senate Bill 1387, which was passed in 2009, directs the Texas Railroad Commission (RRC) to seek primary enforcement authority for geologic storage from the EPA. The EPA's Underground Injection Control (UIC) program regulates six groups – or "classes" – of injection. SB 1387 does not apply to the injection of fluid associated with oil and gas production through a UIC Class II well; rather, it applies strictly to the injection of anthropogenic CO_2 into deep rock formations through a Class VI well. In no uncertain terms, this new statute mandated that "the railroad commission shall seek primacy to administer and enforce the program" for the geologic storage and associated injection of CO_2 that is currently administered and enforced by the EPA, and that the state of Texas

[10] A detailed summary of the UIC program is available at https://www.epa.gov/uic.
[11] The Texas Railroad Commission (RRC) has primacy over UIC Class II wells pursuant to Section 1425 of the Safe Drinking Water Act and the 1982 primacy agreement between the RRC and EPA.
[12] Medlock, Kenneth B. and Keily Miller, "Carbon Capture in Texas: Comparative Advantage in a Low Carbon Portfolio," Working Paper, 8-9, *Baker Institute Center for Energy Studies*, June 2020.

"shall seek primacy to administer and enforce the program for the geologic storage of carbon dioxide in, and the injection of carbon dioxide into, a saline formation."[13]

Why is it, then, that seeking primacy for Class VI injection well permitting still wins the top spot on the priorities lists of so many CCUS stakeholders in Texas eleven years after the passage of SB 1387? To begin, SB 1387 splits the jurisdictional authority for Class VI well permitting between two separate state agencies – the RRC and the Texas Commission on Environmental Quality (TCEQ). Such a jurisdictional split complicates any application to EPA for primacy over Class VI injection wells, which suggests a legislative remedy on jurisdiction could help facilitate a successful application for primacy.

Currently, the RRC has jurisdictional authority over sequestration in saline formations in, directly above, or directly below reservoirs that may be productive of oil, gas or geothermal resources, in the past, present, and potentially in the future, as well as extraction of sequestered CO_2.[14] Meanwhile, TCEQ has jurisdictional authority over geologic storage of CO_2 in deep saline formations not associated with the potential for oil or gas production.

The regulations enacted after the passage of SB 1387 were, in the language of that bill, "subject to the review of the legislature based on the recommendations made in the preliminary report," where the preliminary report was prepared jointly by the RRC, TCEQ, General Land Office (GLO), and the University of Texas Bureau of Economic Geology (UT BEG).[15] The report, which was submitted in 2010, recommended that Texas lawmakers clarify jurisdiction over Class VI well permitting by selecting one of two options: (1) RRC assumes jurisdiction over all CO_2 storage, with TCEQ responsible for an advisory letter; or (2) jurisdiction remains split between the RRC and TCEQ with enactment of additional legislation clarifying criteria for TCEQ permitting and granting TCEQ access to the Anthropogenic Carbon Dioxide Storage Trust Fund, a special fund that SB 1387 established for use by the RRC for long-term monitoring and other activities during the post-closure phase of geologic storage facilities.[16] The report

[13] Added by Acts 2009, 81st Leg., R.S., Ch. 224 (S.B. 1387), Sec. 2, eff. September 1, 2009. TX. SB 1387, https://www.legis.state.tx.us/tlodocs/81R/billtext/html/SB01387F.htm

[14] The regulation states that "the railroad commission has jurisdiction over the geologic storage of carbon dioxide in, and the injection of carbon dioxide into, a reservoir that is initially or may be productive of oil, gas, or geothermal resources or a saline formation directly above or below that reservoir." Tex. Water Code §27.041 (2009), https://statutes.capitol.texas.gov/Docs/WA/htm/WA.27.htm

[15] Texas Water Code §27.041 (2009), https://statutes.capitol.texas.gov/Docs/WA/htm/WA.27.htm

[16] Texas Natural Resources Code §120.003. [Redesignated from Natural Resources Code, Chapter 120 by Acts 2011, 82nd Leg., R.S., Ch. 91 (S.B. 1303), Sec. 27.001(44), eff. September 1, 2011.] https://statutes.capitol.texas.gov/Docs/NR/htm/NR.121.htm#121.003

recommended option (1) – that lawmakers clarify jurisdiction by granting regulatory authority over all CO_2 storage to the RRC.[17]

Topic #2: Long-Term Liability

Liability associated with CO_2 sequestration generally refers to unexpected releases of stored CO_2 due to facility containment failure, damages associated with induced seismic activity, and/or reducing some yet-to-be-defined future value of nearby surface or subsurface rights. Some stakeholders view liability as primarily resolved through the selection of a site that undergoes a rigorous examination and review culminating in agency authorization. The expectation is that sites that meet certain qualifications will be able to demonstrate to the investment community that potential liabilities are understood, properly estimated and financial assurances (in the form of any number of financial instruments such as surety bonds, letters of credit, insurance, self-insurance or escrow accounts) against potential liabilities will be available. Others view a lack of clarity over long-term liability as injecting uncertainty into project evaluation that negatively impacts investment. Conversely, if risks are quantified at arbitrarily low levels, then a classic problem of “moral hazard” can ensue with excessive investment and inadequate safety protocols.

For onshore sequestration sites in Texas, there is no legislation for the transfer of ownership or long-term liability. While SB 1387 established a fund for long-term stewardship of onshore sequestration sites and placed the RRC in charge of the fund, no transfer of ownership or liability is addressed. But, as noted above, liability regimes that arbitrarily absolve liability risks raise a moral hazard that presents risk to the state, landowners and general public that must also be understood and addressed. Absent the emergence of an insurance market or a negotiated transfer of liability, this is an area that may require future attention.

For sequestration sites located in offshore state waters, the rules are different. HB 1796 designated that the Land Commissioner of the GLO contract the Bureau of Economic Geology at the University of Texas (UT-BEG) to identify suitable locations for permanent storage of CO_2, so site characterization work has been completed. HB 1796 also designated the School Land Board as the final determinant of suitable locations for CO_2 storage upon receiving recommendations from the Land Commissioner. At that point, the School Land Board has authority to contract for infrastructure development and operation of the site. Once operational, the School Land Board has authority to set

[17] See “Injection and Geologic Storage Regulation of Anthropogenic Carbon Dioxide: A Preliminary Joint Report by The Texas General Land Office, The Railroad Commission of Texas, The Texas Commission on Environmental Quality, in Consultation with The Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin” (1 December 2010).

fees for storage, with UT-BEG acting as scientific advisor with an obligation to provide data on measurement, monitoring and verification of stored CO_2.

The steps delineated in HB 1796 regarding site characterization and determination, administration of site fees, and data collection are all important prerequisites for the handling of ownership and liability of stored CO_2. Specifically, HB 1796 designates that the School Land Board will take title to stored CO_2 when permanent storage has been verified and all requirements are met for site closure. Moreover, on the date that occurs, HB 1796 relieves the *producer* of the CO_2 of liability, and provides that storage operators retain responsibility for the sites they operate.

To be clear, there has been a wide diversity of opinion expressed on this among industry and environmental groups. In general, no consensus exists about how to govern liability post-site closure. Some view it as an area that can be resolved through a combination of technical expertise and available financial instruments. Among those that view it as a concern, there is some agreement that its addressment is important for mitigating uncertainties facing a nascent CCUS industry. In either case, reasonable assessments of liability must be internalized by project developers to promote the efficient level of investment. Hence, liability management is an area that will likely need to be addressed. Absent a legislative approach to the transfer of liability on state or private lands, it is reasonable to expect that some risk-sharing would be negotiated through private agreements between commercial participants and that that some risks would be alleviated or even eliminated through negotiation of private agreements with the owners of relevant property rights impacted by injection operations. This may or may not prove to be a sticking point in the advancement of CCUS. At a minimum, requirements for sufficient data reporting and long-term monitoring of injected CO_2 provides transparency and can resolve some uncertainties associated with liability, but that is merely one step.[18]

Topic #3: Pore Space Access

Answers to questions about securing the requisite interest in pore space were identified by some working group members as needing clarity.[19] Unlike a few other states, Texas has not by legislation or adjudication directly addressed the question of pore space

[18] Indeed, the preliminary joint report by the RRC, TCEQ, GLO, and UT BEG suggested regulations that "require adequate data to allow regulators to predict the activity of the CO_2 plume when the project enters into the post-operational phase." See "Injection and Geologic Storage Regulation of Anthropogenic Carbon Dioxide: A Preliminary Joint Report by The Texas General Land Office, The Railroad Commission of Texas, The Texas Commission on Environmental Quality, in Consultation with The Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin" (1 December 2010).
[19] Although phrased as a question of pore space, a storage project would necessarily also need to ensure that injected CO_2 could not be lost should a third party compromise an overlying confining layer.

access for CCUS.[20] Consequently, the question of how to legally secure rights to access and use pore space could serve as an impediment to broader CCUS deployment.

Where there is no mineral estate, the surface estate owns the land in fee simple, including not only the surface but the underlying matrix of earth. In Texas, the current prevailing view is that a sequestration project would need to negotiate an agreement with the surface owner, and possibly adjacent surface owners, to secure interest in pore space sufficient for the volume of CO_2 injected and to accommodate movement of the CO_2 plume in the subsurface. Such an approach is well understood. However, this could prove to be burdensome and lead to suitable sequestration sites remaining unused, particularly if the involved parties cannot reach agreement on the value of a property's pore space.

Where a mineral estate has been severed from the surface estate, which is commonly encountered in areas of Texas with suitable storage sites, questions of access to pore space must also consider the dominance of the mineral estate. The mineral estate will have a right to use as much of the surface and subsurface as is reasonably necessary to recover its minerals. Further, EOR operations necessarily take place in formations that are well-suited for CO_2 sequestration and often are subject to the terms of a unit agreement and unit operating agreement that could convey the requisite interest in the pore space (and control of overlying formations that serve as confining layers) for sequestration.

Whether or not a severed mineral estate exists, potential issues can arise, including intended (or competing) use and subsurface trespass – that can impede sequestration project investment.

(1) Intended (or competing) use: Once injection of CO_2 into a subsurface formation or deep saline aquifer commences, the presence of the injected gas can preclude other "competing" uses of the subsurface (e.g.- oil and gas extraction, natural gas storage or waste disposal) or potentially add cost to future extraction activities (e.g.- cost associated with separation and reinjection of previously stored CO_2 in a deep saline aquifer in the future).

[20] The Texas Supreme Court has considered the question of rights to possess the specific place or space where minerals are located in the context of offsite surface use and horizontal drilling. *Lightning Oil Co. v. Anadarko E&P Onshore, LLC*, 520 S.W.3d 39 (Tex. 2017). Importantly, the court opined that "[t]he accommodation doctrine has long 'provided a sound and workable basis for resolving conflicts' between owners of mineral and surface estates that allows the mineral owner to use as much of the surface – and subsurface – as is reasonably necessary to recover its minerals" (citing Coyote Lake Ranch, LLC v. City of Lubbock, 498 S.W.3d 53 (Tex. 2016), a case applying the accommodation doctrine outside of the typical oil and gas application to a dispute between a surface owner and owner of a severed groundwater estate). Balancing the longstanding policy of Texas to encourage maximum recovery of minerals and to minimize waste, the *Lightning* court rejected a claim of trespass.

(2) Subsurface trespass: With land ownership in the US divided into many separate, privately-owned tracts, ownership rights in a single reservoir can often belong to many different owners. Therefore, CO_2 that is injected in one location then migrates through the subsurface to another location can potentially constitute trespass, at least where the injector has not obtained appropriate rights to the subsurface from the owners of the relevant property rights.[21] The parameters of subsurface trespass remain unsettled in Texas. For example, in *Lightning v. Anadarko*, the Texas Supreme Court, balancing a longstanding policy that encourages maximum recovery of minerals while minimizing waste against the small potentially recoverable damages, rejected a claim for trespass when Anadarko drilled a well through Lightning's mineral estate.[22] In another context, FPL Farming[23] illustrates that it can sometimes be difficult for a landowner to prove actual injury from deep subsurface wastewater migration, and there remains some question as to whom an actionable trespass claim accrues where deep saline aquifer formations are used for sequestration because of the usufructuary nature of the rights to groundwater in Texas. Of course, CO_2 is distinguishable from injected produced water, and how the court might consider a trespass claim in a CO_2 sequestration case is uncertain.

According to the findings of a 2010 report required by SB 1387, the consensus among various Texas state agencies on the pore space question is that because Texas statutory law does not specify which estate owns the pore space for storage purposes, "adjacent property owners may bring a trespass action if they can demonstrate reasonable and foreseeable damages caused by unauthorized use of their pore space."[24,25] Hence, to secure interest in pore space sufficient for a storage project, an operator may choose to negotiate with multiple landowners, mineral owners and lessees to obtain the legal

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[21] Joseph A. Schremmer (2020). Getting Past Possession: Subsurface Property Disputes as Nuisances. 95 Washington Law Review 315, 34. Note, while Schremmer reports that CO_2 could migrate significant distances, such subsurface behavior is highly formation dependent - Texas has numerous formations that can be managed to maintain CO_2 within certain delineated boundaries.

