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The Economic Implications of Carbon Capture and Sequestration for the Gulf Coast Economy

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Center for Energy Studies

About CES

The Louisiana State University Center for Energy Studies (LSU-CES) was created by the Louisiana Legislature in 1982 with the stated mission of conducting, encouraging, and facilitating research and analysis to address energy-related problems or issues affecting Louisiana's economy, environment, and citizenry. The Center's goal is to provide a balanced, objective, and timely treatment of issues with potentially important consequences for Louisiana.

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Gulf Coast Sequestration (GCS) commissioned LSU-CES to assess the economic implications of carbon capture and sequestration (CCS) for the Gulf Coast economy utilizing the GCS project as a case study. GCS provided information about the project and was given the opportunity to review and provide feedback on the report. The analysis and opinions expressed are those of the authors alone.

GULF COAST
SEQUESTRATION

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1 | Executive Summary

Countries around the world have made ambitious commitments and are implementing policies aimed at reducing greenhouse gas (GHG) emissions across their economies.[1] Simultaneously, private companies are making similar commitments and investments to reduce their carbon footprints across global value chains. Although some progress has been made to reduce emissions over the past decade, global anthropogenic greenhouse gas emissions continue along an upward trajectory, posing both a significant challenge and an opportunity for the Gulf Coast region of the United States, namely southern Louisiana and Texas.

It is useful to examine the Gulf Coast region for two reasons. First, the region, and the state of Louisiana in particular, has a uniquely large and highly concentrated industrial sector responsible for both significant greenhouse gas emissions and significant employment. While the industrial sector accounts for some 22 percent of GHG emissions nationwide, in Louisiana that number is 61 percent. Additionally, Louisiana and its neighbor Texas have an outsized number of industrial manufacturing facilities including refiners and petrochemical plants which account for approximately 14 percent of manufacturing employment (150,000 jobs) and over $23 billion in earnings (an average of $154,000 per worker) in the two states. Over the past decade (2011-2021), the Gulf Coast has supported more than $180 billion in energy manufacturing investment; as much as $5.5 billion on an average annualized basis. Decarbonizing the existing facilities is important for achieving environmental and economic goals but is also a technical challenge because these facilities are energy intensive.

Secondly, the Gulf Coast plays a significant role in the domestic energy market and in international energy trade. The Gulf Coast region is vital to American energy production, accounting for approximately two-thirds of U.S. oil production, more than 40 percent of natural gas production and approximately half of domestic refining capacity. Additionally, Gulf Coast-made petrochemical products are sold throughout the world. As energy demand, particularly in the developing world, is projected to grow, the Gulf Coast region is well situated to meet that growing demand through exports. Successful decarbonization can create a competitive advantage for the region, which can continue to export products such as liquid fuels, chemicals, fertilizers, and plastics globally. These products do not currently have viable substitutes. Thus, the Gulf Coast and products produced there have the potential to play a key role in both U.S. and global decarbonization.

This report focuses on how the Gulf Coast region of the United States might reduce its greenhouse gas footprint by capturing industrial carbon emissions and storing carbon dioxide (CO_2) permanently underground. The creation of a “carbon hub” can facilitate a market for carbon, where companies can have a viable strategy for reducing emissions from industrial sources. A planned project, Gulf Coast Sequestration in Calcasieu Parish in Southwest Louisiana, bordering Texas, serves as the case study for the paper. Gulf Coast Sequestration (GCS) is planning to build the first hub in the United States to permanently store CO_2 emissions. The target market is large industrial facilities that are increasingly seeking opportunities to safely reduce their lifecycle greenhouse gas emissions while preserving the employment and economic competitiveness of the region.

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[1] According to the United Nations, achieving the Paris Agreement goals will require emissions of 45 percent by 2030 and net zero by 2050.

The project will include three phases, and construction on all three phases will take approximately five years. Combined, the project is anticipated to have a capital investment of approximately $555 million. Once fully complete, GCS plans to store over 10 million tons of CO_2 per year for 30 years. The purpose of this report is to discuss the implications of establishing a market for carbon capture and storage (CCS) in the region and estimate the specific economic impacts of the construction and maintenance of GCS as a case study.

Potential economic implications of GCS are as follows:

- Utilizing the Environmental Protection Agency's (EPA's) social cost of CO_2, the project has the potential to abate climate damages by **$11.3 billion over its lifetime** by **sequestering a total of 300 million tons of CO_2**.
- Considering the construction and approximately 30 years of operations, the facility will pay a net present value (utilizing a 4 percent discount rate) of **$560 million in earnings** and **$980 million in Gross State Product regionally**, which includes the states of Louisiana and Texas.
- Nationally, the project will support an estimated net present value (again utilizing a 4 percent discount rate) of **$698 million in net present value earnings** and **$1.2 billion in U.S. Gross Domestic Product**.
- During the five years of construction, the project will support an estimated **977 jobs regionally** and **1,149 jobs nationally**.
- Once fully complete, on an annual basis, the project itself will support approximately **375 jobs nationally** paying **$21 million in earnings**. Regionally, it will support an estimated **286 jobs** and **$16 million in earnings** annually.
- We identify approximately **51 thousand jobs** in the refining, petrochemical manufacturing, and LNG export sectors **within 100 miles** of the GCS facility that have non-combustion emissions that are candidates for sequestration. There are over **95 thousand such jobs** within **200 miles** of the GCS facility.
- Considering the share of emissions that are "non-combustion," the sequestration capacity of the GCS facility once all three phases are fully operational, and the jobs at these facilities, we estimate that GCS has the potential to facilitate **the decarbonization of approximately 6,500 jobs**.
- As the U.S. government, and governments around the world, accelerate steps to address greenhouse gas emissions, pragmatic business leaders will increasingly shift towards their supply chains to reduce emissions. All else held equal, decarbonized jobs are less vulnerable to being replaced during the energy transition.

2 | Introduction

Deep underneath the U.S. Gulf Coast region lies a vast resource that has been at the heart of the regional economy for over a century. Since the Spindletop well was drilled near the Texas/Louisiana border in 1901, the region has played a critical role in the nation's energy landscape. The region's oil and gas resources have been the source of jobs, income and prosperity for many. The resources have also provided the needed energy to power vehicles, generate power, and produce heat across the United States and other nations. The global economy runs on energy, and the U.S. Gulf Coast is at the heart of the national and global energy landscape. The U.S. Gulf Coast accounts for approximately two-thirds of U.S. oil production, and more than 40 percent of natural gas production.[2] In addition, approximately half of the U.S. refining capacity is in the corridor between New Orleans, LA and Corpus Christi, TX. For a half century, southern Louisiana has been the base for offshore operations in the Gulf of Mexico that currently produces more than 15 percent of U.S. oil production.[3]

The petroleum-based economy thrived across the twentieth century. Fuel produced from oil is energy dense and, because it is liquid, easy to transport, making it ideal to power our transportation system. Oil has powered our military dating back to World War I, and after World War II, the petroleum-fueled automobile reshaped American life by enabling the creation of suburban areas. Today, oil continues to power our mobile society, supporting the 3.3 trillion ground vehicle miles traveled each year in the U.S. alone,[4] as well as the global aviation industry that has democratized air transportation and brought far-flung parts of the world closer together.

Natural gas is likewise a critical component of our energy landscape. It is used to generate over one third of all electricity in the United States,[5] all of which is dispatchable. Approximately half of the homes in the United States use natural gas for space heating and water heating.[6] Natural gas is used by industry in combined heat and power systems, as a raw feedstock to produce chemicals, fertilizers, and hydrogen, and for many other purposes. Given energy is essential for modern society, it is perhaps unsurprising that academic research has found that countries and regions with fossil fuel endowments have grown faster than countries and regions without vital fossil fuel endowments, and today are significantly wealthier on average.[7]

Along with the obvious benefits provided by oil and natural gas are significant challenges. Approximately 40 percent of petroleum production comes from only three countries: the United States, Russia, and Saudi Arabia.[8] Similarly, only three countries, the United States, Russia, and Iran, produce approximately 44 percent of the world's natural gas. These resource endowments have had far-reaching geopolitical implications over the past century. The need to secure supplies of oil or natural gas has played a role in several wars,[9] and other conflicts have caused restricted access

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[2] Dismukes & Upton, 2021. Gulf Coast defined as Texas, Louisiana, Mississippi, Alabama and the Gulf of Mexico itself. Although the vast majority of this is in Texas and Louisiana.

[3] U.S. Energy Information Administration. Petroleum & Other Liquids. Federal Offshore (PADD 3) as a share of Total U.S. Annual-Thousands Barrels. 2021.

[4] U.S. Department of Transportation. Bureau of Transportation Statistics. U.S. Vehicle-Miles. Highway, Total. Data from 2019. Total transportation miles unsurprisingly dropped in 2020 with the COVID-19 pandemic.

[5] U.S. Energy Information Administration. U.S. utility-scale electricity generation by source, amount, and share of total in 2022. Preliminary data as of February 2022.

[6] U.S. Energy Information Administration. Natural gas explained. *Use of natural gas*. Last updated: Dec 7, 2021.

[7] E.g. Allcott & Keniston (2018); Cassidy (2019); Oliver & Upton (2022).

[8] U.S. Energy Information Administration. International. Annual petroleum and other liquids production. Based on 5-year average from 2017 to 2020.

[9] Yergin, Daniel "The Quest: Energy, Security, and Remaking the Modern World," at 11, 231 (2011); McNally, Robert, "Crude Volatility: The History and the Future of Boom-Bust Oil Prices," Columbia University Press, at 161 (2019).

to those resources.[10] Most recently, energy security has been central to the geopolitical response to the current Russo-Ukrainian war. There are open questions to the extent to which OPEC today, and historically Rockefeller's Standard Oil and U.S. state regulators in partnership with major international oil companies, have served as constructive balancing authorities in stabilizing the price of oil.[11]

The effects of oil price shocks on global business cycles have also been debated in the academic literature for decades,[12] where energy price increases have been hypothesized to induce global recessions. And perhaps most importantly over the long term, both oil and natural gas generate carbon emissions that the Intergovernmental Panel on Climate Change (IPCC) estimates are the primary cause of the global increase in temperature that scientists have observed.[13] The IPCC has warned, and policymakers are increasingly in agreement, that the continued emissions of carbon and other greenhouse gases into the atmosphere will impact the very ecosystems in which we live, spurring the movement to transition our energy sector to reduce emissions of greenhouse gases.

As the world energy landscape plans to shift to a low carbon future, there lies under the Louisiana landscape another valuable resource.[14] There are vast volumes of space in geological formations, such as sandstone, limestone, and shale that can hold gas – vast quantities of gas, which can be used to sequester CO_2, the most ubiquitous greenhouse gas. As the world attempts to transition to a low carbon economy, one pathway is to place greater reliance on renewable sources of power.[15] Despite their promise, however, we will continue to rely on natural gas to generate dispatchable power and to support industrial processes for the foreseeable future.[16] The capture of carbon emissions and their sequestration can enable the continued use of natural gas for power generation and industrial uses by reducing or eliminating the emission of CO_2 into the atmosphere. As industry looks for approaches to adapt to a low-carbon economy while continuing to process or manufacture goods, the availability of geologic formations in which CO_2 can be stored can allow users to continue using natural gas and capture and store the emissions underground.