[22] *Lightning Oil Co. v. Anadarko E&P Onshore, LLC*, 520 S.W.3d 39 (Tex. 2017).

[23] *See FPL Farming Ltd. v. Environmental Processing Systems, L.C.*, 351 S.W.3d 306, 313-14 (Tex. 2011) and *Environmental Processing Systems, L.C. v. FPL Farming Ltd.*, 457 S.W.3d 414, 426 (Tex. 2015).

[24] Injection and Geologic Storage Regulation of Anthropogenic Carbon Dioxide: A Preliminary Joint Report by The Texas General Land Office, The Railroad Commission of Texas, The Texas Commission on Environmental Quality, in Consultation with The Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin (1 December 2010).

[25] R.R. Comm'n of Tex. v. Manziel, 361 S.W.2d 560, 568 (Tex. 1962).; Mission Res., Inc. v. Garza Energy Trust, 166 S.W.3d 301, 310 (Tex. App.—Corpus Christi 2005, review granted).

right to use all of the affected pore space and avoid any risk of liability for trespassing or nuisance.[26]

A few states have passed unitization statutes to aggregate pore space and thus resolve this issue (see Appendix for more on what other states have done). State agencies in Texas have concluded that a regulatory program for geologic storage of CO_2 would "benefit from clear rules about how these rights will be recognized and protected, as well as a process for assuring that the storer secures the legal property right to store carbon dioxide."[27]

Topic #4: Unitization

The underlying principle of compulsory unitization – and the basis for understanding the recent actions that several states have taken to introduce compulsory unitization for CO_2 storage – is that by aggregating pore space, no single interest owner within a desired project area could block the development of a project. Although unitization is widely used in Texas, it is not compulsory and therefore requires negotiation. Leases not included in a unit plan must be administered independently and the production accounted for as if that portion of the reservoir were not in the unit. Only in Texas is EOR production of older, nearly depleted fields limited by the requirement to have 100% of the working, mineral and royalty interest owners' ratifications of the unit. Consequently, EOR sites can be prime candidates for CO_2 sequestration depending on the terms of an existing unit agreement and unit operating agreement and because parties have already reached a previous agreement.

Compulsory unitization can add a layer of certainty to project investments and establishes a clear regulatory framework for assigning, transferring and possibly severing the ownership of pore space.[28] However, compulsory unitization is an issue rife with contention in Texas. Trying to compel property owners to relinquish property rights in Texas is anathema to many in the policymaking and business arenas alike, and such attempts can easily unleash a slew of skirmishes and political wrangling. Nevertheless, because a single property owner could decline to reach an agreement on reasonable terms, thereby preventing sequestration at a suitable site, unitization within

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[26] R Lee Gresham & Anderson, "Legal and Commercial Models for Pore Space Access and Use for Geologic Storage of CO2 Sequestration," *University of Pittsburgh Law Review*, Vol. 72 No. 4, 2011 (https://doi.org/10.5195/lawreview.2011.170)

[27] "Injection and Geologic Storage Regulation of Anthropogenic Carbon Dioxide: A Preliminary Joint Report by The Texas General Land Office," The Railroad Commission of Texas, The Texas Commission on Environmental Quality, in Consultation with The Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin (1 December 2010), 64

[28] Audrey Marie Rozsypal (2011), "Aggregating Pore Space Ownership for Geologic Sequestration of CO_2." Ph.D. Thesis, UT Austin. https://repositories.lib.utexas.edu/bitstream/handle/2152/ETD-UT-2011-05-3565/ROZSYPAL-THESIS.pdf?sequence=1&isAllowed=y

the strict context of geologic storage of CO_2 might well be an issue worth revisiting. It is not yet known whether a compulsory unitization bill could garner widespread support in Texas if the scope of such a bill were restricted exclusively to geologic storage of CO_2 (not oil & gas operations) and carefully addressed provisions such as conflicting use, compensation and lien provisions.

Topic #5: Eminent Domain

Eminent domain refers to the right of governments to expropriate private property, with compensation, for public use or benefit. Common examples include airspace and private land for roads and highways. With regard to energy, the principle can be applied to infrastructure, such as oil and gas pipelines, railways, and electric transmission, but rarely is it done without conflict. In general, it is incumbent on the government to make a sufficient public benefit argument for eminent domain to be exercised.

With regard to pipelines in Texas, the path to eminent domain is relatively straightforward. Pipeline operators can obtain "common carrier" status if a pipeline facility is used to transport commodity for more than just own use, which conveys a broader beneficial use of the facility. Once a pipeline is designated common carrier status, it can exercise eminent domain to secure access to rights of way on private lands. Of course, the pipeline company has an obligation to pay affected landowners fair market value for the captured land, but common carrier status makes pipeline permitting and construction easier.

For CO_2 pipelines, the path to eminent domain appears equally as straightforward as confirmed by the Texas Supreme Court's 2017 ruling in Texas Rice II.[29] Some working group members view the Texas Rice II decision as confirming that the question of eminent domain turns on a demonstration of a reasonable probability that, at some point after construction, a pipeline will serve the public by transporting CO_2 for one or more customers who will either retain ownership of their gas or sell it to parties other than the pipeline carrier. Other working group members expressed concern that should CO_2 be designated as a waste product, there may be some uncertainty as to whether customers using the pipeline will retain ownership or would be construed as selling CO_2 that was designated for disposal. Under this second scenario, the transport of bulk waste via pipeline may not satisfy the public use or benefit criteria required to receive common carrier status.

Eminent domain does not stop with pipeline citing. It is also relevant for pore space access for long term CO_2 storage. In fact, states such as Indiana and Louisiana have

[29] Denbury Green Pipeline Tex., LLC v. Tex. Rice Land Partners, Ltd., 2017 WL 65470 (Tex. 2017) (Texas Rice II).

already enacted legislation governing the process by which eminent domain can be exercised for pore space access.[30] The working group convened by the Baker Institute, however, did not identify this as an area of concern for advancement of CCUS in Texas.

Topic #6: Fiscal Incentives

In general, federal, state and local fiscal incentives, when applied to any part of the value chain, have stimulatory effects for all parts of the value chain. Fiscal incentives improve the commercial prospects for full value chain development. The federal tax credit for CO_2 sequestration (Section 45Q of the Internal Revenue Code), originally established in 2008, was extended and expanded by the Bipartisan Budget Act of 2018. 45Q is often touted as the most progressive CCUS-specific incentive that exists globally.[31] It provides a monetary credit per metric ton of qualified CO_2 that is captured and sequestered. Depending on when the qualifying capture equipment was placed in service, projects can be eligible to receive as much as \$50/ton CO_2 for permanent geologic storage and \$35/ton CO_2 for EOR.[32]

The Bipartisan Budget Act of 2018 introduced significant enhancements to qualifying credits – in both magnitude and scope – but the new law also stipulated the end of 2023 as a start-of-construction deadline for eligible projects to qualify for the credit. During the working group deliberations, concern was raised that the end-2023 date was too nearby given the long lead times associated with large-scale project development, thus rendering 45Q largely inaccessible to newer projects still seeking permits for development.[33] However, in December 2020, new legislation extended the date for start of construction to January 2026. Nevertheless, several working group members noted that the scale of carbon capture project development needed to significantly reduce CO_2 emissions means there will be a need for continued investment beyond January 2026. Moreover, project developers grappling with state and local legal and regulatory uncertainties may still be unable to benefit from the recent extension to January 2026, thus rendering the fiscal incentive fallow. A further extension of the construction start date for 45Q would provide a fiscal incentive that is magnified as legal and regulatory uncertainties are addressed in upcoming state legislative sessions, which could trigger

[30] See Appendix ("Eminent Domain Legislation for Subsurface Storage in Other States") for information on legislation outside of Texas. See also Indiana Senate Bill 442 (2019); Louisiana House Bill 661 (2009).
[31] Lee Beck, "The US Section 45Q Tax Credit for Carbon Oxide Sequestration: An Update," *Global CCS Institute*, Apr 2020, https://www.globalccsinstitute.com/wp-content/uploads/2020/04/45Q_Brief_in_template_LLB.pdf
[32] Jones, Angela and Molly Sherlock, "The Tax Credit for Carbon Sequestration (Section 45Q)," *Congressional Research Service*, IF11455, Version 1, March 2020, https://fas.org/sgp/crs/misc/IF11455.pdf
[33] King et al, "Opportunities for Advancing Industrial Carbon Capture," *Rhodium Group*, September 2020, https://rhg.com/research/industrial-carbon-capture/

broad use of tax equity finance measures for CCUS similar to those deployed in the financing of large-scale wind generation projects.

It should be noted that 45Q alone does not necessarily provide sufficient commercial certainty for CCUS projects to move forward. For CCUS deployment to realize its full potential, additional measures may be needed. To be clear, the federal tax credit is an excellent first step, and its effectiveness increases when working in tandem with local and state policies that can offer incentives that are tailored to the local context. For this reason, it may be necessary for states to provide supplemental forms of fiscal support. There are many levers that the state of Texas and local municipalities can pull to encourage investment in CCUS projects. For instance, the Center for Climate and Energy Solutions tracks the range of policy options that states have been adopted in the US, including:[34]

- **Direct Financial Assistance** such as grants or loans to CCUS projects and/or CO_2 pipelines
- **Tax Incentives** for EOR and geologic storage, such as reduced corporate income taxes, reduced severance taxes, or property and sales tax exemptions
- **Off-Take Agreements** guaranteeing that utilities purchase electricity from power plants with carbon capture technology
- **A Utility Cost Recovery Mechanism** authorizing utilities to pass on the costs of carbon capture technology to ratepayers; and
- **A Clean Energy Standard** that counts carbon capture technology as eligible towards state generation portfolio standards or voluntary goals.

Lawmakers in Texas have, heretofore, focused on providing support in very targeted ways to support specific projects in the form of direct financial assistance or through tax incentives. In 2007, HB 3732 introduced a grant and loan program to help finance advanced clean energy projects, such as coal-fired power plants with carbon capture technology.[35] Two years later, the passage of HB 469 established incentives in the form of tax credits of up to $100 million for the first three carbon-fueled power plants that could produce at least 200 megawatts of power and sequester at least 70 percent of CO_2 emissions.[36] The bill also authorized a 30-year severance tax reduction for oil producers deploying EOR using CO_2 captured by a qualifying clean energy project.

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[34] US State Energy Financial Incentives for CCS, *Center for Climate and Energy Solutions,* February 2019, https://www.c2es.org/document/energy-financial-incentives-for-ccs/

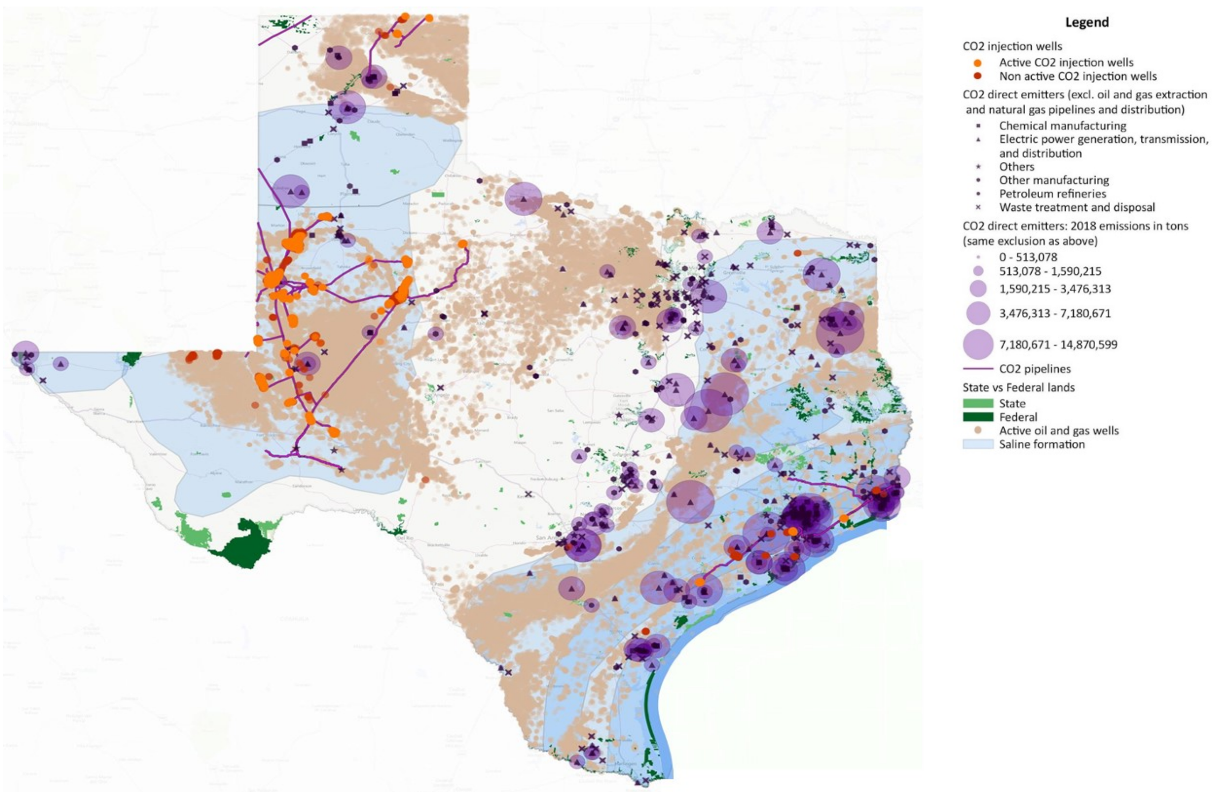
[35] Tx HB 3732, http://www.legis.state.tx.us/tlodocs/80R/billtext/pdf/HB03732F.pdf#navpanes=0

[36] Tx HB 469, http://www.legis.state.tx.us/tlodocs/81R/billtext/html/HB00469F.HTM

IV. Mapping the CCUS opportunity across the state of Texas

Texas has a unique opportunity to expand deployment of carbon capture technologies owing to its comparative advantages in industrial scale, geologic endowment, and human capital footprint.[37] As depicted in figure 4, there is significant oil and gas production activity owing to the rich geology in the state, existing CO_2 pipeline infrastructure, active CO_2 injection wells, and robust sources of CO_2 emissions, all of which are key ingredients for the full-scale development of a CCUS value chain. The opportunity is not, however, equally distributed across the state.