The opportunity to capture and sequester the emissions generated from fossil fuels is of particular importance to the Gulf Coast economy. Texas and Louisiana consume more natural gas in industrial applications than all other states. This reflects the importance of natural gas to the Gulf Coast's industrial economy, and both the value of the opportunity to sequester industrial CO_2 emissions and the importance of doing so as U.S. industry looks to reduce its carbon footprint. Given the role that oil and natural gas play in the regional economy and the trend towards decarbonization, the opportunity to undertake geologic sequestration of CO_2 has the potential to be a critical opportunity to support industrial activity.

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[10] See McNally (2019) at 135, 148; Yesica Fisch, Jon Gambrell, and Vanessa Gera, "Russia Cuts Off Gas to 2 NATO Nations in Bid to Divide West," AP News (Apr. 27, 2022).

[11] See McNally (2019) for a historical discussion of past periods of volatility and oil prices.

[12] E.g. see Hamilton (2009), Hamilton (1983), and Barsky & Kilian (2004).

[13] See IPCC AR5. The forward states: "The IPCC is now 95 percent certain that humans are the main cause of current global warming."

[14] Carbon capture potential also exists in Texas, but geologists have indicated that much of the potential for carbon capture is located specifically in Louisiana, and off the coast of Louisiana. This of course also extends into eastern Texas.

[15] Such as wind, solar, and hydroelectric.

[16] E.g. AEO (2022) states in its key takeaways that "Petroleum and natural gas remain the most-consumed sources of energy in the United States through 2050, but renewable energy is the fastest growing."

2.1 The Climate Challenge

The average temperature in the contiguous Unites States in 2021 was 54.5 degrees (Fahrenheit), 2.5 degrees above the average temperature for the twentieth century, and is estimated to be the fourth warmest temperature in the past 127 years.[17] The six warmest years on record have occurred since 2012,[18] and this is consistent with a trend in which the average temperature has risen 0.16 degrees per decade since 1901 and between 0.31 and 0.54 degrees per decade since 1979.[19] The global trend has also been increasing: the average global temperature has risen by at least 1.9 degrees since 1880, with much of the warming occurring since 1975, at a rate of 0.27 to 0.36 degrees per decade.[20]

The IPCC estimates that the primary cause for this observed increase in temperatures is due to the anthropogenic (i.e., human caused) emission of greenhouse gasses (GHGs).[21] The average concentration of CO_2, the predominant greenhouse gas, rose by 43.5 parts per million (ppm) between 2000 and 2020 to 412.5, almost 50 percent higher than the estimated pre-industrial levels of about 280 ppm.[22] According to IPCC AR6, atmospheric concentrations of CO_2 are estimated to need to stabilize around 350 ppm in order to limit the rise of average global temperature to 2 degrees centigrade by 2100.

The U.S. Environmental Protection Agency (EPA) has identified four major greenhouse gases, the most important of which is CO_2,[23] which enters the atmosphere as the result of combusting fossil fuels for transportation, power generation, and industrial uses, as well as during the production of agriculture and land use practices.[24] It also is emitted through process emissions from the production of cement, chemicals, and non-ferrous metals, which are the result of the chemical transformation of materials and not from the combustion of fossil fuel, as well as fugitive emissions, which is the inadvertent leakage of GHGs into the atmosphere.[25]

The effects of warmer temperatures are a source of extensive scientific examination. It is, without question, difficult to predict the future, especially with respect to such a complicated system as an entire planet. Nevertheless, scientists have studied the potential effects of climate change extensively. The IPCC has estimated that warmer temperatures will lead to more heat waves[26] and longer warm seasons. It also expects that rising temperatures will impact human health[27] and agriculture.[28] Its most recent report forecasts that changing water cycles will affect rainfall patterns,[29] thaw permafrost in the Arctic regions,[30] and reduce snow cover in aggregate globally.[31] Warming temperatures can

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[17] National Oceanic and Atmospheric Administration. News & Features. "U.S. saw its 4th-warmest year on record, fueled by a record-warm December." January 10, 2022.

[18] Ibid.

[19] United States Environmental Protection Agency. "Climate Change Indicators: U.S. and Global Temperature." Accessed April 8, 2022.

[20] The National Aeronautics and Space Administration (NASA). Earth observatory. World of Change: Global Temperatures. Accessed April 2022.

[21] See IPCC AR5. The forward states: "The IPCC is now 95 percent certain that humans are the main cause of current global warming.

[22] National Oceanic and Atmospheric Administration. Climate.gov. Climate Change: Atmospheric Carbon Dioxide. Published August 14, 2020. Updated October 7, 2021. By Rebecca Lindsey. Reviewed by Ed Dlugokencky.

[23] United States Environmental Protection Agency. Greenhouse Gas Emissions. Overview of Greenhouse Gasses. Accessed April 2022.

[24] Fischedick et al (2014).

[25] U.S. Environmental Protection Agency. Greenhouse Gas Reporting Program. Emissions Calculation Methodologies. Accessed April 2020.

[26] Intergovernmental Panel on Climate Change, "Climate Change 2020: Impacts, Adaptation and Vulnerability," at B.1.5, p. 6-21, 6-111, 6-117 (2022).

[27] IPCC at B.1.3., B.1.4, B.1.5.

[28] IPCC at B.1.3, B.4.2.

[29] IPCC at B.5.1.

[30] IPCC at B.1.2, B.5.2.

[31] IPCC at 2-19, 2-85, 10-39.

also affect the ecology of the oceans[32] and lead to rises in global sea levels,[33] impacting coastal communities around the globe.[34]

The physical effects of climate change might also have profound economic effects across the globe. A seminal paper in the economics literature states that “Climate change is the mother of all externalities: larger, more complex, and more uncertain than any other environmental problem.”[35] Anthropogenic climate change has the potential to have far reaching implications, such as property loss from flooding,[36] effects on agriculture,[37] and labor productivity,[38] among many others.[39] Moreover, these effects are unlikely to be evenly distributed across the globe, and those in low-income countries who have contributed the least to climate change are plausibly the most vulnerable to its effects.[40]

2.1.1. International Action

Because greenhouse gases mix in the atmosphere, the location of emissions has no effect on its contribution to global concentration in the atmosphere. As a result, any jurisdiction that decides to act will incur the costs of its action, but the climate benefits of such an action are distributed globally. Thus, for virtually any jurisdiction, the climate benefits it reaps from its actions will be less than the costs it incurs. Economists refer to this as a *global commons problem*.[41] For this reason, meaningful action to reduce anthropogenic effects on climate change realistically need to be global in nature.[42]

The nature of this problem has motivated a global call to action to address GHG emissions, which has been ongoing for three decades and is growing in volume. The public sector’s first substantial commitment to addressing climate change occurred at the “Earth Summit” in Rio de Janeiro in 1992, where 154 nations agreed to the United Nations Framework Convention on Climate Change in which they committed to ongoing scientific research regarding climate change, regular meetings of the parties to continue the conversation about climate change, and negotiations and future policy agreements to address climate change.[43] This process led to the Kyoto Protocol and the Paris Agreement, in which nations made commitments to address climate change. A myriad of other policies have been adopted across the globe to address climate change by national and sub-national governments.[44] For perspective on the growing attention of this topic globally, the Kyoto Protocol signed in 1997 included just 14 percent of global emissions, while the Paris Agreement signed in 2016 includes approximately 97 percent of global emissions.

Concurrent with these policy initiatives are the implementation by large international corporations of “environmental, social, and governance” (ESG) policies that include decarbonization commitments.

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[32] IPCC at B.1.1, B.1.2.

[33] IPCC at B.1.1, B.1.3.

[34] IPCC at B.2.5, B.3.1.

[35] Tol (2009).

[36] E.g. Eccles, Zhang & Hamilton (2019).

[37] E.g. Howden et al. (2007).

[38] E.g. Tol (2009).

[39] See Tol (2009) for a review of potential economic effects of climate change.

[40] Ibid.

[41] See Stavins (2011).

[42] For more discussion, see *Decarbonizing the Global Economy: Balancing Economic Efficiency and Political Feasibility*. 2022 American Economic Association. Panel Discussion. January 8, 2022.

[43] United Nations (1992). “Status of Ratification of The United Nations Framework Convention on Climate Change,” United Nations Framework Convention on Climate Change Interim Secretariat (1994).

[44] E.g. Baldwin et al. (2016) and Upton & Snyder (2017).

For example, some of the largest vertically integrated oil and gas firms, many of which have large Gulf Coast footprints (i.e., ExxonMobil, BP, and Shell) have made specific decarbonization commitments. Large publicly traded utilities in the Gulf Coast region, such as Entergy and American Electric Power (AEP), have also made such commitments.

It seems clear that the global call to address climate change, which began in earnest in the 1980s, has been growing in volume. But even as these calls to action have intensified, global greenhouse gas emissions continue along an upward trajectory. And even an industrialized country like the United States is likely to have petroleum and natural gas as the most-consumed sources of energy through 2050.[45] The questions for society today are: *Have we reached an inflection point? Will industrialized countries such as the United States and Western European countries experience the rapid decarbonization that is needed to meet the goals set forth in the Paris Agreement?* Only time will tell. But as the U.S. government, and governments around the world, accelerate steps to address greenhouse gas emissions, pragmatic business leaders will increasingly shift towards their supply chains to reduce emissions.

2.1.2. An Increasingly Global Economy

Modern societies are increasingly global in nature. Industrialized nations, such as the United States and Western European countries, have experienced remarkably consistent economic growth over the past century. As a result, people who are fortunate enough to live in these countries experience standards of living that are unprecedented from historical standards. But economic theory predicts that the developing world, in particular Asian countries like China and India, are anticipated to experience rapid economic growth over the next several decades, eventually “converging” with the developed world.[46] As this occurs, hundreds of millions of people will gain access to products that are taken for granted in the developed world, such as air conditioning and a vehicle. For perspective, the average income per worker in the United States is more than six times the level of China, and 30 times that of India.[47] Although the United States has a much higher standard of living, the United States has a population of 330 million people, compared to approximately 1.4 billion in both China and India. Thus, long-run energy demand growth is projected to lead to increases in U.S. hydrocarbon-based exports, especially to the growing developing world.[48] Due to the exporting nature of this industry in the Gulf Coast region, decarbonization of this region has the potential to play a key role in global decarbonization. The key is for the region to decarbonize both successfully and cost competitively.

2.1.3. Managing Carbon Emissions

Carbon emissions are ubiquitous across all sectors of the economy. They are generated by the combustion of fossil fuel to generate electricity, to power vehicles, to generate heat for commercial and residential buildings, and for cooking. They are also generated by agricultural activity, and by industry, not only in the combustion of fuel to generate heat or power, but also through non-combustion process

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[45] AEO (2022).

[46] This theory of convergence was originally conceptualized in the basic Solow-Swan neoclassical growth model (1956). See Johnson and Papageorgiou (2020) for a recent survey of the convergence literature.