Figure 4. The Carbon Capture Landscape in Texas



Data sources: Data and shapefiles (with sources in parentheses) used in mapping are CO_2 injection wells and active oil and gas wells (DrillingInfo), CO_2 direct emitters by industry and emissions (EPA), CO_2 pipelines (Texas RRC), State versus Federal Lands (Texas Parks and Wildlife), Subsurface saline formations (NATCARB)

In general, certain institutional, legal and regulatory factors, legacy infrastructure considerations, and the prevalence of state and federal lands all impact the feasibility of expanded CCUS activities. In Texas, the evolution of CCUS across the state will likely

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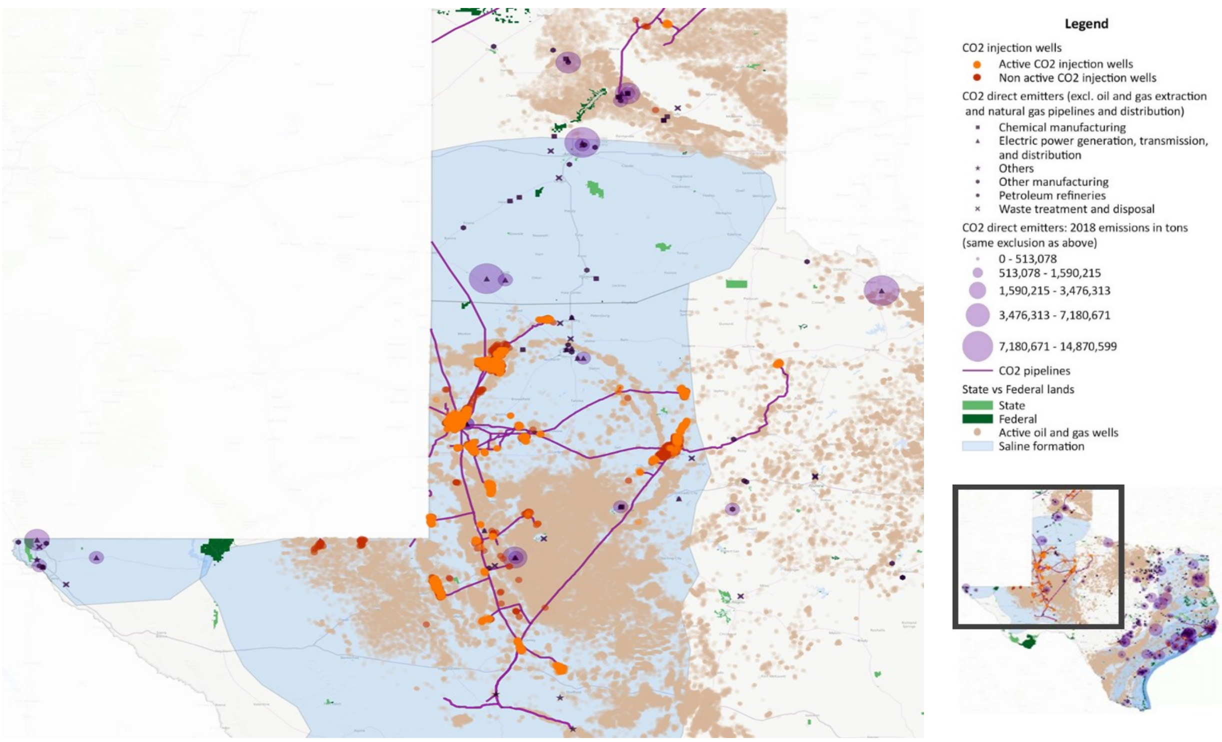
[37] See https://www.bakerinstitute.org/research/carbon-capture-texas-comparative-advantage-low-carbon-portfolio/.

be on a regional basis until significant price differentials begin to emerge, thereby incentivizing the development of infrastructure in order to arbitrage price differentials.[38] In what follows, we consider three regions – West, Northeast and Gulf Coast – where the Gulf Coast region here includes South and Central Texas.

In West Texas there is already existing pipeline infrastructure to move CO_2 to active injection wells (see figure 5). That activity is geared toward EOR. CO_2 is primarily sourced from active oil and gas operations, such as CO_2 that is captured at processing facilities, or CO_2 that is piped in from outside the state of Texas, largely sourced from naturally occurring geologic formations.

Figure 5. The Carbon Capture Landscape in West Texas



Data sources: Data and shapefiles (with sources in parentheses) used in mapping are CO_2 injection wells and active oil and gas wells (DrillingInfo), CO_2 direct emitters by industry and emissions (EPA), CO_2 pipelines (Texas RRC), State versus Federal Lands (Texas Parks and Wildlife), Subsurface saline formations (NATCARB)

A recent National Petroleum Council (NPC) study puts the total amount of CO_2 from anthropogenic sources injected for EOR activities at 17 million metric tons per annum

[38] This is how the electricity market and transmission infrastructure in Texas developed.

(MMTPA).[39] In a topic paper published in companion to the NPC report, Brown and Ung (2019) note the relatively elastic influence that oil prices have on the commercial prospects for CO_2 injection for EOR. Accordingly, they estimate the total amount of CO_2 injected for EOR could rise as high as 200 MMTPA across the entire US.[40] Other analysis conducted on behalf of the Regional Carbon Capture Deployment Initiative puts this number as high as 262 MMPTA.[41] Both estimates represent a sizeable step towards reducing net CO_2 emissions in the US, and neither addresses the added potential that CO_2 injection via UIC Class VI wells into permanent storage represents.

Shifting focus to the Gulf Coast, we see a different landscape for carbon capture (see figure 6). To begin, there is an abundance of large industrial sources of CO_2 emissions. Notably, connecting those sources to potential sequestration sites in West Texas would require significant new long-distance pipeline infrastructure, which can add cost to the entire value chain. There is also some existing CO_2 pipeline infrastructure that carried captured CO_2 from the (now mothballed) Petra Nova power plant for regional EOR activities.[42] However, in comparison to West Texas, there is a much less infrastructure to transport and inject CO_2 across the region.

Despite this, the potential for long-term storage in the Gulf Coast is robust. In particular, geography provides an opportunity that has not yet been tapped as there is significant storage potential in deep saline aquifer formations in the subsurface of state offshore waters. The Gulf Coast Carbon Center of UT-BEG has done extensive characterization of CO_2 sequestration potential in the State of Texas. According to the latest assessment, prospective storage resources in the subsurface of state offshore waters total an estimated 172 billion metric tons[43] a resource large enough to store all of Texas' industrial CO_2 emissions for the next 700 years based on 2017 emissions rates.[44]

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[39] "Chapter Eight: CO2 Enhanced Oil Recovery." Part of the NPC Study, *Meeting the Dual Challenge: A Roadmap to At-Scale Development of Carbon Capture, Use and Storage* (December 2019), 8-5. Available at https://dualchallenge.npc.org/files/CCUS-Chap_8-072220.pdf

[40] See Brown, Jeffrey D. and Ung, Poh Boon, "Supply and Demand Analysis for Capture and Storage of Anthropogenic Carbon Dioxide in the Central U.S." (Dec 12, 2019) Working Document available online at https://dualchallenge.npc.org/.

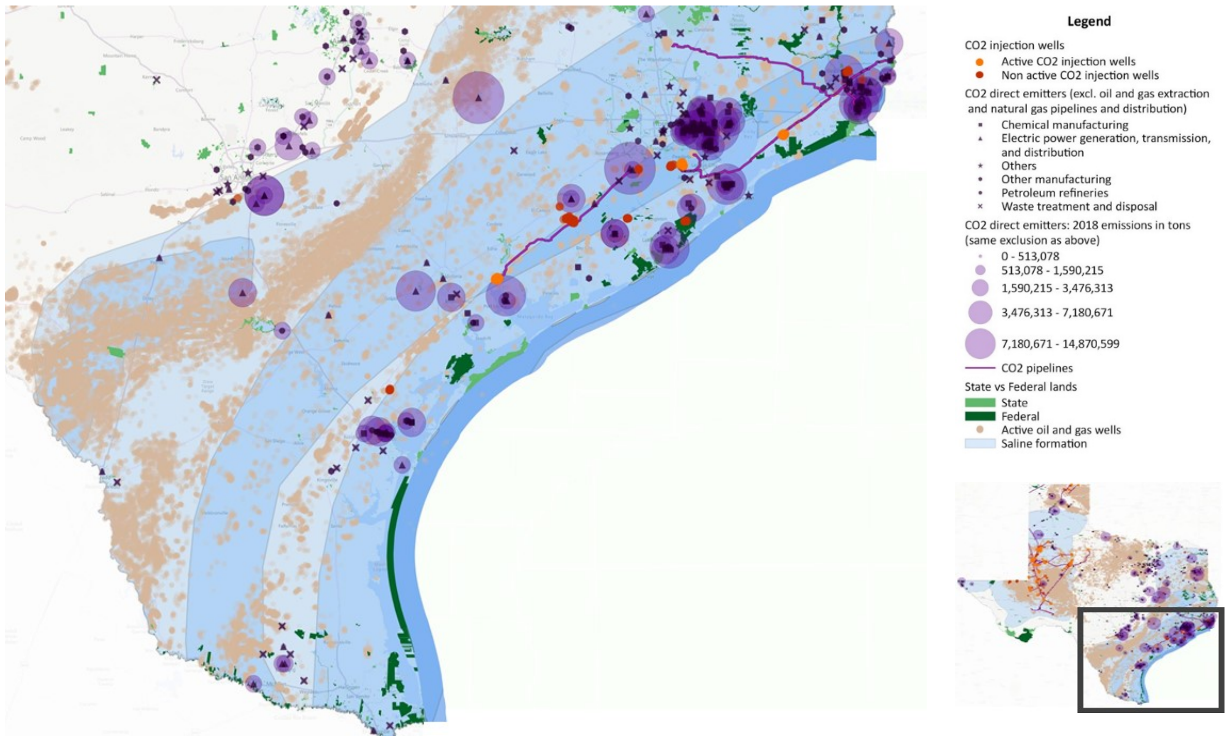
[41] Abramson, McFarlane and Brown, "Transport Infrastructure for Carbon Capture and Storage," analysis conducted on behalf of the Regional Carbon Capture Deployment Initiative (June 2020), 34.

[42] Notably, this project was "mothballed" recently due to low oil prices, which highlights a commercial risk associated with CO_2 for EOR, but the operations can resume in a better commercial environment.

[43] Meckel, Hovorka and Trevino, "GoMCARB Update," *University of Texas Bureau of Economic Geology*, presented at the 4th International Workshop on Offshore Geologic CO_2 Storage (University of Bergen, Norway, February 11-12, 2020). Available at https://www.beg.utexas.edu/files/gccc/media/4th%20international%20workshop%20on%20offshore%20geologic%20co2%20storage/20_0212_Tip%20Meckel%20GoMCARB%20Update.pdf

[44] "2017 State energy-related carbon dioxide emissions by sector," *US Energy Information Administration* (May 2020), available at https://www.eia.gov/environment/emissions/state/

Figure 6. The Carbon Capture Landscape in the Gulf Coast, Central and South Texas



Data sources: Data and shapefiles (with sources in parentheses) used in mapping are CO_2 injection wells and active oil and gas wells (DrillingInfo), CO_2 direct emitters by industry and emissions (EPA), CO_2 pipelines (Texas RRC), State versus Federal Lands (Texas Parks and Wildlife), Subsurface saline formations (NATCARB)

One area of potential uncertainty regarding CO_2 storage in offshore state waters involves the Marine Protection, Research, and Sanctuaries Act (MPRSA), also known as the Ocean Dumping Act. It has been suggested that subsurface injection of CO_2 within 12 nautical miles of the US coast is included under the MPRSA, which would include state waters, especially if CO_2 to be stored is classified as industrial waste.[45] Moreover, the potential for CO_2 plume migration into the subsurface pore space of federal offshore acreage may have to be addressed. However, there is ambiguity on this front.[46]

Finally, shifting focus to Northeast Texas (see figure 7), we see, yet again, a different landscape for CCUS. While the region has some sizable CO_2 emission sources, it lacks

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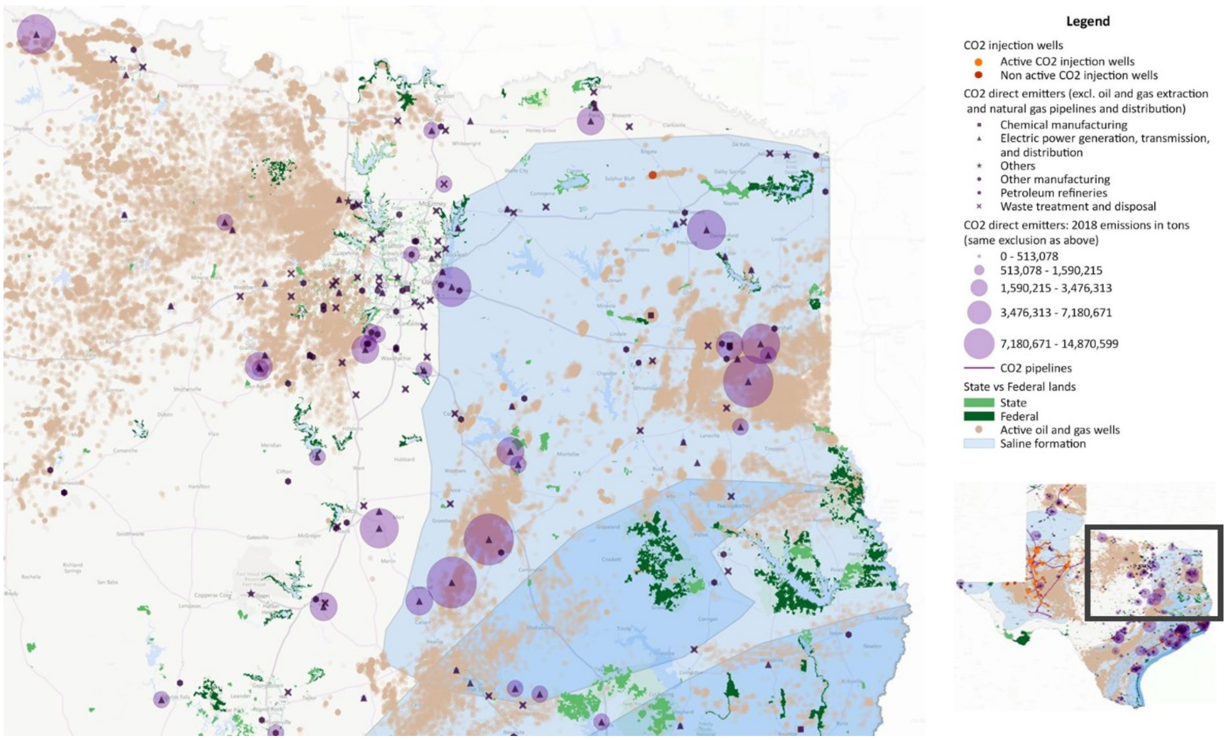
[45] Webb, Romany M. and Michael B. Gerrard, "Overcoming Impediments to Offshore Carbon Dioxide Storage: Legal Issues in the US and Canada," *Sabin Center for Climate Change Law (Columbia Law School)*, March 2019, http://columbiaclimatelaw.com/files/2019/03/Webb-Gerrard-2019-03-Offshore-Carbon-Dioxide-Storage.pdf

[46] Webb, Romany M. and Michael B. Gerrard (2018), "Sequestering Carbon Dioxide Undersea in the Atlantic: Legal Problems and Solutions," *UCLA Journal of Environmental Law and Policy*, 36(1), https://escholarship.org/uc/item/8wz8f131

any infrastructure to capture, transport and use or store CO_2. There is significant oil and gas production in the region, so opportunities could exist for EOR, but any movement in that direction would be an entirely greenfield effort to develop the full CCUS value chain – from capture to transport to injection. In addition, there is significant intersection between saline aquifer formations, oil and gas producing wells, and state and federal lands, which can present an encumbrance to scaling CCUS.

Figure 7. The Carbon Capture Landscape in Northeast Texas



Data sources: Data and shapefiles (with sources in parentheses) used in mapping are CO_2 injection wells and active oil and gas wells (DrillingInfo), CO_2 direct emitters by industry and emissions (EPA), CO_2 pipelines (Texas RRC), State versus Federal Lands (Texas Parks and Wildlife), Subsurface saline formations (NATCARB)

Analysis of the three regions, as outlined, in Texas indicates that there may be distinctly different pathways associated with scaling CCUS – onshore CO_2 with EOR, onshore long-term storage in saline aquifers, and offshore long-term storage in saline aquifers. Each pathway carries its own set of challenges, varying across legal, regulatory and commercial uncertainties. Nevertheless, if we collectively account for the full scale and scope of the Texas potential for CO_2 use and storage – (1) CO_2 for EOR, (2) long-term storage of CO_2 in saline aquifers onshore and offshore, and (3) alternative uses of CO_2 in other industrial processes or for advanced materials – the scale could be massive. Of course, the value chain for each option is distinctly different, involving different technologies (e.g.- CO_2 for cement, or pyrolysis combustion of hydrocarbons to generate hydrogen and carbon black, the latter of which can be a feedstock for a variety of carbon-based materials) with different time scales to feasibility, or different regulatory and permitting requirements (e.g.– Class VI injection wells for long-term storage as opposed to Class II injection wells for EOR).

V. Considering CCUS Pathways in Texas

The primary pathways for sequestering CO_2 in Texas that are eminently available include onshore sequestration via EOR, injection for permanent storage in the subsurface of onshore privately-owned and state-owned lands, and injection for permanent storage in the subsurface of offshore state waters. The CCUS value chain is an evolving space in Texas. Beginning with EOR as an "on-ramp" for carbon capture, the value chain will continue to expand and evolves towards onshore and offshore injection for long-term storage.

EOR

The appeal of EOR as a pathway to CCUS deployment in Texas stems from the intrinsic economic advantage it holds. The production revenues generated from EOR operations help to offset the costs of capture and infrastructure along the CCUS value chain. In addition, the passage of HB 3732 in 2007 established a reduced tax rate for producers of oil recovered by EOR through CO_2 injection.[47] Moreover, there is no ambiguity as to the primary enforcement authority; the RRC has jurisdiction over sequestration with EOR.

From a commercial standpoint, the price of oil represents a major uncertainty, and the costs of capture and transport are critical for the economic feasibility of a CO_2 driven EOR project. Much of the legacy CO_2 infrastructure in the Permian Basin was developed to move CO_2 from formations in Colorado and New Mexico and was stimulated through tax incentives specifically targeted at EOR. With the introduction of 45Q, which exclusively targets anthropogenic CO_2, the new provisions on the fiscal front aid commercial certainty that can make captured CO_2 more competitive relative to legacy CO_2 sources.[48] In a region teeming with oil, gas and CO_2 injection wells, EOR projects in West Texas currently rely on sources of CO_2 from outside the region, which

[47] Tax Code, §202.0545, Tax Exemption for Enhanced Recovery Projects Using Anthropogenic Carbon Dioxide) (Title 16 Chapter 5, Subchapter C.)

[48] Moreover, subject to feasibility, it could even eventually incentivize injection of CO_2 for storage in the naturally occurring formations that have been drawn down to supply EOR activities. By reversing compression on existing CO_2 pipelines from natural formations, CO_2 could be injected and stored in those natural formations. Such an approach leverages existing EOR infrastructure and provides a pathway for permanent storage. It also enables eligibility to receive a tax credit through 45Q in the amount of $50 per ton instead of $35 per ton. In addition, the knowledge that these formations have successfully stored CO_2 for thousands of years could lessen concerns about long-term liability.

is handled by adequate legacy infrastructure connecting nearby naturally occurring sources of CO_2. In addition, EOR activities in West Texas occur in voluntary units subject to existing unit agreements and unit operating agreements that may include provisions providing a field operator with a right to use the pore space, even if only incident to oil and gas production. Altogether, the prospect of expanding EOR activities in West Texas looks very promising, all else equal.

The Gulf Coast region, while similar to West Texas in that it has a large number of nearby active oil and gas fields, stands in contrast on other fronts – it hosts a high local concentration of large CO_2 emissions sources, has much less legacy infrastructure to move captured CO_2 to points of potential injection, and is not nearby sources of naturally occurring CO_2. So, ramping up EOR activities would require investment in capture facilities and pipelines to transport the capture CO_2. Indeed, the sizeable sources of CO_2 in the Gulf Coast could potentially feed EOR in West Texas, provided long haul pipelines could be developed.

Northeast Texas stands in contrast to the rest of the state, and in many ways can be viewed as a hybrid of West Texas and the Gulf Coast. To begin, there is active oil and gas drilling activity in the region, just as in the other two regions. But there is no active CO_2 injection for EOR. Like the Gulf Coast, there are also large sources of CO_2 emissions that could provide opportunities for scale economies in the capture phase of the CCUS value chain. However, there is no CO_2 pipeline infrastructure. Altogether, even for EOR activity, Northeast Texas would be a purely greenfield activity as there is no existing legacy backbone infrastructure from which to grow a CCUS value chain.

Onshore Saline Aquifer Injection

For onshore sequestration projects that do not involve EOR, the administrative and financial difficulties of carbon sequestration tend to escalate (recall figure 3). According to a recent study published by GPI, the economic feasibility of onshore saline aquifer injection is limited to only a couple of locations across the state.[49] Onshore sequestration projects involving saline injection face legal and regulatory uncertainties that may include primacy, pore space access, and long-term liability in addition to the fiscal and commercial challenges of developing a full greenfield CCUS value chain.

(1) ***Primacy.*** Unlike with EOR projects where CO_2 injection wells are permitted as Class II, CO_2 injection wells for permanent storage in saline aquifers are permitted as Class VI wells. Given the overlap of saline formations and of oil and gas bearing formations throughout the state (see Figure 2), the question of

[49] Dane McFarlane, "Regional Carbon Capture Deployment: Texas Gulf and Houston Area," *Great Plains Institute*, 10, February 19, 2020.

whether jurisdiction for primary enforcement belongs to the RRC, TCEQ or both remains to be answered, and could be clarified through legislative action.

(2) ***Pore Space Access.*** Access to pore space can present a concern for storage operators, since no clear legislative or regulatory process currently exists for assuring that the storer secures the requisite property interest to store CO_2 beneath private lands in Texas. Historically, this issue has been addressed through private agreements between an injector/operator and the owner of a surface estate. With geologic sequestration, however, the horizontal extent of injected CO_2 plumes can present the storage operator with a series of negotiations with the surface owner and adjacent surface owners overlying the predicted CO_2 pressure front, with the goal of securing the legal property right to use the pore space and reduce or eliminate the minimal risk of trespass or nuisance claims later on. Where negotiated property rights would be impractical, legislative efforts may be helpful in the future to facilitate an injector obtaining requisite property rights, but legislation recently introduced in other states to clarify pore space access and aggregation in other states – and particularly in North Dakota – has proven contentious (see Appendix).

(3) ***Long-Term Liability.*** In addition to potential exposure by the storage operator to compensable trespass and nuisance liability, in the absence of negotiated surface use rights, long-term liability can be difficult to quantify and thus may present a substantial risk for project finance. Some stakeholders believe that properly selected sites subjected to a rigorous examination and review culminating in agency authorization can largely ameliorate liability concerns – and certainly make them easier to secure financial instruments against any risk. Other stakeholders believe that in the absence of a provision – either legislated or negotiated – that sets limits to liability, provides for transfer of long-term liability, establishes an insurance market or creates a trust fund, this risk will remain and could impede development of sequestration.