[47] The World Bank. World Development Indicators. Comparison of net national income per capita (current US$) in 2019 (most recent year available).

[48] See Dismukes & Upton (2021).

emissions. Some of the activities that generate carbon emissions can be achieved without any carbon emissions, though often at a higher cost. Electricity can be generated using renewable resources or nuclear power, all of which do not generate carbon emissions when power is generated.[49] Vehicles can be powered by electric power, which eliminates tailpipe emissions, but the life-cycle emissions of electric vehicles are ultimately still impacted by the source of their electric power.[50] Many commercial and residential uses, such as heating air or water, or using gas to cook, can also be electrified. Even agriculture offers opportunities to reduce carbon emissions, through proper treatment of waste, for instance, though they are difficult to eliminate. Economic theory suggests that societies will reduce the lowest marginal cost emissions first. Thus, holding technology constant, the marginal cost of abating emissions might grow as “low hanging fruit” is picked, so to speak.[51]

Industrial processes are unlikely to be decarbonized through electrification alone.[52] A portion of industrial carbon emissions is generated by burning fossil fuels for on-site power, heat, or other industrial processes. In some instances, those applications may be electrified, presenting an opportunity to reduce source-point carbon emissions, though in some cases electrification is unlikely to substitute for combustion, because electricity cannot efficiently generate the heat required for a process. In other instances, including the production of chemicals, fertilizer, iron and steel production, and cement, the manufacturing process generates substantial non-combustion emissions. In those instances, it may be more difficult to reduce or eliminate carbon emissions because of the lack of alternative processes to manufacture the same goods. For those reasons, emissions from industrial production are typically thought of as “hard to abate.”[53]

Importantly, environmental regulations are not the same across countries, and therefore emissions leakage in response to environmental regulations has been a topic of study by economists.[54] Thus, if a country reduces its emissions, it will likely still import emission intensive products from other regions of the world. Recognizing this, the European Union (EU) and United States recently announced a plan to put aside past trade disputes and negotiate the world’s first carbon-based steel and aluminum trade, which together account for 10 percent of global emissions.[55] There have also been proposals for carbon border adjustments (i.e. a carbon tax) in both the U.S. and Europe.

As the global community looks to address climate change, there are several tools at our disposal. On the demand side, increased energy efficiency and conservation are perhaps a key means for reducing greenhouse gas emissions, but the effectiveness of such policies has been debated in the economics literature.[56] To this end, the government has established federal energy efficiency standards for over 60 categories of appliances, a process that began in the late 1970s, and remains in place today.[57] Likewise, the federal government further promotes the use of energy efficiency products through programs like Energy Star and tax credits that promote efficiency or conservation.

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[49] But of course have emissions associated with the lifecycle of each power source.

[50] Although as the U.S. electric grid has experienced emissions reductions, EVs likely have lower lifetime emissions. This is not necessarily the case, though, in all locations. See Holland et al. (2016).

[51] See any environmental economics text. E.g. Chapter 3 of Hanley, Shogren & White, Second Edition.

[52] Based on EPA Greenhouse Gas Inventory. Data from 2019.

[53] Max Ahman, “Unlocking the ‘Hard to Abate’ Sectors,” World Resources Institute (2019). Material Economics, “*Industrial Transformation 2050: Pathways to Net-Zero Emissions from EU Heavy Industry*,” Cambridge: University of Cambridge Institute for Sustainability Leadership (2019).

[54] E.g. See Fowlie (2009), Baylis, Fullerton & Karney (2014) and Fell & Maniloff (2018).

[55] White House, “Fact Sheet: The United States and European Union to Negotiate World’s First Carbon-Based Sectoral Arrangements on Steel and Aluminum Trade,” October 31, 2021.

[56] E.g. see Gillingham, Newell, and Palmer (2009) for a review of this literature.

[57] “The Department of Energy’s Appliance and Equipment Standards Program,” Congressional Research Service (Feb. 18, 2022).

The government's efforts have also extended into the transportation and power sectors, which are responsible for the largest share of carbon emissions. In the power sector, the government has a long history of supporting the development of wind, solar, geothermal, and other sources of renewable power. In the transportation sector, the government has supported the development and deployment of electric vehicles as a means to reduce petroleum-based emissions. Combined with increased use of renewable power, electrification can substantially reduce the transportation sector's carbon footprint.

While viable pathways to decarbonize the electric power system and the ground transportation system are described above, there remains the challenge of addressing emissions from activities where it is particularly difficult or expensive to eliminate carbon emissions. For those industrial activities described above, which fall within the universe of "hard to abate" emissions, carbon capture and sequestration offers a clear pathway to an improved carbon footprint, which can allow such activities to continue and thrive in a low-carbon environment. Under current technologies this is a realistic pathway for the region to achieve rapid decarbonization over the next decade. As such, CCS is poised to be an important part of the toolbox with which we will address greenhouse gas emissions in a manner that supports industrial activity and economic growth.

2.2 What is CCS?

Carbon capture and sequestration is the process of capturing CO_2 from fossil fuel use at large source points to be transported to safe geological storage, rather than being emitted into the atmosphere.[58] This process offers an opportunity to reduce net carbon emissions from facilities at which it might be difficult or impossible to eliminate the production of CO_2. In some cases, recovered CO_2 can be used as an industrial input or injected underground to assist in enhanced oil recovery. Where emitters capture more CO_2 than can be used, however, it can be stored safely in permanent underground repositories.

CO_2, in a supercritical state[59], can be injected into underground depleted oil and gas reservoirs, deep saline reservoirs, or unmineable coal seams, which are located below a layer of impermeable rock, such as shale, which can prevent leakage of the CO_2 into the atmosphere or Underground Sources of Drinking Water (USDW). When injected into reservoirs more than a half-mile deep, the pressure generally keeps the CO_2 in a supercritical state, reducing the likelihood of leakage.[60] The opportunity presented by CCS to capture CO_2 is significant. Although, there is significant uncertainty over how much geological capacity to sequester carbon exists in the United States, estimates range from 2.6 trillion metric tons to almost 22 trillion metric tons.[61] Though not all formations are economic, well-located, capable of meeting regulatory requirements, or available from their owners, there is still likely enough capacity to store many hundreds of years of U.S. CO_2 emissions at current rates.

Once captured at an industrial facility or power plant, CO_2 is generally purified and compressed for transportation. CO_2 is generally transported by pipeline, though occasionally by marine vessel. There

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[58] See Gibbins & Chalmers (2008) for an overview of carbon capture technologies.

[59] A supercritical fluid is a state of matter that has both gas-like and liquid-like properties. CO_2 is at a supercritical state above 31 C and 7.3 MPa

[60] Congressional Research Service, "Carbon Capture and Sequestration (CCS) in the United States," at 9 (Oct. 18, 2021).

[61] See CRS (2021) at Table 1.

are more than 5,000 miles of CO_2 pipelines in the United States, which generally transport CO_2 to oilfields for use in enhanced oil recovery operations.[62] CO_2 pipelines generally operate similarly to natural gas pipelines. Early CO_2 sequestration projects tended to be vertically integrated, where an industrial facility capturing carbon was connected to a dedicated pipeline to transport the captured CO_2 to its injection site.[63] This allowed the project to take advantage of sequestration as a valuable tool, which holds out the prospect of making an important contribution to addressing the climate challenge. In the past few years, several European CCS projects have been designed with connections to pipeline networks that allow them to receive CO_2 for sequestration from multiple facilities.[64]

Thirty-two commercial CCS projects were in operation in 2020 across the globe, of which 12 were in the United States (see Figure 14), with a total capacity of up to 35.5 million metric tons of CO_2 storage capacity per annum (mtpa), of which 16.83 mtpa is in the United States.[65] These projects sequester CO_2 from natural gas processing, fertilizer production, petrochemical production, hydrogen production, power generation, iron and steel production, and ethanol refining. Another 19 projects are in various stages of development in the United States. The growing interest in CCS is reflected in the inclusion of more than $6 billion in CCS research, development, and demonstration projects in the U.S. Energy Act of 2020. Then, in the summer of 2022, the Inflation Reduction Act extended and expanded Section 45Q tax credits. Credits are now available for between $60 and $85 for each ton of CO_2 sequestered, for facilities where construction begins before 2033, provided that certain wage and employment qualifications are met. This enhanced support for CCS reflects the understating that it is a critical technology because it offers a path to decarbonization for industries and technologies that are particularly difficult to decarbonize.

2.2.1. Regional Significance of CCS

As will be highlighted throughout this report, the Gulf Coast region and Louisiana specifically, has an outsized share of industrial emissions. The region is home to critical petrochemical and crude oil refining industries, which are among the most energy intensive industries in the country. The petrochemical and fertilizer industries are among the largest industrial emitters of process carbon emissions.[66]

Given its composition, and the fact that these products are shipped all over the world, the emissions intensity of the region's manufacturing base is likely to be increasingly considered by customers of these products. Pragmatic companies will respond to this incentive, not only in adjusting their manufacturing processes, but also in their decision of where to locate. Thus, the region's ability to attract new investments is also likely to be affected by individual companies' ability to operate in a low emission environment. For business to be able to operate in a carbon constrained world, it needs a path to manage, and ultimately reduce, its carbon footprint. Addressing carbon emissions is likely to be important in the future because of government regulation and because there is a growing preference in the economy for goods that are produced in a responsible manner with as light a carbon footprint as is feasible. While there may be some opportunity to reduce industrial emissions by

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[62] See CRS (2021) at 8.

[63] Global CCS Institute (2021) at 18.

[64] Global CCS Institute (2021) at 18.

[65] Global CCS Institute (2021) at 62-63.

[66] Environmental Protection Agency, "Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2020," at 2-18, 4-1, 4-2 (2022).

shifting to reliance on renewable power, a complete shift would be both difficult and expensive, and it will be impractical to reduce or eliminate some process emissions.

One opportunity for emissions reductions lies in the region's geology. The region is rich in geologic formations in which captured carbon can be sequestered permanently underground. This geology presents the opportunity to be among the first regions to embrace carbon sequestration as a tool to help transition to a low carbon economy. While the United States has 13 carbon sequestration projects in place, all but one of them inject carbon for the primary purpose of enhanced oil recovery. Only one project, an Archer Daniels Midland corn processing facility in Illinois, is dedicated solely to carbon sequestration, and that project serves a single industrial facility.[67] There is clearly an opportunity to advance CCS technology, and a new Louisiana company is planning to provide a solution to benefit the region.

Gulf Coast Sequestration is planning to build and operate the country's largest geologic sequestration facility to date, partnering with industrial customers to capture CO_2 and safely contain it underground. Located in Southwest Louisiana between the Sabine River and Lake Charles, GCS controls both the surface and subsurface rights for a large, contiguous landholding located in close proximity to one of the nation's busiest industrial corridors, including some of the largest refiners and manufacturers. Its location allows for the development of the nation's first regional sequestration "hub," capable of securely storing CO_2 volumes from multiple large industrial customers, in a well-studied, high-quality pore space that is ideally suited for safe carbon storage.