Offshore Saline Aquifer Injection

Sequestration sites located offshore simplify much of the regulatory and legal complexities that come with long-term storage of CO_2 onshore. As outlined in section 3 above, access to pore space in state offshore acreage is controlled by the GLO and administered by the School Land Board. Moreover, the producer of CO_2 is relieved of liability upon site closure, although the site operator is not. Nevertheless, this meaningfully de-risks project investment for a capture facility.[50]

[50] HB 1796; Tex. Health & Safety Code Ann. § 382.508 (2009) https://statutes.capitol.texas.gov/Docs/HS/htm/HS.382.htm#382.508

In 2017, UT BEG published an atlas that summarized research undertaken as part of a multiyear study. According to this atlas, perhaps the most compelling reason to focus on sequestration in near offshore state waters "is their location overlying the Gulf of Mexico Basin, one of the world's largest accumulations of porous sedimentary rocks with proven fluid-trapping capabilities. Studies conducted by UT BEG highlight the Gulf of Mexico as one of the most prospective basins in the US for industrial-scale CO_2 utilization and storage."[51] Given the concentration of industrial emissions and proximity of potential CO_2 capture facilities to the Gulf Coast, as outlined in Section IV above (see figure 6), the remaining challenges facing offshore sequestration as a pathway are primacy, the uncertainty surrounding application of the MPRSA, and the need for fiscal support for commercial surety in order for a supply chain to develop.

Regarding commercial prospects, currently no CO_2 gathering or transport infrastructure exists offshore, so constructing and financing the necessary infrastructure at scale may require fiscal support. Here, the cost-benefit of such a policy approach is important, and leasing revenues for access to pore space for the permanent storage of CO_2 in the subsurface of state offshore waters would contribute to the state education fund. Hence, offshore CO_2 sequestration provides a compensating long-term fiscal benefit to the state that effectively acts as a return on investment for fiscal support provided by the state to project developers. The actual return would dependent on a number of yet-to-be-determined factors such as the level of fiscal support provided, the leasing terms for access to pore space for permanent storage, and the volume of CO_2 injected. Thus, further study is needed to evaluate any potential for a net economic benefit.

VI. Supply, Demand and the Shifting CCUS Landscape

A full cost-benefit analysis is central to any evaluation of the net economic impact of various actions associated with CCUS value chain development and the role the state may directly play in it. This is beyond the scope of this paper, but given the range of possibilities that present themselves across regions in the Texas, it is useful to consider a general framework to understand how different factors influence CCUS adoption.

Figure 8 depicts a simple supply-demand framework.[52] "Supply" is the availability of CCUS services at different prices, and it is inclusive of the entire value chain from capture to transport to injection for long term storage; "Demand" represents how firms

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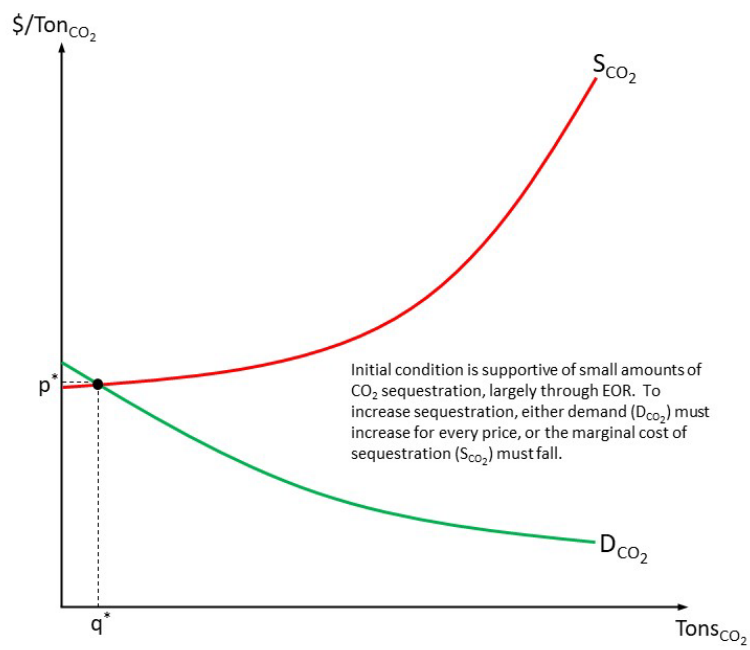
[51] "Geological CO_2 Sequestration Atlas of Miocene Strata, Offshore Texas State Waters," edited by R. H. Treviño and T. A. Meckel. Seven chapters, 1 appendix, 74 p., 2017. ISSN: 2475-367X. ISBN: 978-1-970007-12-1. DOI: doi.org/10.23867/R10283D

[52] A similar framework is presented in the previously referenced topic paper by Brown, Jeffrey D. and Ung, Poh Boon, "Supply and Demand Analysis for Capture and Storage of Anthropogenic Carbon Dioxide in the Central U.S." (Dec 12, 2019). However, the exposition herein is quite different.

will utilize CCUS services at different prices. Supply is upward sloping because as the price of carbon dioxide rises the availability of options for capture and sequestration will increase. Demand is downward sloping because greater amounts of CCUS services will be called upon as the price declines. Factors other than price that influence supply and demand shift the respective curves. In such basic partial equilibrium frameworks, the intersection of supply and demand represents a "market clearing equilibrium" at a prevailing price and quantity.

Figure 8. Supply and Demand for CCUS – Status Quo



Examples of Supply Shifters*

- Innovation, new technologies, new products
- Tax/fiscal policy that lowers infrastructure and project fixed/operating costs
- Policy addressing uncertainties and removing permitting/access restrictions or legal barriers to entry

Examples of Demand Shifters*

- Consumer preference and ESG investor sentiment focused on lower corporate net carbon footprints
- Direct government regulation of emissions
- CO_2 tax

* - These are illustrated as examples only. The list is not meant to be all inclusive.

Note: Brown and Ung (2019) present a supply curve that has an initial "step", but for the sake of exposition we keep the representation of supply relatively simple.

In Figure 8, a relatively low volume of CO_2 is sequestered in the depicted equilibrium. There are currently several active carbon capture and sequestration projects.[53]

- NRG's Petra Nova Project, which captures CO_2 from a coal-fired power plant then moves the CO_2 by pipeline for EOR. From January 2017 through August 2019, the facility had captured and transported more than 3.27 million tons of CO_2 for EOR. The operation was mothballed in May 2020 amidst low oil prices.

[53] See "Major CCUS Demonstration Projects" US Department of Energy, Office of Fossil Energy, https://www.energy.gov/sites/prod/files/2019/10/f67/Major%20CCUS%20Demonstration%20Projects.pdf.

- The Air Products and Chemicals project in Port Arthur, which opened in 2013, captures CO_2 from steam methane reformers during hydrogen production, then moves the CO_2 for EOR. The project is part of the US Department of Energy's Industrial Carbon Capture Storage (ICCS) initiative and captures over a million tons per year.
- The Archer Daniels Midland project is also part of the ICCS initiative, but it captures CO_2 for injection in a Class IV well for permanent storage. As of August 2019, the facility had sequestered over 1.4 million tons of CO_2 in the Mount Simon Sandstone saline reservoir since its opening in April 2017. The facility is rated for a maximum injection of just over one million tons per year.
- There are other active EOR projects, but a majority have been associated with CO_2 sourced from natural formations (e.g.– Jackson Dome in Mississippi, McElmo Dome and Sheep Mountain in Colorado, and Bravo Dome in New Mexico) then piped to locations for injection. CO_2 separated at natural gas processing facilities is another important source for EOR activities.[54]

Figure 8 captures the notion that there are some relatively low-cost pathways for CO_2 storage that are already being utilized, but other options for CO_2 capture and storage are not being utilized due to their being cost prohibitive. EOR is an example of a relatively low-cost technology along the supply curve, as indicated by recent research from GPI and ARI, which suggests potential demand of an additional 94 million tons of CO_2 for EOR at an oil price of $40 per barrel, and 165 million tons at a price of $60 per barrel oil.[55]

Shifting Demand

The market for CCUS services is changing. On the demand side, we see this manifesting in multiple ways.

- The Oil and Gas Climate Initiative (OGCI), to which 12 different major oil and gas firms representing 30% of global oil and gas production are party, launched *CCUS Kickstarter* in 2019, which is aimed at facilitating "large-scale commercial investment in CCUS" with a focus on enabling multiple low-carbon industrial hubs to "bring economies of scale by sharing transport and storage infrastructure." The effort explicitly targets the creation of "market conditions for

[54] See https://www.netl.doe.gov/sites/default/files/netl-file/CO2_EOR_Primer.pdf.
[55] Dane McFarlane, "Regional Carbon Capture Deployment: Texas Gulf and Houston Area," *Great Plains Institute*, 17, February 19, 2020.

CCUS to play a significant role in decarbonizing industry."[56] Notably, the US Gulf Coast is identified as a region for hub development.

- Recent announcements of net-zero ambitions by several large firms, including but not limited to BP, Shell, Equinor, Repsol, Eni, Occidental Petroleum, Cenovus, Canadian Natural Resources, Southern Company, Entergy, Total, Lundin Petroleum, Dominion Energy, NRG, Baker Hughes, Duke Energy and Williams. The net-zero ambitions of this growing list of companies that have large portions of their portfolios tied to fossil fuels sends a powerful message.
- A growing number of large banks and investors – including Morgan Stanley, JPMorgan, Citigroup, BlackRock, Pimco and Bank of America – have recently pledged to review climate impacts of future capital allocations. In addition, several shareholder groups have expressed a desire for lower carbon intensity. Altogether, this represents an emerging constraint on access to capital that will drive firms to take steps towards meeting stipulated carbon reduction requirements.
- The European Union is contemplating ways to drive lower carbon intensity in the products it imports, including a border carbon adjustment mechanism. This will, to the extent a firm sees the European market as vital to its business and the border adjustment is high enough, drive investments in lower carbon production methods to avoid the tariffs.
- Many governments are either acting on, contemplating, or announcing intentions to reduce net carbon emissions within their borders. Various pathways are under consideration, including greater adoption of renewables, increased electrification, expanded use of hydrogen, and greater use of carbon capture technologies.

In short, the demand for sequestration services is rising, which is depicted in figure 9. This simply means that the willingness to pay for abating CO_2 emissions is rising as firms see the opportunity cost of maintaining the status quo increase. While not every firm will necessarily respond in the same manner, investor sentiment, consumer preference, and government action each play a role in shaping demand for CCUS.

Studies continue to emphasize the important role that carbon capture technologies must play if certain carbon mitigation strategies are to be met. Notably, the IEA recently released a study[57] noting that the suite of CCUS technologies is unique because it "contributes both to reducing emissions in key sectors directly and to removing CO_2 to

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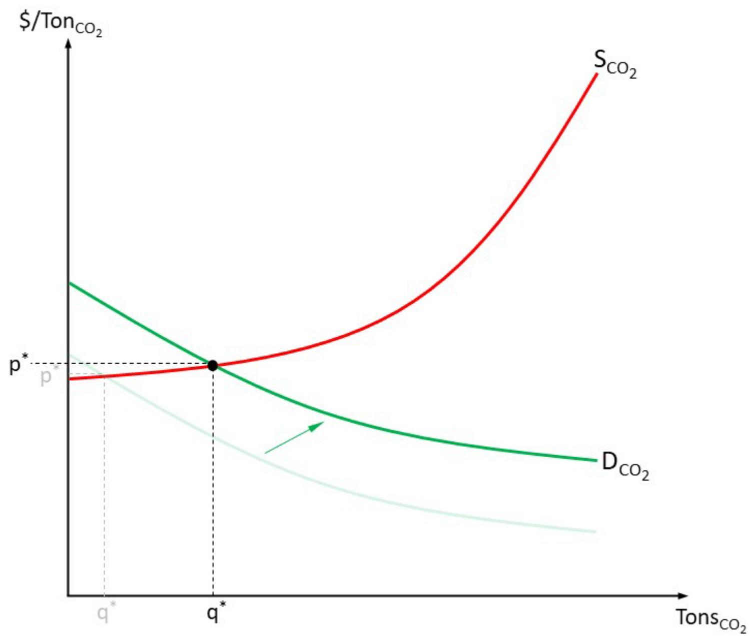
[56] See https://oilandgasclimateinitiative.com/action-and-engagement/ccus/#kickstarter.

[57] See https://www.iea.org/reports/ccus-in-clean-energy-transitions.

balance emissions that are challenging to avoid – a critical part of 'net' zero goals." This is yet another signal of a growing international appetite for carbon capture technology.

A caveat is warranted here. Specifically, the quantitative impact of shifts in demand and/or supply on the market clearing price of CO_2 and quantity sequestered will depend on the relative elasticity of supply and demand, or the slopes of the curves. While some recent studies have attempted to quantify this, there remains uncertainty, which highlights a need for additional research. However, this is not necessarily an argument for delayed action as the extent that demand and supply are changing will ultimately manifest in the investment behavior of participating firms.

Figure 9. Supply and Demand for CCUS – Effect of a Demand Shift



Examples of Supply Shifters*

- Innovation, new technologies, new products
- Tax/fiscal policy that lowers infrastructure and project fixed/operating costs
- Policy addressing uncertainties and removing permitting/access restrictions or legal barriers to entry

Examples of Demand Shifters*

- Consumer preference and ESG investor sentiment focused on lower corporate net carbon footprints
- Direct government regulation of emissions
- CO_2 tax

* - These are illustrated as examples only. The list is not meant to be all inclusive.