The GCS project can effectively demonstrate to the nation the opportunity for CCS to help meet our climate goals. It can offer a path for industry to adapt to a low-carbon economy by capturing carbon emissions from industrial facilities. Designed as a hub and connected to a network of pipelines, it can allow the continued operation of multiple industrial facilities. In doing so, the GCS project will operate as critical infrastructure that will allow continued growth of the Gulf Coast industry in a low-carbon economy.

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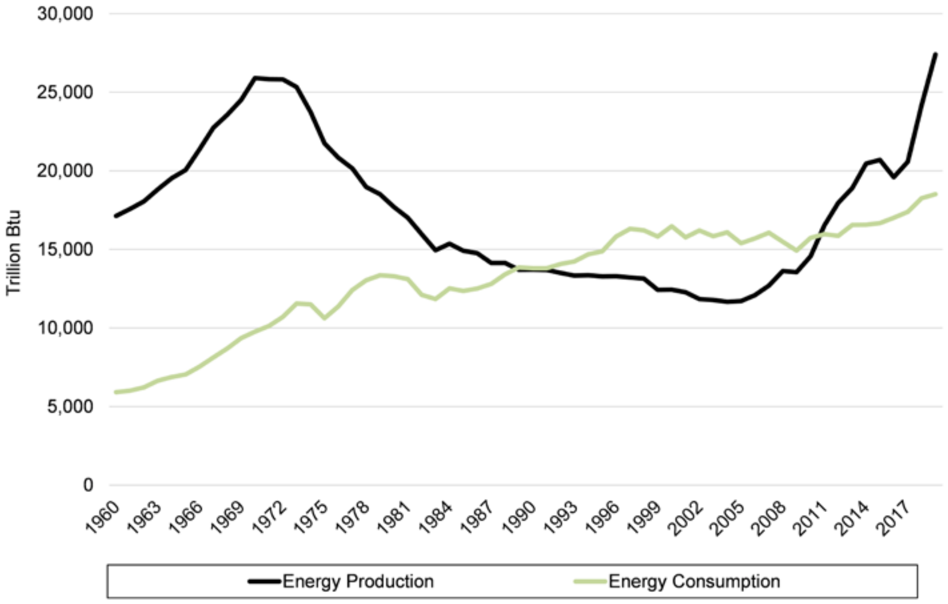
[67] Global CCS Institute (2021) at 62-63; Archer Daniels Midland, "Illinois Industrial Carbon Capture and Storage Project," (2017); CRS (2021) at 15.

3 | The Importance of Industrial Decarbonization for the Gulf Coast

The Gulf Coast has a large, energy-intensive economy. Figure 1 shows the clear upward trend in energy consumption over the past half century or so. From 1960 until 1989, the region was a net energy producer, meaning the total British thermal units (Btus) of energy produced exceeded the regional demand for energy. But as U.S. oil production declined both regionally and nationally, energy production declined below energy consumption, making the region a net energy consumer. This period was characterized by refining and chemical manufacturing industries that relied on feedstocks imported from other parts of the world that would then be processed and sold to other parts of the country and world.

But fortunes began to reverse in 2005, when oil and gas firms learned how to economically produce natural gas shale geological formations, beginning with the Barnett Shale in Texas. Around 2009, companies adapted this technology to produce oil. This upward trend has continued, and in 2011, the region once again became a net energy producer. Today, the Gulf Coast has a robust energy-based economy that balances production of energy with the manufacturing and processing into liquid fuels, chemicals, fertilizers, and plastics. These products, as well as oil and natural gas itself, are transported all over the United States and worldwide through the robust port system that accesses the Gulf of Mexico. For perspective, the total exports of energy products in Texas and Louisiana account for approximately 10 percent of the total economic activity in these states.[68]

Figure 1: Regional energy consumption and production



Source: U.S. Energy Information Administration. State Energy Data Systems (SEDS) and authors' calculations. Includes states of Texas and Louisiana.

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[68] Source: Exports data from U.S. Census Bureau's USA Trade Online. Includes NAICS sectors 211, 324, and 325. Gross state product obtained from the U.S. Bureau of Economic analysis. Averages over most recent five full years of data; 2017-2021.

The region is also increasingly focusing on midstream energy investments that include various types of storage facilities, product and chemical pipelines, and processing. These midstream investments themselves are becoming more focused on moving energy commodities, of various types, from domestic locations into international commerce, not simply moving these commodities back and forth across the Gulf Coast. A good example of this new international focus is highlighted by the billions invested in Southwestern Louisiana in liquefied natural gas (LNG) export facilities. Each major LNG investment runs in the \$2 billion to \$3 billion per "train" of liquefaction capacity.

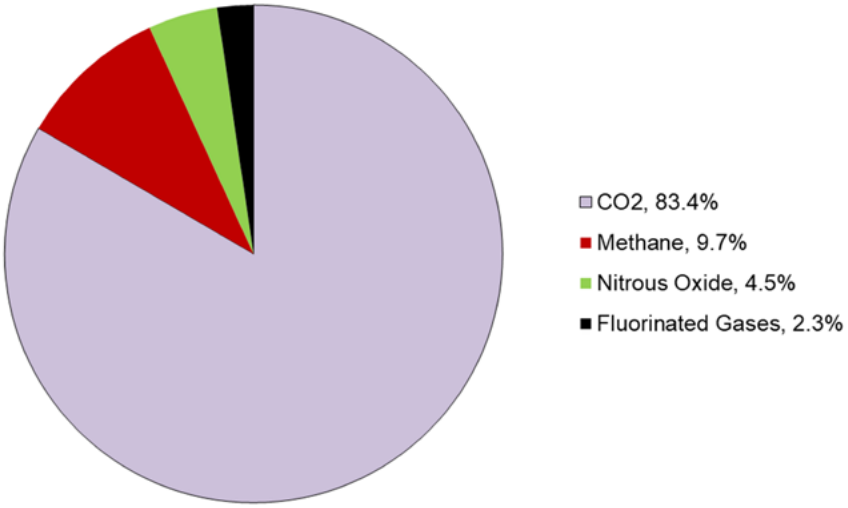
However, these burgeoning economic opportunities are facing challenges in reconciling existing and proposed energy manufacturing investments with state and federal GHG emission reduction goals. Unfortunately, many of these energy intensive industries have large and geographically concentrated GHG emissions. Understanding the size, location, and scope of these GHG emissions is important in understanding both the challenge of reducing Louisiana's GHG emissions and importance that CCS, and projects like GCS, will have in maintaining and expanding Louisiana's economic base.

In addition, it is critical to understand and appreciate the important contribution these industries make to the local and regional economy. Neither Louisiana nor coastal Texas wants to see these important energy manufacturing sectors lose their economic competitiveness due to an inability to react to changing climate policies, rules, and regulations. The following subsections discuss each of these considerations (emissions, economic importance) in greater detail.

3.1 Regional Industrial Greenhouse Gas Emissions

While the media and popular press often discuss CO_2 and generally "carbon" emissions when talking about climate related challenges, GHGs are a combination of a variety of differing emissions as shown in Figure 2. Many of these additional GHGs are emitted by industrial sources through various manufacturing processes or hydrocarbon uses.

Figure 2: Regional GHG emissions and emission shares

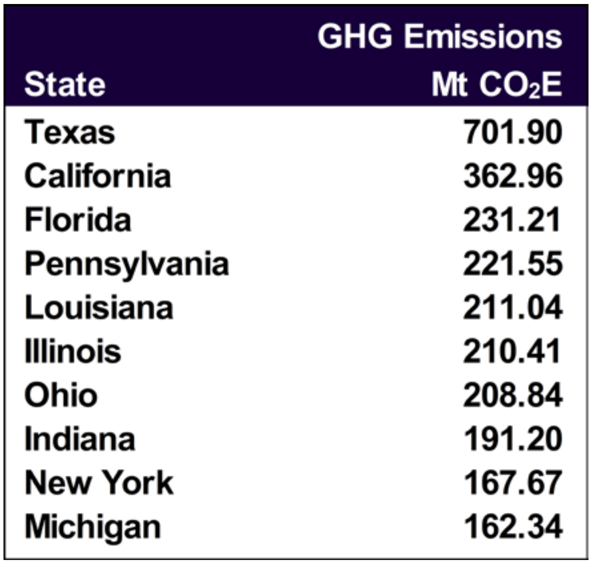


Source: United States Environmental Protection Agency. State GHG Emissions. Author's calculations based on Dismukes (2021). Includes states Texas and Louisiana.

Roughly 83 percent of all GHG emissions in Louisiana and Texas come from the combustion of fossil fuels. The remainder of the GHG emissions are typically associated with various industrial production releases. Methane releases, for instance, account for 10 percent of all GHG emissions. These methane emissions, while small relative to combustion activities, have a global warming potential (GWP) that are 27-30 times the impact of a standard CO_2 molecule. Although the half-life of methane in the atmosphere is estimated to be 12 years, relative to the estimated 100 year + half-life of CO_2, methane releases occur in refining operations, as well as across the entire crude oil and natural gas value chain (i.e., production, transportation, and distribution).

As shown in Table 1, Texas and Louisiana are the first and fifth leading GHG emitting states, owing in large part to the states' large, energy intensive industrial base. Note that although Louisiana ranks fifth in state-level GHG emissions, it is behind much larger states such as California, Florida and Pennsylvania. For perspective, Texas GHG emissions are 3.3 times those reported in Louisiana, whereas California's GHG emissions are over 1.71 times the Louisiana GHG emissions level. California (Texas) has over eight (six) times the population of Louisiana.

Table 1: Top 10 GHG emitting states (2018)

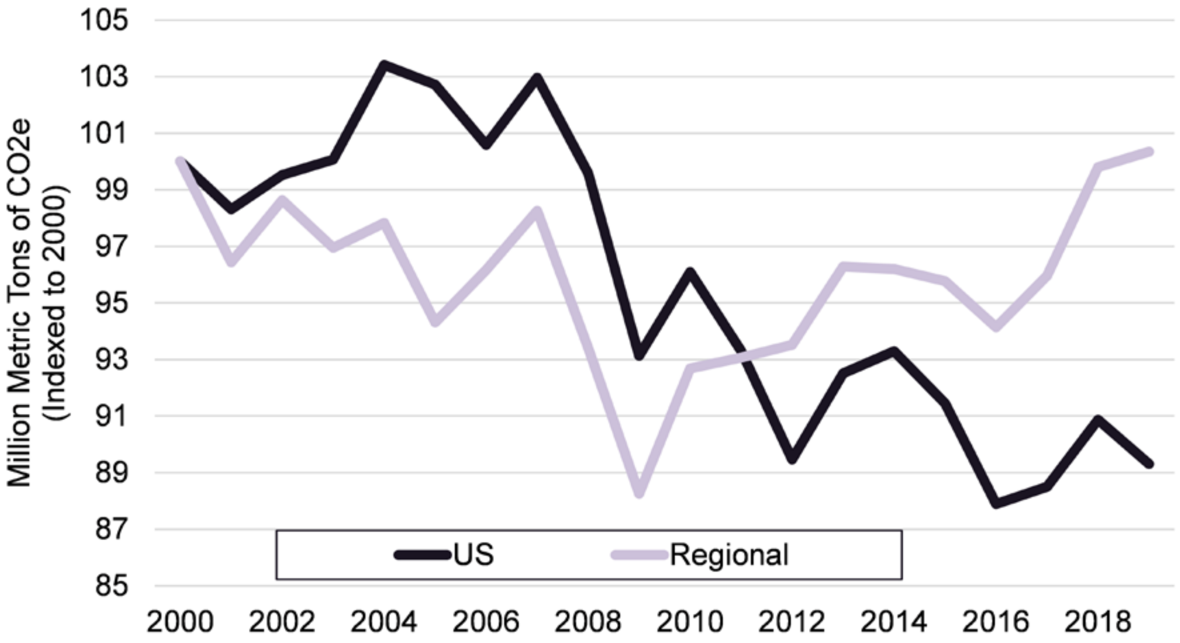


State	GHG Emissions Mt CO_2E
Texas	701.90
California	362.96
Florida	231.21
Pennsylvania	221.55
Louisiana	211.04
Illinois	210.41
Ohio	208.84
Indiana	191.20
New York	167.67
Michigan	162.34

Source: *U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018, 2022; and Environmental Protection Agency, State CO_2 Emissions from Fossil Fuel Combustion, 2022.*

Figure 3 compares regional GHG emission trends to U.S. totals. Regional GHG emission trends were decreasing from 2002 until their minimum level in 2009, when they were approximately 88 percent the level experienced in 2000. But as oil production from shale formations increased, alongside billions of dollars in energy manufacturing, in 2019, for the first time, regional emissions eclipsed the emissions levels experienced in year 2000. Unlike the region, U.S. GHG emissions continued to grow from 2000 until 2006 at which time these emissions started to decrease as the overall U.S. power generation fuel mix began its transition away from coal and into natural gas and renewables. The downward trend in total U.S. GHGs is primarily the result of fuel switching from coal to natural gas and renewables in the power generation sector. While the Gulf Coast region has also seen a recent reduction in power generation related GHG emissions (although not shown here), those GHG emission reductions have primarily been driven by enhanced thermal efficiencies by the state power generators but not through fuel switching.

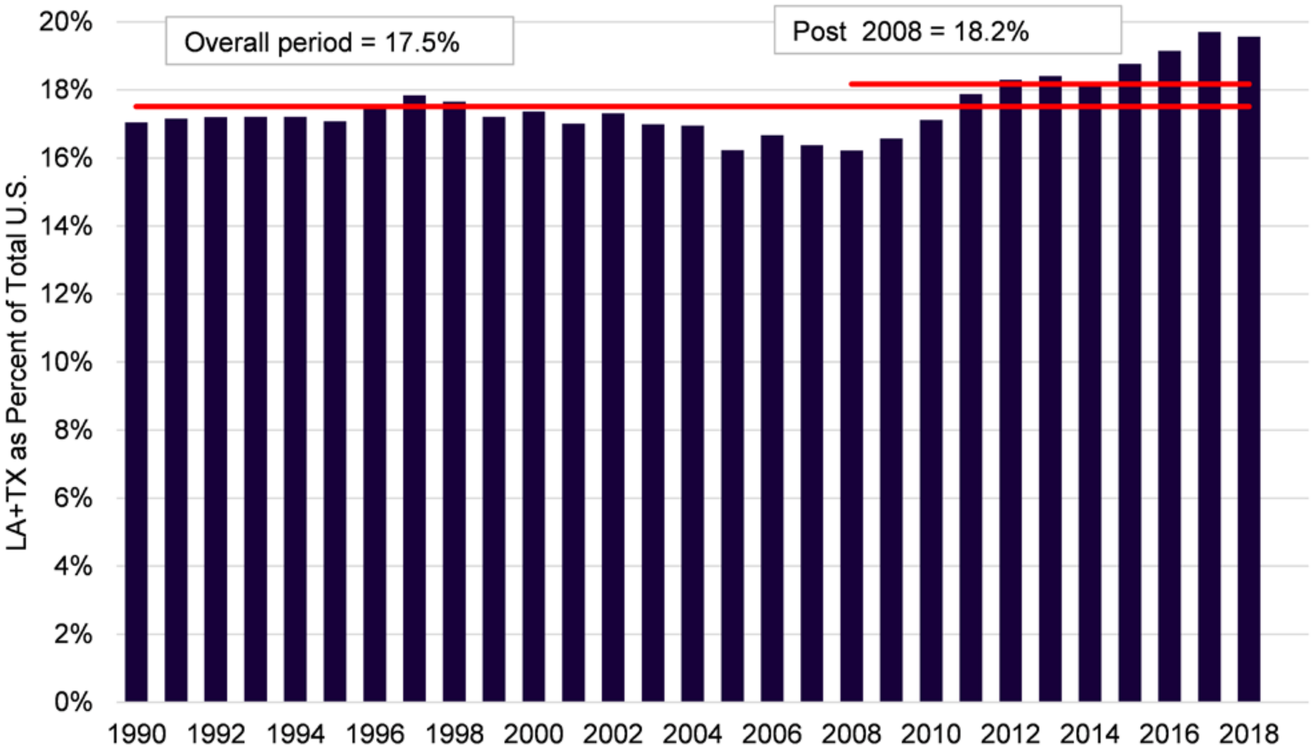
Figure 3: U.S. and regional GHG trends



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*, 2022; and Environmental Protection Agency, *State CO_2 Emissions from Fossil Fuel Combustion*, 2022. Region includes the states of Texas and Louisiana.

Historically, regional GHG emissions have hovered between 16 and 18 percent of total U.S. GHG emissions. Figure 4 shows that throughout the early 1990s, when natural gas prices were low, and the energy manufacturing base was prospering, the region's GHG emissions were closer to 17 percent of total U.S. GHG emissions. Regional GHG emissions as a share of total U.S. GHG emissions fell during the 2000s, when natural gas prices were high, and a considerable amount of chemical production was "offshored." The industrial renaissance in Louisiana and Texas, which started around 2008 with the shale revolution, led to a substantial increase in industrial production, as well as new industrial investment, that also contributed to an increase in GHG emissions. With this increase, regional GHG emissions have now eclipsed 19 percent of total U.S. GHG emissions.

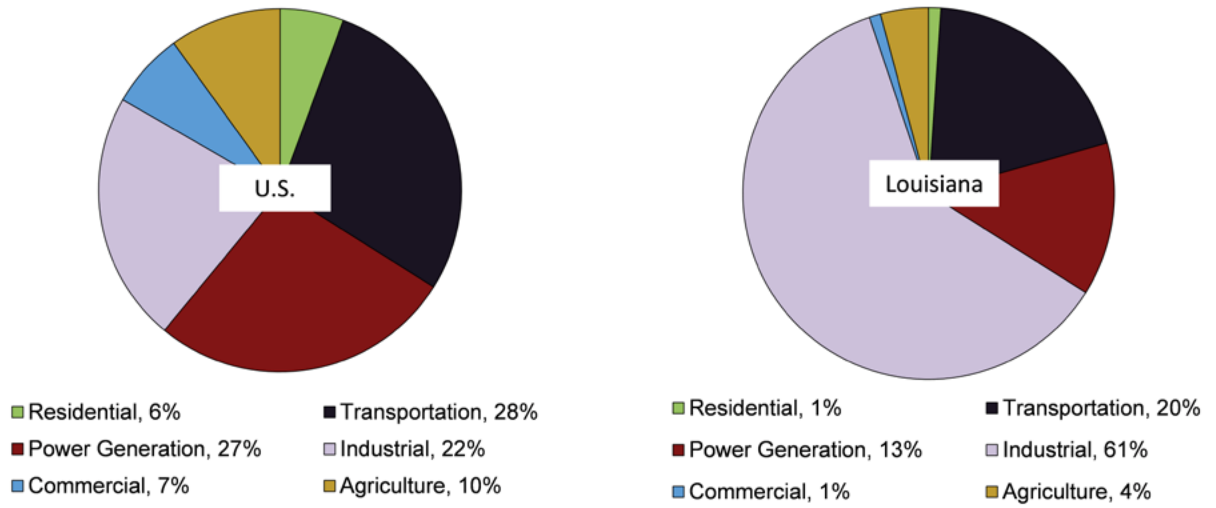
Figure 4: Regional GHG emissions as share of U.S. total GHG emissions



Source: *U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018, 2022; and Environmental Protection Agency, State CO_2 Emissions from Fossil Fuel Combustion, 2022. Region includes the states of Texas and Louisiana.*

Focusing now on Louisiana, the specific location of the GCS project, the composition of Louisiana's GHG emissions differs considerably from U.S. averages. Figure 5 compares the sectoral disposition of GHG emissions at the national and Louisiana level and shows that while industry comprises 22 percent of total U.S. GHG emissions, that share is as high as 61 percent in Louisiana. Likewise, while the power generation sector accounts for 27 percent of total U.S. GHG emissions, power generation only accounts for 13 percent of Louisiana's GHG emissions given the state's higher-than-average reliance on natural gas and nuclear power. Thus, this further corroborates the importance of addressing industrial emissions if Louisiana, and the Gulf Coast region, are to achieve decarbonization goals.

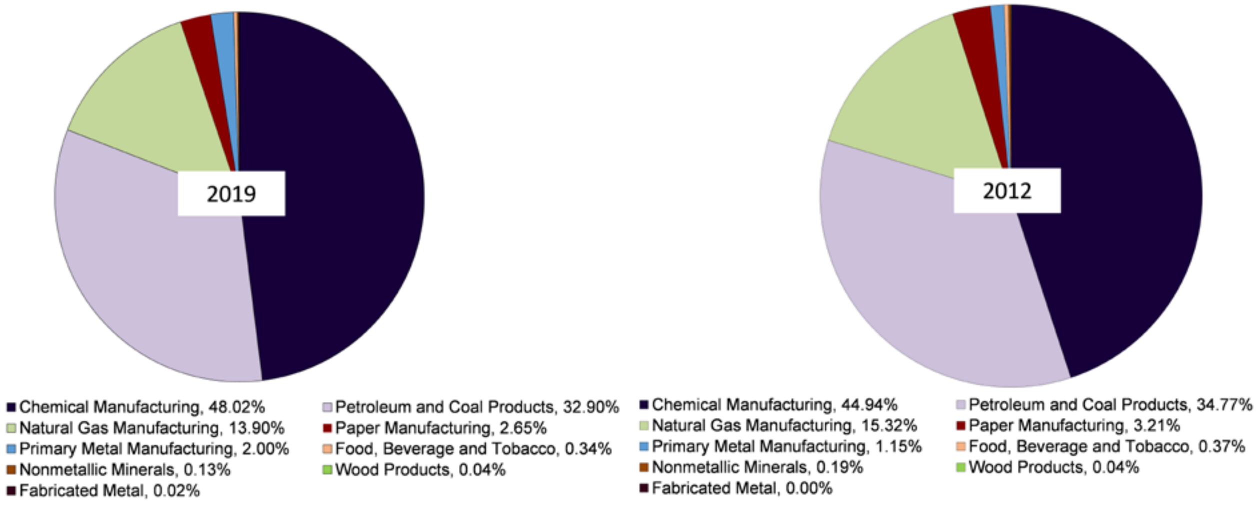
Figure 5: U.S. and Louisiana GHG emissions per sector



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*, 2022; and Environmental Protection Agency, *State CO_2 Emissions from Fossil Fuel Combustion*, 2022.