Shifting Supply

While shifts in demand for CCUS can have a material impact on the market for sequestration services, the supply side also matters. Several intervening forces – from technology improvements to policy changes – can affect the cost of CCUS, including

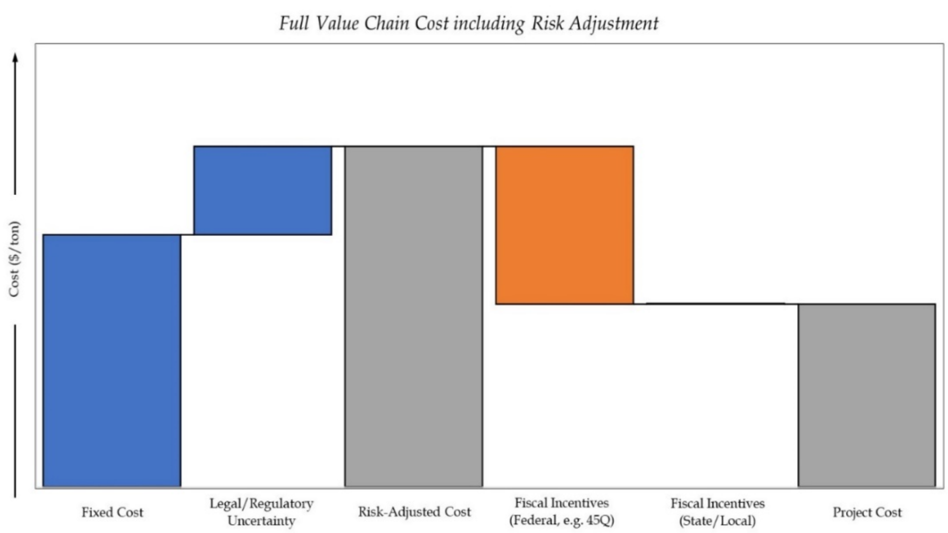
- new innovations that enable more cost-effective capture and storage of CO_2. Innovation is often stimulated by government funded R&D;

- the removal of regulatory and legal uncertainties that present effective barriers to capital investment in various parts of a CCUS value chain, from capture to transport to injection/use; and
- tax and fiscal policies that lower infrastructure costs and/or operating costs (policies that have been deployed to promote broader investment in renewables provide one recent example).

Each of these factors lowers the cost of CCUS, thereby shifting the supply curve.

There is a continuum of possible projects at any point in time that make up the supply curve. Figure 10 indicates an arbitrary, illustrative project that represents a particular point along the supply curve in figure 9.[58] As indicated in figure 10, there is a "full-cycle" fixed cost associated with the installation of capture equipment, the development of transportation options, and injection for EOR or long-term storage. Regulatory and legal uncertainties add cost because they raise the cost of financing the project, skew the project developer to adopt higher risk factors, and erect barriers to entry. Fiscal incentives at the federal, state and local levels, depending on how they are structured, lower cost through a reduction of financing cost, a tax credit/abatement, or commercial support for operations. 45Q is depicted in figure 10 as an example of a federal fiscal incentive. There is no state and local fiscal support indicated in figure 10.

Figure 10. Cost of a CCUS Project



[58] Waterfall charts can be useful tools for understanding the contributions of various factors to overall project cost. Then, one can adjust various factors to determine the impact on overall cost. Importantly, the reference point for a waterfall chart is project specific, so it is representative of a single point along a supply curve. Hence, the waterfall can be a useful tool in determining how things shift the supply curve.

Figure 11 illustrates the impact of removing regulatory and legal uncertainties. While the fixed costs of the project do not decline, the cost of executing the project does, precisely because the opportunity is de-risked and/or barriers to entry are removed. Just as removing legal and regulatory uncertainties lower the cost of executing a project, providing additional fiscal support has a similar effect. Moreover, it is often the case that removing legal and regulatory uncertainties lowers barriers to project finance, which can open channels for fiscal support, such as Department of Energy support through its Loan Program Office, that would not otherwise be available.

Figure 11. Cost of a CCUS Project – Reducing Regulatory and Legal Uncertainties

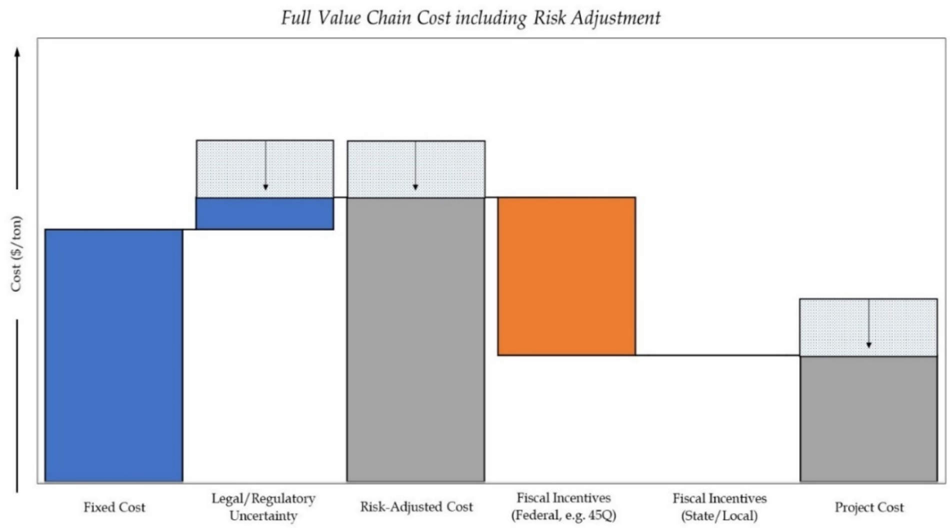


Figure 12. Cost of a CCUS Project – Adding State/Local Fiscal Support

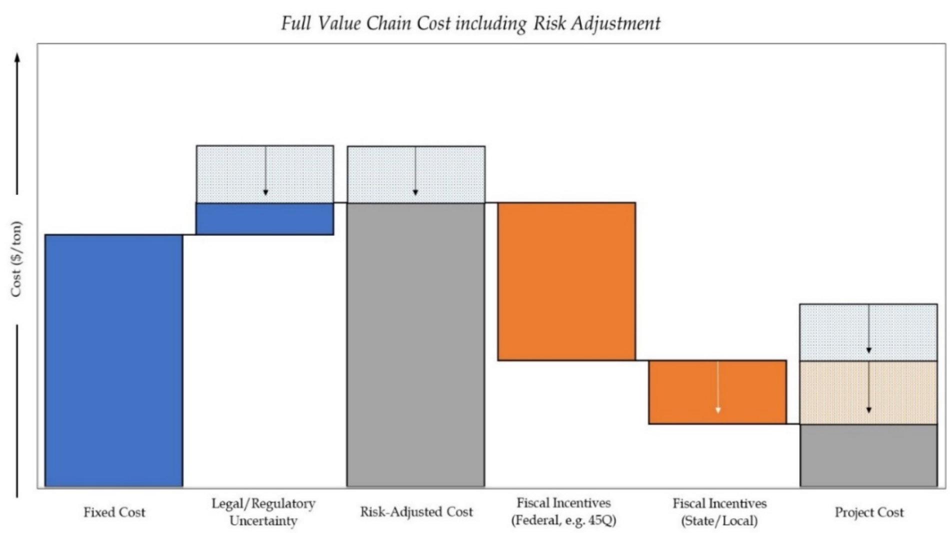
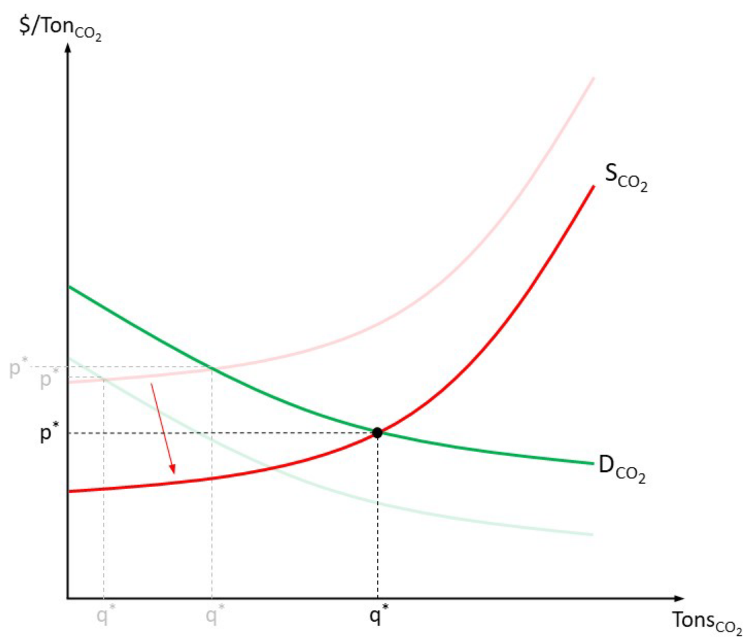


Figure 12 indicates, additively, the effect of state/local fiscal support. It is important to note if meeting aggressive carbon reduction goals at the least possible cost is a desired option, and technologies such as CCUS are to play an important role, then cost reductions through (i) the removal of legal and regulatory uncertainties and (ii) fiscal incentives (at federal and state/local levels) will have a stimulatory effect. But taking such steps will not, in and of themselves, ensure adoption. All they ensure is that the cost of providing CO_2 sequestration services is reduced.

Notably, as the cost of CCUS project development is reduced, the supply curve representing CO_2 sequestration services shifts down, as indicated in figure 13. A supply curve that is shifting down certainly improves the commercial prospects of CCUS, but simply addressing cost is not sufficient for understanding whether a technology will be deployed. Demand conditions must also be sufficient. Figure 13 builds on figure 9 to provide a qualitative assessment of the impact on the supply curve of cost reductions borne by the removal of legal and regulatory uncertainties and the provision of fiscal incentives. The quantitative implication remains an open question subject to additional study, but the directional implication is clear.

Figure 13. Supply and Demand for CCUS – Effect of a Supply Shift



Examples of Supply Shifters*

- Innovation, new technologies, new products
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- Policy addressing uncertainties and removing permitting/access restrictions or legal barriers to entry

Examples of Demand Shifters*

- Consumer preference and ESG investor sentiment focused on lower corporate net carbon footprints
- Direct government regulation of emissions
- CO_2 tax

* - These are illustrated as examples only. The list is not meant to be all inclusive.

When we combine increasing demands for CCUS with actions that lower the overall cost of supply of CCUS, or by shifting both demand and supply together, we get an increase in the use of CCUS that can exceed the effect of just shifting demand or just shifting supply.[59] Moreover, it is possible that the resulting price of CCUS services is lower. The exact outcome requires quantitative analysis and, hence, further study. But the relatively simple analysis herein indicates policy that facilitates market expansion would be important for bringing significant scale to CCUS in Texas.

VII. Recommendations

Over the past decade, fiscal incentives and policy frameworks have played a central role in advancing the diffusion of renewable energy technology into energy systems in the US and Texas. In a recent paper, Cohn and Jankovska (2020) explore the role of transmission investment in Texas for expanding wind in the power mix.[60] They note that the rapid expansion of wind power capacity in Texas, which is larger than any other state in the US, has benefitted dramatically from the construction of the CREZ. The Texas experience in wind highlights the role that policy can play in expanding new value chains.

By parallel, policy will play a central role in scaling up the CCUS value chain. Commitment from state regulators and policymakers to resolve legal and regulatory uncertainties and provide supportive commercial frameworks – both now and in the future – will underpin the pace and scale of the full CCUS value chain in Texas. As consumers and investors increasingly reveal preferences for lower CO_2 emissions, market agents are shifting their investment and marketing strategies. This provides an opportunity for regulators and policymakers to reduce uncertainties that can impeded investment, and explore fiscal measures that provide value to legacy industries and create pathways for growth in new industries. This is certainly true for the CCUS value chain, which can underpin decarbonization efforts associated with traditional oil and gas activities in the state of Texas, and support additional investments to grow the hydrogen industry. Notably, hydrogen as a fuel in heavy transport and in port facilities will also have local air quality benefits, which could help propel CCUS adoption. But, if various legal and regulatory uncertainties persist, the CCUS value chain will face significant hurdles.

Providing **(i) legislative clarity on jurisdiction for permitting Class VI injection wells, with authority given to the RRC**, is a step that could be taken immediately. Then, when the agency files for (and receives) **primacy for regulatory authority over Class VI**

[59] The actual outcome depends on the relative elasticities of demand and supply. Moreover, if the elasticities change, which would occur if, for example, the cost reductions increase as we move farther out the supply curve – perhaps through technical innovations, fiscal support, or addressment of uncertainties that more greatly impact higher cost options – then the results could be even larger.

[60] See "Texas CREZ Lines: Stakeholders and Energy Infrastructure" available online at https://www.bakerinstitute.org/research/texas-crez-lines-how-stakeholders-shape-major-energy-infrastructure-projects/.

injection wells, it would remove an element of uncertainty, streamline permitting, and have beneficial impacts for CCUS project finance. Of course, sufficient financial resources must be in place to adequately handle the anticipated permitting activity.