Louisiana's industrial GHG emissions have been and continue to be highly concentrated in the chemical industry, followed closely by refinery operations. Figure 6 compares the disposition of GHG emissions across Louisiana industry, which shows (1) a relatively stable break-out of shares across industry segments (comparing recent 2019 shares to 2012 shares), (2) a high concentration in chemical and refining (combined at close to 80 percent of total industrial GHG emissions), and (3) a large dispersion of residual GHG emissions across numerous smaller industrial sectors. What is perhaps most notable in the context of potential for CCS, is that the top 20 industrial facilities in Louisiana account for close to half of the state's industrial GHG emissions (42 percent) totaling between 48 million metric tons (2012) and 61 million metric tons per year (2019).[69]

Figure 6: Louisiana industrial GHG emissions per sector



Source: Environmental Protection Agency. FLIGHT data. 2022.

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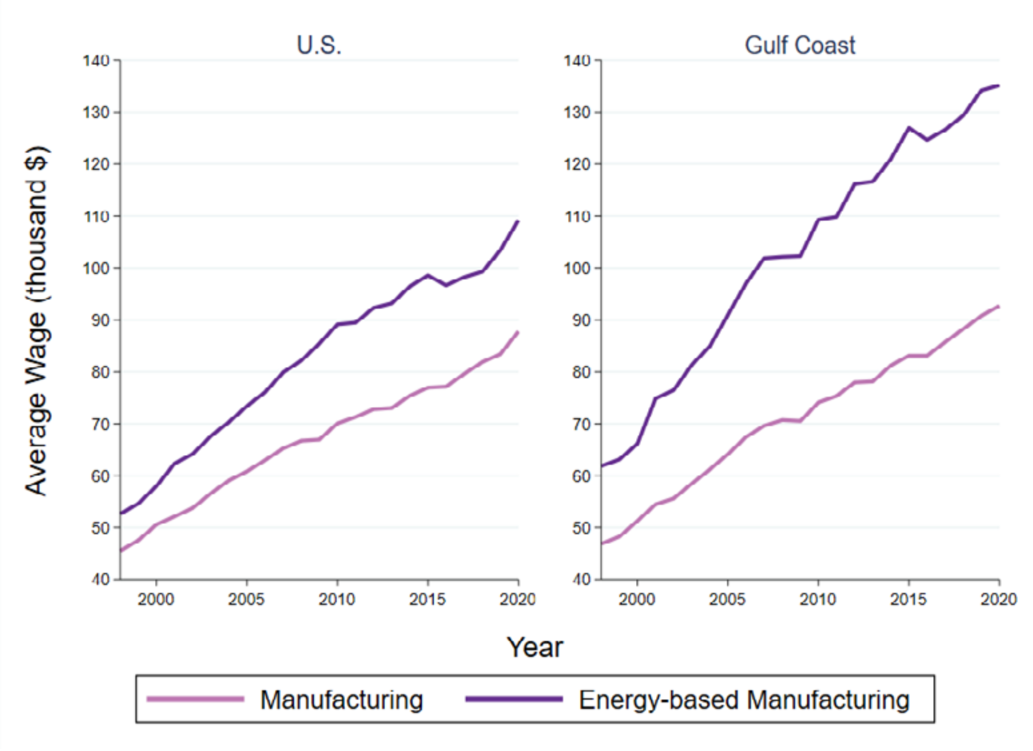
[69] See Table 6 of Dismukes (2021). Authors are not aware of a comparable analysis for Texas.

3.2 Importance of Energy Manufacturing

The Gulf Coast economy relies heavily on industrial activity, particularly that activity associated with energy manufacturing. While traditional manufacturing is capital intensive and uses a variety of resources to make various goods and products, energy manufacturing tends to be even more capital intensive, relying on scale, as well as forward and backwards economic linkages to create efficiencies. Further, and equally important, is the fact that energy manufacturing uses energy as a primary input, typically as a feedstock, in creating various types of intermediate and final products. Energy manufacturing industries, like chemicals and refining, compete globally on usually very thin margins across standardized, relatively homogenous products. Thus, small changes in operating costs, which are often determined by local conditions, can impact overall plant-level profitability, and continued economic viability.

Figure 7 compares manufacturing wages to those earned in energy manufacturing, for both the U.S. and the Gulf Coast region. It is well recognized that manufacturing jobs tend to pay higher than average wages. What is less well appreciated is that energy manufacturing jobs, as an important subset of overall manufacturing, pay even higher wages and, since 2008, have seen wage increases at rates that are faster than U.S. average manufacturing wages. In 2020 energy-based manufacturing wages were approximately 25 percent higher than U.S. manufacturing in aggregate. Similar energy manufacturing trends exist for the Gulf Coast region, including Louisiana and Texas. Specifically, in 2020, energy-based manufacturing wages were 46 percent higher than average Gulf Coast manufacturing wages, and as seen from the chart have increased at a much faster annual average rate (close to four percent) relative to average manufacturing wages (3.5 percent).

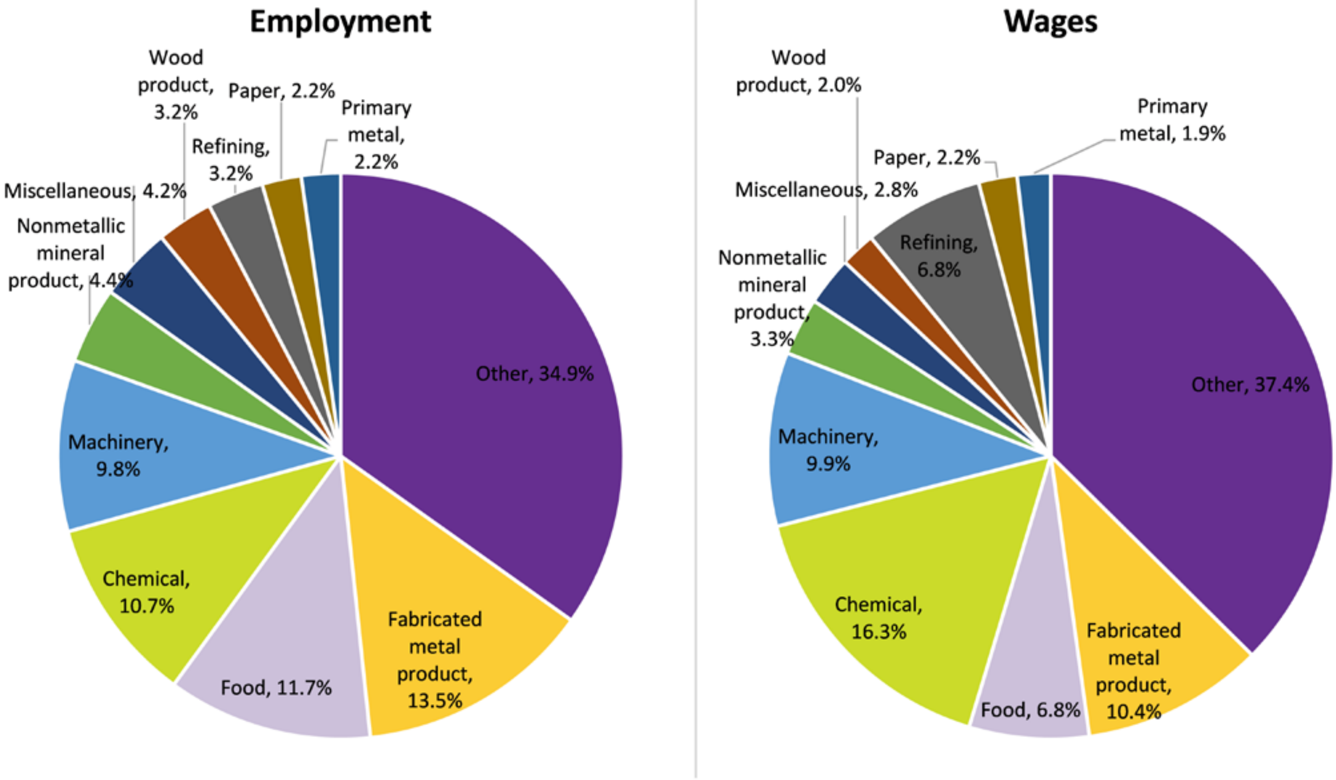
Figure 7: U.S. and Gulf Coast manufacturing wage comparisons



Source: Bureau of Economic Analysis, U.S. Department of Commerce.

Next, Figure 8 shows the share of employment and earnings by sector in Texas and Louisiana combined. In 2020, refining and chemical manufacturing employment accounted for approximately 14 percent of manufacturing employment, supporting over 150 thousand jobs directly between the two states. Not only are these sectors large employers, but they also play an outsized role in wages, accounting for 23 percent of manufacturing wages, or over $23 billion in wages. This averages approximately $135 thousand in wages per worker.

Figure 8: Regional manufacturing employment and wages by sector (2020)



Source: Bureau of Economic Analysis, U.S. Department of Commerce.

The regional energy manufacturing base continues to grow and has expanded to include new investments in facilities designed to facilitate the international trade of energy.[70] Figure 9 shows the energy manufacturing investments made in Louisiana as well as the Texas Gulf Coast. Over the past decade (2011-2021), the Gulf Coast has supported more than $180 billion in energy manufacturing investment; as much as $5.5 billion on an average annualized basis. These investments were evenly spread across Louisiana and the Texas Gulf Coast. Forecast project development, from 2022 forward, anticipates considerably more investment in coastal Louisiana, mostly dedicated to liquefied natural gas (LNG) export facilities.

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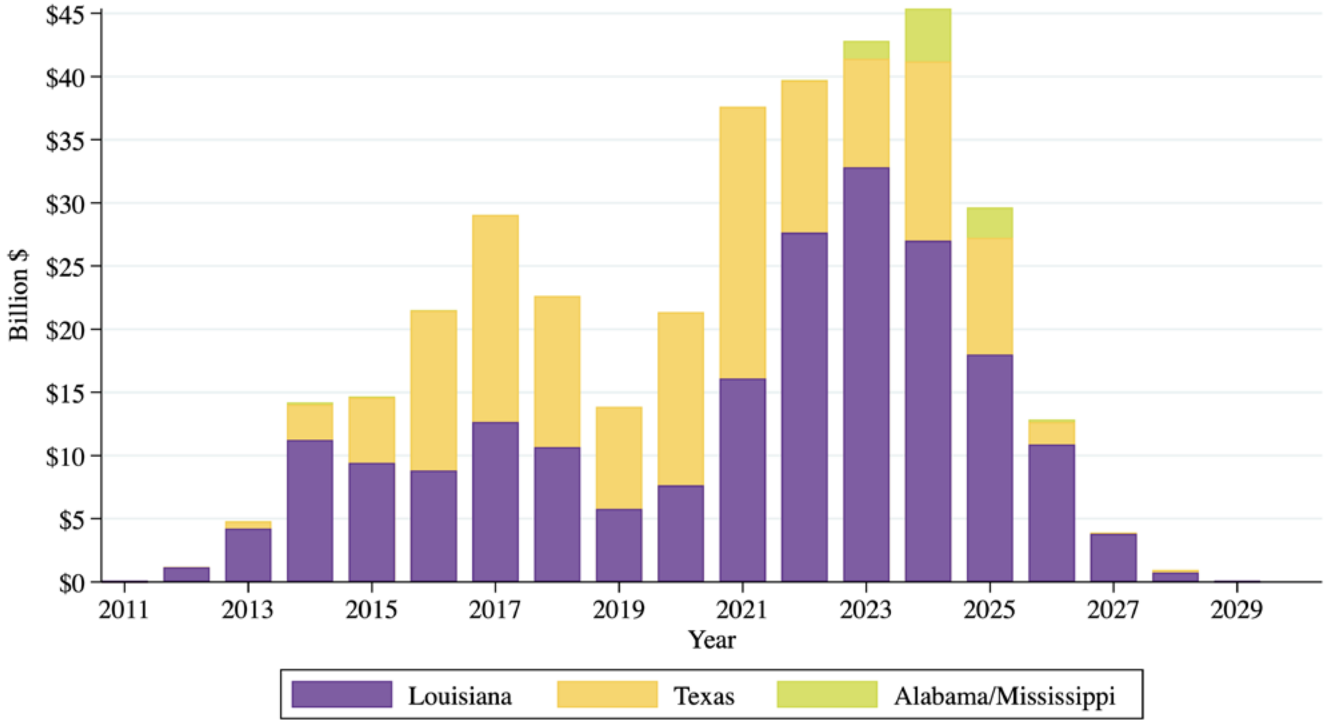
[70] Data based on Dismukes & Upton (2021)

Figure 9: GOM energy manufacturing and export investments by state



Source: *2023 Gulf Coast Energy Outlook*

Figure 10 breaks down total Louisiana and coastal Texas investments by type of energy manufacturing activity. Of the $180 billion in total investment through 2021, approximately 59 percent ($106 billion) is associated with such sectors as olefins, methanol, ammonia, with the remainder ($74 billion) being invested in LNG export facilities. As noted earlier, projected investments are heavily leveraged into additional LNG export facilities, most of which are located in the coastal areas of Louisiana, particularly southwestern Louisiana.[71]

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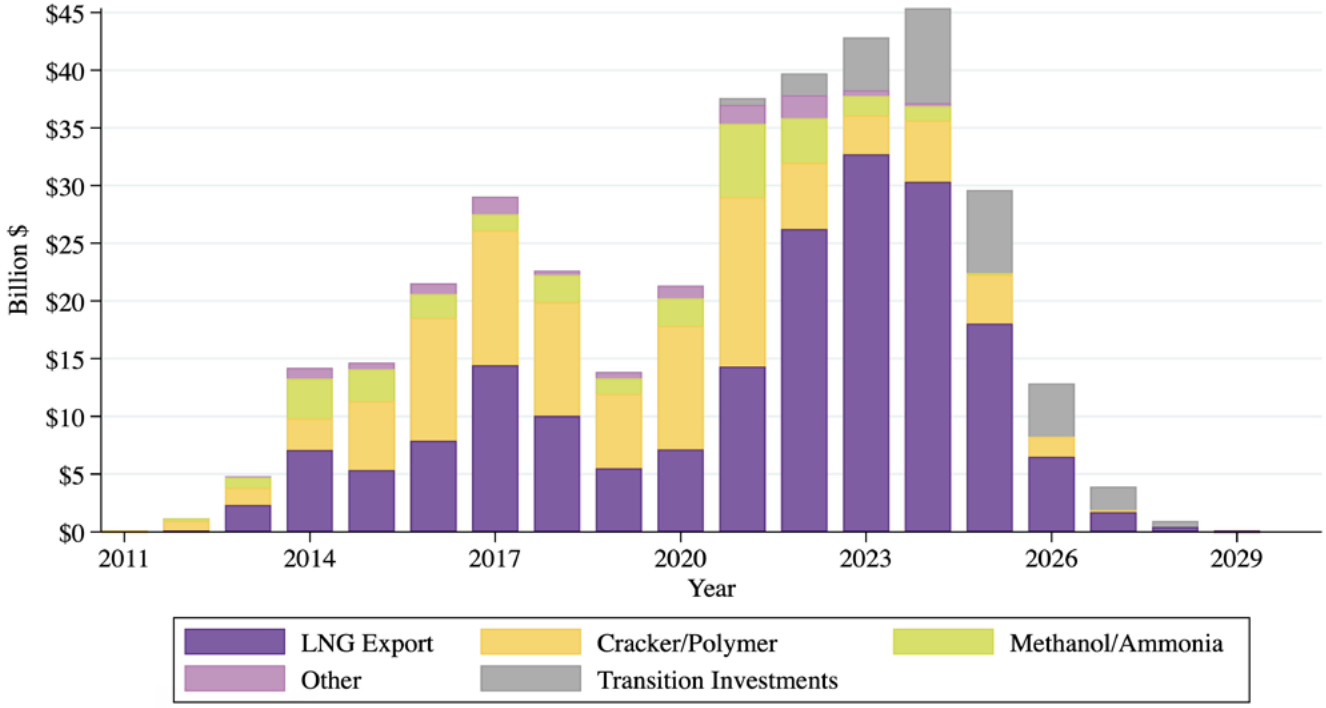
[71] For more discussion of regional investment, see the LSU Center for Energy Studies' *2023 Gulf Coast Energy Outlook*.

Figure 10: GOM energy manufacturing and export investments by type



Source: *2023 Gulf Coast Energy Outlook*

3.3 Summary

Gulf Coast Greenhouse Gas emissions are heavily concentrated with industry. While the development of renewable energy in power generation will be important, industrial emissions reductions are equally important. To illustrate this, in Louisiana specifically, overall power generation emissions are only 35 Mtpa relative to a statewide emissions total of over 200 Mtpa.[72] This is the real challenge for industrial decarbonization since (a) that is where the highest concentration of GHG emissions rests and (b) the alternatives and substitutes for traditional energy and combustion uses for industry are limited. As will be discussed later, the ability to use renewable, or "green," resources for steam and heat, while emerging, are still very nascent. In the short run, the regional economy has an opportunity to use bridge approaches that will allow for a leveraging of existing hydrocarbon resources in ways that capture GHG emissions and move industry to carbon neutrality.

The challenge for reducing industrial GHG emissions is not limited to cost and technology alone. As discussed above, energy manufacturing is a very important component of the regional economy. There are simply no substitutes for the significant economic contribution these industries provide using existing technologies. In addition, these industries pay wages and provide benefits that exceed what is commonly found in traditional manufacturing, much less the economy as a whole. Thus, the stakes of being successful and facilitating industrial decarbonization are significant.

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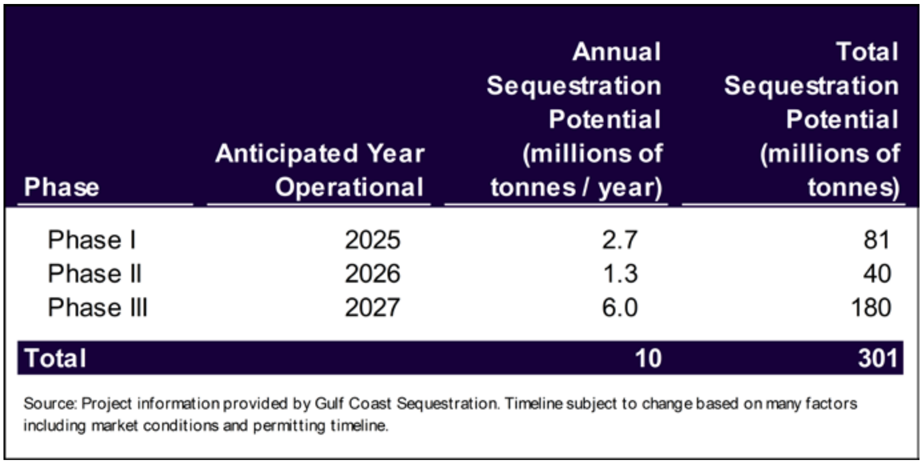
[72] See Dismukes (2021). Authors are not aware of a comparable analysis for Texas.

4 | The Proposed Gulf Coast Sequestration Project

As briefly introduced in Section 2, Gulf Coast Sequestration is planning to build the first hub in the United States to permanently store CO_2 emissions. The target market is large industrial facilities that are increasingly seeking opportunities to reduce their lifecycle greenhouse gas emissions to preserve the economic competitiveness of the region. The first phase of the project plans to store 2.7 million metric tons of CO_2 per year for the next 30 years. Phase II is expected to begin sequestering in 2026 and sequester an additional 1.3 million metric tons per year. Phase III is anticipated to begin sequestering in 2027 and is anticipated to sequester up to an additional 6 million metric tons per year. Table 2 shows the anticipated timeline and sequestration potential of the three phases of GCS. **In sum, GCS plans to construct a facility with three or more project sites that combined have the ability to sequester 300 million tons over 30 years, or about 10 million tons per year.**

Table 2: Gulf Coast sequestration timeline



Phase	Anticipated Year Operational	Annual Sequestration Potential (millions of tonnes / year)	Total Sequestration Potential (millions of tonnes)
Phase I	2025	2.7	81
Phase II	2026	1.3	40
Phase III	2027	6.0	180
Total		**10**	**301**

Source: Project information provided by Gulf Coast Sequestration. Timeline subject to change based on many factors including market conditions and permitting timeline.

Figure 11 shows the proposed location of Phase I. Phase II and Phase III are within several miles of the Phase I sequestration location. This is an attractive location due to the confluence of three factors. First, the site is located on wholly-controlled acres. This is a significant advantage as it eliminates the need to sign leases with, in some cases, hundreds of landowners. Second, and as will be discussed further in Section 5.3, there are approximately 51 thousand workers in the refining, chemical manufacturing, and LNG export sectors within a 100-mile radius of the facility with ample emissions for sequestration. Third, geologists have determined that the site has the correct subsurface characteristics for injection. The developers of the hub have access to proprietary data including extensive 3D seismic and proprietary well records to augment publicly available data. Geologists have analyzed this detailed data and determined that the property has (1) sufficient amount of storage volume, (2) cap rock to prevent CO_2 from migrating upwards, and (3) minimal pathways for CO_2 to move within the reservoir.[73]

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[73] Source: information provided by GCS. The authors of this report are not engineers or geologists, and therefore cannot comment on the technical feasibility of this, or any, CCUS project.

At the time of this writing, GCS has submitted two complete applications for Class VI Underground Injection Control permit from the U.S. Environmental Protection Agency (EPA) for Phases I and II. The hub is ready to move forward to construction and injection once the permits are received. GCS is currently in discussions with multiple industrial facilities to obtain contracts to sequester CO_2 once the project is complete. The goal is for Phase I to be sequestering CO_2 by early 2025, with all three Phases completed and operational in 2027.