Authorize a **(ii) study exploring the use of fiscal policy measures** to support CCUS value chain development to provide important datapoints as to whether such measure would bear a positive net benefit to the state. In general, federal, state and local fiscal incentives, when applied to any part of the value chain, have stimulatory effects for all parts of the value chain. There are some interesting opportunities in Texas that could, if leveraged, provide a return to the state.

- One potential fiscal approach could involve a state lands intervention in which a state agency sets a precedent for pricing captured CO_2. In turn, this could be an avenue that affords the state a return on investment, promotes the development of a new CCUS industry, and supports legacy oil, natural gas and petrochemical industries, all of which have tremendous importance for the Texas economy. As referenced above in section 5, one area where this concept could be applied is in state offshore waters, which may be one of the least encumbered pathways for CCUS in the state of Texas from a legal and regulatory perspective, notwithstanding potential uncertainties related to the MPRSA. Piloting CCUS in offshore state waters with the aim of setting a benchmark price would enable the capture of the existing regulatory advantage to being offshore. If this path is pursued, there is a potential revenue benefit to the state insomuch as income from leases permitted by the GLO in offshore state waters goes to the School Land Board. The extent to which this is a financial net positive to the state requires further investigation. It is important to note that the role of surface owners cannot be overstated in this context. Broad legislation that includes mandatory unitization can easily be construed as erosive of the rights of surface and subsurface owners.[61]
- Another potential fiscal policy approach is rooted in models already successfully deployed in the wind industry. In particular, production tax credits offered to wind generators effectively guaranteed a revenue stream for every kilowatt-hour of power generated. That, in turn, provided income certainty that was the basis for tax equity finance models that provided an abundance of capital needed to scale up wind capacity fairly quickly. Similar tax and finance mechanisms would conceivably work for CCUS. Of course, in this case, the tax credit would be calculated based on the amount of CO_2 sequestered thereby providing an incentive for the CCUS industry to maximize net carbon reductions.

[61] Indeed, examples from outside Texas give rise to a concern over the risk of triggering Takings litigation if the state's legislature takes actions that attenuate or eliminate landowners' ownership rights in subsurface pore space.

Importantly, this would also yield a stronger financial footing for the full carbon capture value chain, and enable payment for storage of CO_2 in deep saline aquifers on both state and private lands.

- In addition to consideration of state and local tax incentives, a state-focused emphasis on support for extending 45Q would provide some commercial surety for CCUS value chain participants in Texas. Moreover, extension of 45Q would provide a federal incentive that state and local officials could leverage to drive infrastructure investment, employment, and preservation of legacy value-added activities thereby generating a positive local economic benefit.
- CO_2 pricing policy can be a powerful fiscal tool, as was raised in section 6 (see figure 13). Explicit pricing policy would be something like a carbon tax or the adoption of a cap-and-trade system, as other states (e.g. California) have already done. Implicit pricing policy mechanisms could include mandates (or quotas) on CO_2 emissions or a low carbon fuel standard (LCFS), which function as quantitative restrictions that implicitly price CO_2 by forcing firms redirect capital to be in compliance with the standard. Importantly, it is widely recognized that this type of policy is highly unlikely in Texas at the current time, but federal action in this direction could be forthcoming, particularly if federal policy moves to address CO_2 emissions more proactively.

The role of **(iii) research and development (R&D)** in facilitating new technological innovations is very important, and the state could take an active role by, for example, supporting innovation hubs and/or providing increased levels of direct funding for relatively immature technologies as an investment in commercialization. One such possible policy intervention would be to fund R&D of alternative uses of CO_2 or carbon with an aim to creating new value propositions. In general, robust R&D activities are critical to the long-term health of any industry. The US Department of Energy has a number of programs through direct funding and its national labs, but these are national in scope thus not necessarily focused on Texas. In Texas, various programs such as the New Technology Innovation Grants (NTIG) program under the Texas Emissions Reduction Plan (TERP) can serve as examples of funding vehicles that could be streamlined to facilitate targeted R&D funding. Given the vested interest the Texas economy has in hydrocarbons, a robust R&D portfolio focused on improving the efficiency of existing CCUS technologies, exploring new combustion processes, expanding the use of hydrogen (produced from hydrocarbon feedstocks), the development of new carbon-based materials, and pioneering new uses for CO_2 in industrial and power generation activities can all play a major role in achieving desirable economic and environmental outcomes.

Material science breakthroughs, for example, could create new cost competitive uses for carbon into carbon-based materials that can be engineered for uses in building materials, steel, automotive applications, etc. If successful, this would create a co-product value for carbon captured from a hydrocarbon input – either post-combustion or through pyrolysis combustion to generate hydrogen and carbon black – thereby adding a value proposition to investments in carbon capture technologies for commercial application.[62] Note, this is similar to the motivation for using CO_2 in EOR. Just as the DOE has funds allocated directly to the development and deployment of CCUS, allocation of research dollars to co-products would support technological breakthroughs that open new product lines and/or alternative, marketable uses for CO_2, which would dramatically improve the commercial prospects of CCUS.

While R&D expenditures will not typically bear an immediate return, they can provide substantial long-term benefits. Indeed, the much-discussed shale revolution, which was transformative for the US and the world, has its roots in the late 1970s with government support. If such an outcome could be replicated from R&D aimed at creating new lines of carbon-based materials and new uses for CO_2, referring back to section 6 (see figure 13), this would both shift and flatten the supply curve. In turn, this would have dramatic long-term benefits for decarbonization goals.[63]

Longer term, policymakers may need to **(iv) resolve uncertainties associated with long-term liability of sequestration sites**, **(v) address concerns regarding access to pore space for long term storage of CO_2**, at least with respect to circumstances where it is impractical to negotiate subsurface storage rights from the owner of the surface estate overlying the predicted CO_2 plume, and **(vi) take up unitization rules for geologic storage of CO_2**. To be clear, each of these issues has its own set of difficulties. Moreover, they were each raised in the survey of stakeholders that is reported in Medlock and Miller (2020).[64]

- As discussed in section 3 regarding long-term liability, SB 1387 established a fund for long-term stewardship of onshore sequestration sites and placed the RRC in charge of the fund. But, no transfer of ownership or liability is addressed for onshore sequestration. Offshore, HB 1796 designated the School Land Board as the site owner with the authority to set fees for storage. While the state does not assume ownership of or liability for stored CO_2 onshore, it does release the

[62] Rice University's Carbon Hub is one example of such a research endeavor. It is currently funded by a group of industrial partners, but there is a role for federal and state government funded research. See https://carbonhub.rice.edu/.

[63] Indeed, US Government R&D funding directed at shale in the late 1970s was not intended to generate immediate returns, and was done in concert with a number of other energy security motivated policies. Laudable goals for environmental sustainability could motivate policy that recognizes the energy security benefits of the relative hydrocarbon abundance of the US while taking strides to both diversify the energy mix *and* provide a long-term low carbon pathway for US energy resources.

[64] See https://www.bakerinstitute.org/research/carbon-capture-texas-comparative-advantage-low-carbon-portfolio/

producer of CO_2 (but not the site operator) of liability offshore, which raises some interesting possibilities for CCUS development as it reduces risk at the most capital-intensive portion of the value chain. In general, no consensus exists about liability post-site closure, but there is some agreement that its addressment is important for mitigating uncertainties facing a nascent CCUS industry.

- Also raised in section 3, for onshore sequestration, in the absence of the negotiated acquisition of storage rights from the owner(s) of the surface estate overlying the anticipated plume, no clear legislative or regulatory process currently exists to obtain a requisite right to access pore space to store CO_2 beneath private lands in Texas. However, there is a high likelihood that potentially affected owners of surface and subsurface rights would be receptive to contract negotiations with firms seeking access to pore space for CO_2 storage, in which case pore space access becomes a negotiated right. Nevertheless, geologic storage of CO_2 could benefit from clear rules governing the recognition, protection, and legal transfer of access rights to pore space, at least with respect to circumstances where it is impractical to negotiate subsurface storage rights from the owner(s) of the surface estate overlying the anticipated plume. In offshore state waters, pore space is administered by the GLO.
- As addressed in section 3 on the subject of unitization, it is not yet known whether a compulsory CO_2-specific unitization bill could garner widespread support in Texas. Legislative efforts at mandatory unitization directed at oil and gas extraction have historically been construed as erosive of the rights of surface and subsurface owners, and have failed. Any future consideration of such a bill may only be possible if its scope is limited to geologic storage of CO_2 and addresses provisions such as conflicting use, compensation and lien provisions.

While the list of recommendations is not inordinately long, it is potentially cumbersome. But there is a relative temporal ranking that can be applied based on when issues could present as binding to CCUS advancement. In particular, recommendation (i) could be addressed immediately and at very low cost, providing substantive benefit for the CCUS industry. Recommendations (ii) and (iii) convey benefit longer term, but require some allocation of funding. That stated, the potential returns on investment and benefits for the Texas economy could justify the expense. Finally, recommendations (iv), (v) and (vi) get into areas that are generally more contentious, and could be addressed at a future date if ultimately deemed necessary or as they become binding.

VIII. Closing Remarks

Market circumstances have changed dramatically over the past year, bringing sustainability and "net-zero" squarely into the focus of firms in heavy industry, oil and gas, petrochemicals, power generation and more. The Texas economy is heavily dependent on these activities. So, addressing the various legal and regulatory uncertainties confronting the CCUS industry will have a major influence on the pathway(s) for technology adoption. Several other states have already embarked on addressing these challenges. In the end, Texas will need to do the same as the carbon capture market matures. Given its comparative advantages in geology, resource base, co-location and scale of industry, and an incredibly talented human capital resource, Texas should be in a position to lead in carbon capture.

This research identifies legal and regulatory uncertainties that, if not resolved, could impede the development of a CCUS value chain in Texas. This research was not designed to provide a quantitative cost-benefit analysis of expanding CCUS in Texas, although there is certainly a need for work on that front, especially as it pertains to any potential justification for state and local fiscal support. Rather, this research was meant to identify issues – legal, regulatory and commercial – that could trigger coordination failures in the development of a robust CCUS value chain.

Addressing legal and regulatory uncertainties is critical to clearing pathways for CCUS in Texas. If commercial prospects are sufficient, the CCUS industry will grow. Commercial returns can be derived from a number of factors, including investor-driven ESG constraints on access to capital, fiscal policy support, and an explicit price on CO_2, such as a carbon tax or any number of market-oriented activities that result in a market-clearing price for CO_2. Longer term, CCUS "market-making" innovations can drive a paradigm shift in the way hydrocarbons are used. This includes expanding the feedstock applications of hydrocarbons through the development of uses of carbon dioxide in cement, chemical and power applications, and, longer term, new carbon-based products. In turn, this will lend support to long-term, potentially very large, CO_2 value chains, particularly if carbon becomes a feedstock for other industrial processes and new materials. This sort of paradigm shift is made more feasible the sooner a viable CCUS value chain develops.

IX. Appendix

Liability Legislation

Tex. Health & Safety Code § 382.502 (2009): "Offshore Geologic Storage of Carbon Dioxide." Authorizes various state agencies to construct an offshore, deep subsurface geologic repository for carbon dioxide on state-owned land.

Tex. Health & Safety Code Ann. § 382.507 (2009): "The right, title, and interest in carbon dioxide acquired under this section are the property of the permanent school fund and shall be administered and controlled by the board."

Tex. Health & Safety Code Ann. § 382.508 (2009): "On the date the permanent school fund, under Section 382.507, acquires the right, title, and interest in carbon dioxide, the producer of the carbon dioxide is relieved of liability for any act or omission regarding the carbon dioxide in the carbon dioxide repository." However, it expressly provides that it does not relieve any person who contracts with the board of liability for any act or omission regarding the construction or operation, as applicable, of a carbon dioxide repository (i.e., a geologic storage site). 5 Tex. H & S Code §382.508(c).

Storage Fund Legislation

SB 1387 (2009): Texas onshore legislation (SB 1387, 2009) has created the *Anthropogenic Carbon Dioxide Storage Trust Fund* to cover long term monitoring and expenses of CO_2 injection and storage sites. The Railroad Commission is in charge of this fund and stipulates a $75,000 application fee with $50,000/year for each well post injection and pre-closure. SB 1387 has also defined a $0.10/ metric ton of CO_2.

It is not clear whether or not this Trust Fund can be used to perform long-term activities (e.g. to address unanticipated migration of CO_2 post-closure of a site). In addition, TCEQ does not appear to have statutory access to this or any other trust fund for any activities deemed within the jurisdiction of TCEQ.

HB 1796 (2009): Texas offshore legislation (HB 1769, 2009) grants the Texas School Land Board to oversee the offshore CCUS sites that are within 12 miles of the coast. This legislation creates the *Texas Emissions Reduction Plan Fund* and the School Land Board is authorized to set fees for CO_2storage. The exact details of how much is to be paid into this fund and how it to be used is not stipulated. Again, HB1796 expressly provides that it does not relieve any person who contracts with the board of liability for any act or omission regarding the construction or operation, as applicable, of a CO_2 repository (i.e., a geologic storage site).

Pore Space Access

The safe, secure and permanent geologic sequestration of carbon requires a suitable formation, one that includes access to pore space. Questions about access to pore space necessarily require considerations of pore space ownership, surface estate ownership and the separate and severed estates in mineral interests, groundwater, and other non-operating production interests that are common in areas of Texas that are suitable for geologic sequestration. A related consideration is access to surface area that will support ancillary infrastructure, such as injection wells, pipelines, compression, monitoring equipment, etc.

In Texas, access to pore space and the surface can be obtained through any number of agreements with the party or parties that hold a property interest in the pore space and surface. This may include agreements to acquire the property in fee, leases, or easements. In addition, an oil and gas lessee will generally have implied rights to use the subsurface pore space for disposal and injection purposes, to the extent reasonably necessary for production from the lease and lands pooled therewith.[65]

The specific property interests that need to be acquired depend on the type of storage formation, including whether the CO_2 will be injected into a deep saline formation or a mineral formation, and whether any mineral interest has been severed from the surface interest.[66] Where groundwater rights have been severed, a sequestration project may need to analyze whether the anticipated CO_2 injection will impact the severed groundwater rights and, if so, seek agreement from the owner of such rights.[67] Because a formation suitable for geologic sequestration of CO_2 may extend for some distance from an injection well, it may prove difficult to obtain agreements with all parties that

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[65] *TDC Engineering, Inc. v. Dunlap*, 686 S.W.2d 346, 348-349 (Tex. Civ. App. – Eastland, 1985, writ ref'd n.r.e.), and *Key Operating & Equip., Inc. v. Hegar*, 435 S.W.3d 794, 799 (Tex. 2014).

[66] Some commentators advise that a full analysis of property interests requires consideration of whether a mineral estate may be depleted (see Mark A. de Figueiredo,"Property Interests and Liability of Geologic Carbon Dioxide Storage," MIT Laboratory for Energy and the Environment, September 2005, available online at https://sequestration.mit.edu/pdf/deFigueiredo_Property_Interests.pdf). Due to the nature of oil recovery, depletion is not generally a question of physical exhaustion; rather it is a question of whether a reservoir still contains commercially recoverable oil. So, where a severed mineral estate exists, the analysis of relevant property interests must include the mineral estate, even if not producing.

[67] *Coyote Lake Ranch, LLC v. City of Lubbock*, 498 S.W.3d 53, 63 (Tex. 2016) (recognizing the applicability of the accommodation doctrine to severed groundwater rights). Generally, groundwater rights are present in shallow formations (e.g.- those at issue in Coyote Lake Ranch are present at approximately 250 feet below the surface). Geologic sequestration of CO_2 generally occurs much deeper, at more than 5,000 feet below the surface. RRC rules require "all usable-quality water zones be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids be isolated and sealed off to prevent vertical migration of fluids, including gases…." 16 Tex. Admin. Code §3.13. It is unlikely that a property interest in groundwater might be affected by geologic storage of CO_2.

may have some property right in a formation suitable for sequestration or the overlying surface projection. Texas law has not addressed pore space ownership, as it pertains to the geologic sequestration of CO_2, through legislation or adjudication.

Generally, there are three categories of legislation that address pore space as related to the geologic sequestration of CO_2:

(i) statutes that assign ownership of pore space;

(ii) statutes that aggregate ownership of pore space – including unitization as adopted by Mississippi, Wyoming and North Dakota, or eminent domain (or "expropriation"), as used in the case of Louisiana; and

(iii) statutes that regulate the storage of carbon more generally.

This paper does not purport to provide a full description and analysis of Texas law with respect to pore space ownership. Further, to our knowledge no Texas case has directly considered pore space ownership in the context of the geologic storage of CO_2. The generally held prevailing view is that the subsurface pore space, less the recoverable minerals and unless otherwise severed, is held by the surface estate.[68] Table A1 summarizes the relevant property interests for acquisition of a geologic reservoir.

Table A1: Property interests of geologic reservoir and saline formation

	Unsevered Mineral Interest	Severed Mineral Interest	Absolute Dominion (Groundwater)
Non-Depleted Reservoir	Surface owner	Surface owner Mineral owner	--
Depleted Reservoir	Surface owner	Surface owner (Mineral owner*)	--
Saline Formation	--	--	Surface owner

* Since a geologic formation is never fully depleted of minerals, there is likely a cost associated with purchasing the rights of the mineral interest owner who claims that the reservoir is not depleted.

[68] *Lightning Oil Co. v. Anadarko E&P Onshore, LLC*, 520 S.W.3d 39 (Tex. 2017); *Springer Ranch, Ltd. v. Jones*, 421 S.W.3d 273 (Tex. App.—San Antonio 2013, no pet.); *Humble Oil & Refining Co. v. West*, 508 S.W.2d 812, 815 (Tex. 1974); *Dunn-McCampbell Royalty Interest, Inc. v. National Park Service*, 630 F.3d 431, 442 (5th Cir. 2011); *Emeny v. United States*, 188 Ct. Cl. 1024, 1032, 412 F.2d 1319, 1323 (1969); 1 Ernest E. Smith & Jacqueline Lang Weaver, Texas Law of Oil and Gas 2.1, at fn. 95.1 (2020); 1 Eugene Kuntz, The Law of Oil and Gas § 2.6, at fn. 14 (2020); 1 Patrick H. Martin & Bruce M. Kramer, Williams & Meyers, Oil and Gas Law § 222, at fn. 14-26 (2020); Austin W. Brister and Kevin M. Beiter, "Divided Surface and Mineral Estates: Survey of Split Estates, Implied Easement, Accommodation Doctrine, and Selected Emerging Issues," 2020 Fundamentals of Oil, Gas and Mineral Law Ch. 3 (2020), pgs. 23, 31-33.

Unitization

Discussions around compulsory unitization is not new in Texas. In fact, several bills have been introduced into the Texas State Legislature have been introduced and consistently have failed. Examples include Senate Bill 177 and House Bill 100.

SB 177 (2017) failed to receive a vote in the Senate Committee on Natural Resources. The bill would have authorized the RRC to force-unitize tracts into a tertiary recovery unit for CO_2 floods and CO_2 sequestration projects. The bill would have enabled a supermajority of 70% or more of both working groups and royalty interest owners to enter into a pool in order to proceed with field development for secondary and tertiary recovery operations (and geologic storage of CO_2).[69]

Similar to SB 177, HB 100 (2013) also failed. The bill would allow an operator to force-pool mineral, royalty and leasehold interests into a unit if the operator obtains agreement from 70% of the leasehold owners and 70% of the royalty owners in the area to be unitized. Unleased mineral owners could be pooled, and would be treated as owning a 1/6 royalty interest and a 5/6 working interest. The unit operating agreement can provide for a "sit-out" penalty of no more than 300% for a working interest owner who elects not to pay its share of the well costs. The bill does not allow force-pooling of mineral or royalty interests owned by the State.

It is important to note that both HB 100 and SB 177 included provisions that caused a great deal of contention, particularly among landowners in the state (see McFarland (2013) [70], Sartain (2013)[71], TIPRO (2017)[72]). The most contentious of these provisions are encapsulated in the following:

- "Lease or surface use provisions that conflict with the use of the surface for unit operations in such a manner as to prevent or render uneconomical the implementation of the plan of unitization as approved by the commission must be amended by the unit order to the extent, and only to the extent, necessary to implement the plan in an economical and efficient manner." (§104.204(c))

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[69] McFarland, John. 85th Legislature – Legislation of Interest to Land and Mineral Owners. July 3, 2017. https://www.oilandgaslawyerblog.com/85th-legislature-legislation-interest-land-mineral-owners/

[70] McFarland, John (2013). "Taylor and Ellis Introduce Forced Pooling Bill in Texas Legislature." *Oil and Gas Lawyer Blog*. Graves, Dougherty, Hearon & Moody. January 10, 2013. https://www.oilandgaslawyerblog.com/taylor-and-ellis-introduce-for/

[71] Sartain, Charles (2013). "Compulsory Unitization Undermines Texas Values (Rhetorically Speaking)." Gray Reed Attorneys and Counselors. March 12, 2013. https://www.energyandthelaw.com/2013/03/12/compulsor-unitization-undermines-texas-values-rhetorically-speaking/

[72] Texas Independent Producers & Royalty Owners Association [TIPRO] (2017). 2017 Legislative Report, 9. https://tipro.org/UserFiles/TIPRO_2017_Legislative_Report.pdf

- "The plan of unitization must provide for the attachment of or a lien on proceeds of production due to any working interest owner who is not paying the owner 's share of the costs of unit operation as compensation to the paying owner or owners. The compensation amount may not exceed 300 percent of the nonpaying working interest owner's share of unit costs, which is considered to include all penalties and interest." (§104.108(a))
- "Subject to any reasonable limitations in the plan of unitization, a unit operator has a lien on the leasehold estate and other oil, gas, or oil and gas rights in each separately owned tract, the interest of the owners in the unit production, and all equipment in the possession of the unit to secure the payment of the amount of the unit expense and other additional compensation charges as provided for in Section 104.108 charged to each separate working interest." (§104.203(a))

Unitization and Pore Space Legislation Outside of Texas

Three states, North Dakota, Wyoming and Louisiana, have passed legislation that introduces compulsory unitization for the geologic sequestration of anthropogenic CO_2. In North Dakota, Senate Bill 2095 was passed in 2009 declaring geologic storage of CO_2 to be in the public interest. According to the legislation, the North Dakota Industrial Commission may require that the pore space of non-consenting owners be included in the storage facility if "the storage operator has obtained the consent of persons who own at least sixty percent of the storage reservoir's pore space."[73] This legislation does not apply to EOR projects. In 2019, North Dakota sparked fierce opposition with its passage of Senate Bill 2344, which re-defines "Land" to exclude pore space (""Land" means the solid material of earth, regardless of ingredients, but excludes pore space).[74] The Northwest Landowners Association brought suit against the state of North Dakota, alleging unlawful takings. The suit is actively being litigated as of the date of publication.

Similar legislation was also passed both in Wyoming and in Montana in 2009. Wyoming's House Bill 80 introduced legislation allowing the Wyoming oil and gas conservation commission to authorize commencement of unit operations once a "plan of unitization has been signed or in writing ratified or approved by those persons who own at least eighty percent (80%) of the pore space storage capacity within the unit area."[75] One year earlier, in 2008, Wyoming had passed House Bill 89 declaring that ownership of pore space was "to be vested in the several owners of the surface above

[73] Nd. SB. 2095, https://www.legis.nd.gov/assembly/61-2009/bill-text/JQTA0300.pdf
[74] Nd. SB 2344 (2019 North Dakota Session Laws Ch. 300), https://www.legiscan.com/ND/text/2344/id/1997656/North_Dakota-2019-2344-Enrolled.pdf
[75] Wy. HB 80, https://wyoleg.gov/2009/Bills/HB0080.pdf

the strata."[76] In Montana, Senate Bill 498 not only provided for unitization "upon the application of persons owning or holding subsurface storage rights of 60% of the storage capacity of the proposed storage area," but it also declared that pore space was the property of the surface owner unless the estate had legally been severed.[77]

Eminent Domain Legislation for Subsurface Storage in Other States

Several states have enacted eminent domain laws for acquiring underground storage rights, including Indiana and Louisiana.

Indiana SB 442 (2019): "Declares the underground storage of carbon dioxide to be a public use and service, in the public interest, and a benefit to the welfare and people of Indiana. Authorizes the establishment of a carbon sequestration pilot project […]. Provides that if the operator of the pilot project is not able to reach an agreement with an owner of property […], the operator of the pilot project may exercise the power of eminent domain to make the acquisition. Provides that the pilot project operator's acquisitions by eminent domain must be made through the law on eminent domain for gas storage, which provides that a condemnor, before condemning any underground stratum or formation, must have acquired the right to store gas in at least 60% of the stratum or formation by a means other than condemnation."[78]

Louisiana HB 661 (2009): Authorizes parties seeking to conduct geologic sequestration to use eminent domain, provided that all conditions for operating a geologic sequestration site are met. Eminent domain may be applied in acquiring surface and subsurface rights, including property interests necessary for constructing and operating geologic sequestration facilities and pipelines. Eminent domain cannot be used to acquire lands with active or potential oil and gas operations. CO_2 storage is declared to be in the public interest, with HB 661 stating that "the geologic storage of carbon dioxide will benefit the citizens of the state and the state's environment by reducing greenhouse gas emissions."[79]

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[76] Wy. HB 89, https://wyoleg.gov/2008/Enroll/HB0089.pdf
[77] Mt. SB 498, https://leg.mt.gov/bills/2009/billhtml/SB0498.htm
[78] In. SB. 442, http://iga.in.gov/legislative/2019/bills/senate/442#document-36b498ff
[79] La. HB 661, https://www.legis.la.gov/legis/ViewDocument.aspx?d=668800. See La. Stat. Ann. § 30: 1102.