Figure 11. GCS phase I location

Source: Provided by GCS

5 | Economic Impacts of GCS

Next, we estimate the economic impacts of the GCS project. The project will include three phases, with construction anticipated to occur over an approximately five-year period, beginning in 2023 and being completed in 2027. Importantly, this analysis only includes the economic impacts of the construction and operation of the facility. As highlighted previously, the broader economic implications of GCS and other carbon capture projects will be that they facilitate the decarbonization of Gulf Coast industry, potentially increasing the competitiveness of these sectors for decades to come. Notably, such broader economic implications are not included in the estimates presented in this section.

5.1 Modeling

To estimate the economic impacts of the construction and yearly operations of GCS, we use the Regional Input-Output Modeling System (RIMS II). RIMS II was created and is maintained by the Bureau of Economic Analysis (BEA), part of the U.S. Department of Commerce. RIMS II is an input-output (I-O) model that is based on a detailed set of industry accounts that measure the goods and services produced by each industry. Large underlying data sets trace the flow of goods and services throughout the economy to final users. RIMS II is considered a backward linkages model, in that an increase in demand for an output results in an increase in demand in inputs needed to create those outputs.

Importantly, commodity flows are area specific, therefore allowing modelers to consider the impact of specific investments in specific locations. In addition to RIMS II, we utilize data from other government agencies such as the United States Census Bureau and the United States Bureau of Labor Statistics.

Both “Type I” and “Type II” multipliers are provided by RIMS II. Type II multipliers account for both the inter-industry and household spending of a final demand-change. Type I multipliers account for only the inter-industry effect. Thus, Type II multipliers, by definition, are larger than Type I. Utilizing these multipliers, authors further dissect economic impacts into “Direct,” “Indirect,” “Induced,” and “Total” impacts. Where total impacts are identical to RIMS II Type II multipliers, and Direct + Indirect impacts are identical to RIMS II Type I multipliers.

We examine impacts on employment, earnings, and value added. Employment includes counts of workers at establishments that employ workers in relevant sectors. Earnings (synonymous with “labor income”) includes wages and salaries, proprietors’ income, plus employer contributions to insurance, pensions, and social insurance. Value added represents the contribution to gross domestic product (GDP). Earnings is one component of value added. Horowitz and Planting (2009) provides more detailed information on RIMS II and interpretation of the multipliers.

We utilize the study area of Texas and Louisiana as well as the continental United States in total. This is done for two reasons. First, the project is near the Louisiana-Texas border, and thus naturally lends itself to aggregating study areas. Second, aggregated economic impacts will next be allocated across all counties/parishes across both states. Economic impacts will be allocated based on gravity models of trade, for which a region’s share of total impacts is based on both its distance from the project location as well as the sectoral employment in that region. Therefore, counties and parishes that are closer in geographic proximity and have larger labor markets will be allocated larger shares of the economic impact.

Tax impacts are based on the state-local tax burden as a percentage of state income as reported by the Tax Foundation.[74] Federal tax receipts are estimated utilizing federal receipts as a percent of Gross Domestic Product from the U.S. Office of Management and Budget.[75]

We will also separately estimate tax impacts for Calcasieu Parish—the parish hosting the project. Utilizing project-specific information, we will estimate the specific property taxes to the parish considering the Industrial Tax Exemption Program (ITEP). Direct property tax estimates are based on a 25-year depreciation schedule (Louisiana Tax Commission [LTC], General Business Asset Guidelines, Table 2503.D), the 2020 millage rate for Calcasieu Parish (LTC annual report), and capital expenditures provided by GCS. The estimated direct property taxes paid to Calcasieu Parish are added to the local taxes generated by the economic activity more broadly, and these are projected out over a 30-year time frame. The net present value at different discount rates of local tax revenues to Calcasieu parish will be reported.

It is important to note that all tax estimates are just that: estimates. Many factors can change, especially over a 30-year time horizon. We do not recommend tax estimates be used for budgetary purposes, but instead be used to provide perspective to local decision makers and the community.

Utilizing project data provided by GCS alongside estimates of regional purchasing shares, we allocate direct expenditures between in-region and out-of-region purchases. Importantly, expenditures associated with the project that are imported into Louisiana and Texas (and therefore not produced here) are excluded from economic impacts.

5.2 Results

5.2.1. Economic Impacts

Table 3 shows economic impacts during the five-year construction phase of the project as well as yearly impacts once the facility is fully operational. The table also shows economic impacts for both the entire continental United States and for the Gulf Coast study area, which includes the states of Texas and Louisiana. Nationwide, it is estimated that approximately 1,149 workers will be supported per year during the approximately five year construction period. Nationally, construction will be associated with $321 million in labor income and $570 million to the U.S. Gross Domestic Product over five years. Regionally, the project will support 977 workers per year during construction, $279 million in labor income, and $507 million in Gross State Products between Louisiana and Texas.

Table 3 also shows yearly economic impacts once the facility is fully operational. Regionally and nationwide the project will support approximately 286 and 375 jobs per year, respectively. It will support $15.5 million in wages regionally, and $20.6 million in wages nationally.

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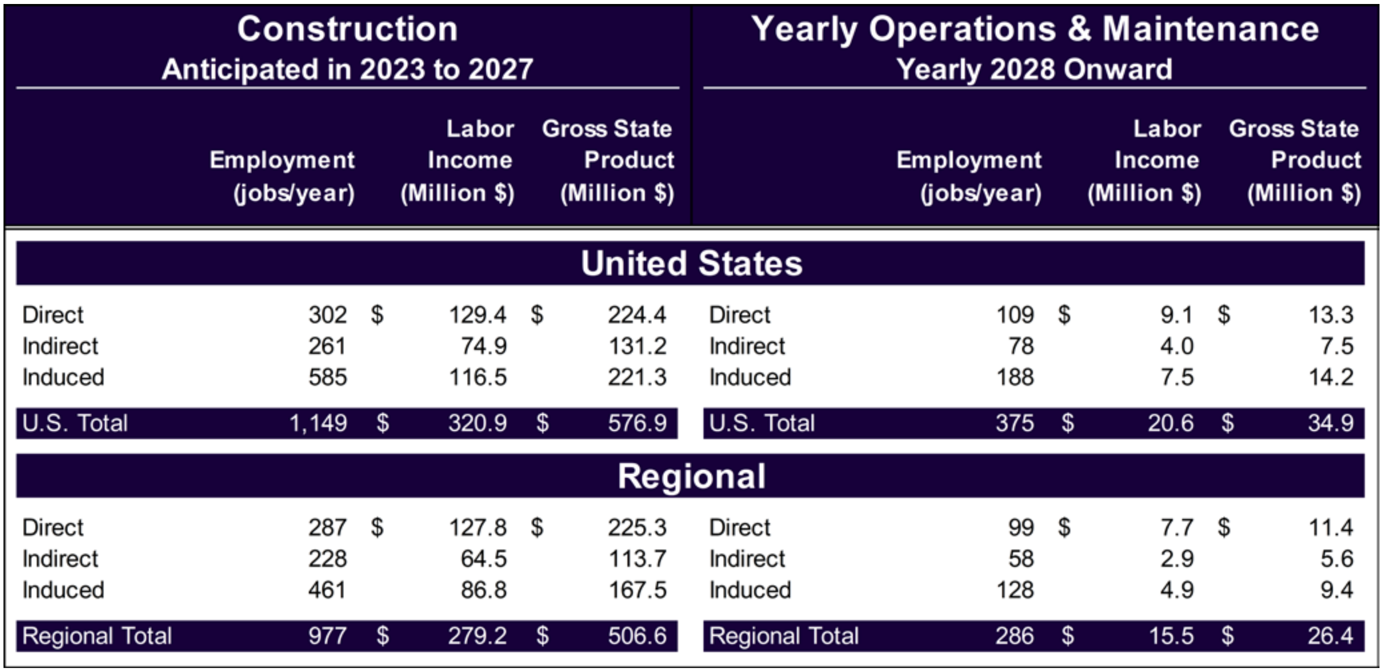
[74] The Tax Foundation is an independent tax policy non-profit. See “State and Local Tax Burdens, Calendar Year 2019” by Erica York and Jared Walczak. Table 3.

[75] Data obtained from FRED. Product key: FYFRGDA188S.

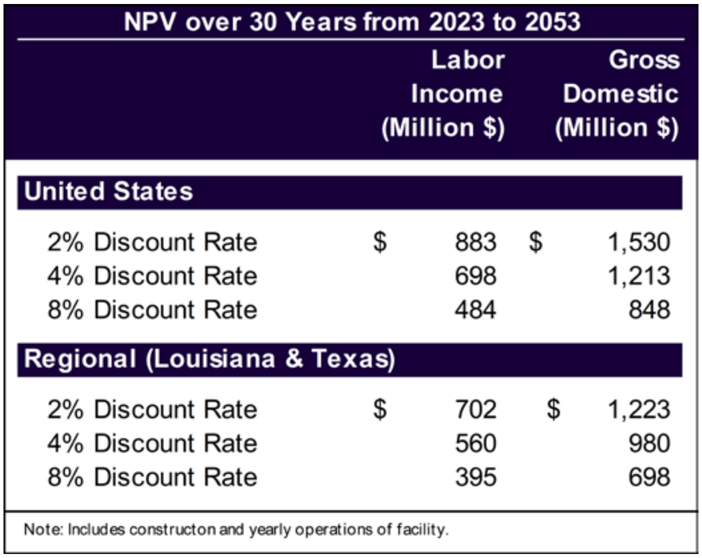
Table 3: Estimated economic impacts of GCS project



Construction Anticipated in 2023 to 2027	Employment (jobs/year)	Labor Income (Million $)	Gross State Product (Million $)	Yearly Operations & Maintenance Yearly 2028 Onward	Employment (jobs/year)	Labor Income (Million $)	Gross State Product (Million $)
United States							
Direct	302	$ 129.4	$ 224.4	Direct	109	$ 9.1	$ 13.3
Indirect	261	74.9	131.2	Indirect	78	4.0	7.5
Induced	585	116.5	221.3	Induced	188	7.5	14.2
U.S. Total	1,149	$ 320.9	$ 576.9	U.S. Total	375	$ 20.6	$ 34.9
Regional							
Direct	287	$ 127.8	$ 225.3	Direct	99	$ 7.7	$ 11.4
Indirect	228	64.5	113.7	Indirect	58	2.9	5.6
Induced	461	86.8	167.5	Induced	128	4.9	9.4
Regional Total	977	$ 279.2	$ 506.6	Regional Total	286	$ 15.5	$ 26.4

The net present value impacts on labor income and Gross Domestic Product are presented in Table 4. On a net present value basis, the project will support between $484 million and $883 million in labor income within the United States, using an 8 percent and 2 percent discount rate respectively. Within the region, which includes the states of Louisiana and Texas, the construction and operations of the GCS facility will support between $395 million and $702 million in labor income, utilizing an 8 percent and 2 percent discount rate, respectively.

Table 4: Net present value of economic impacts



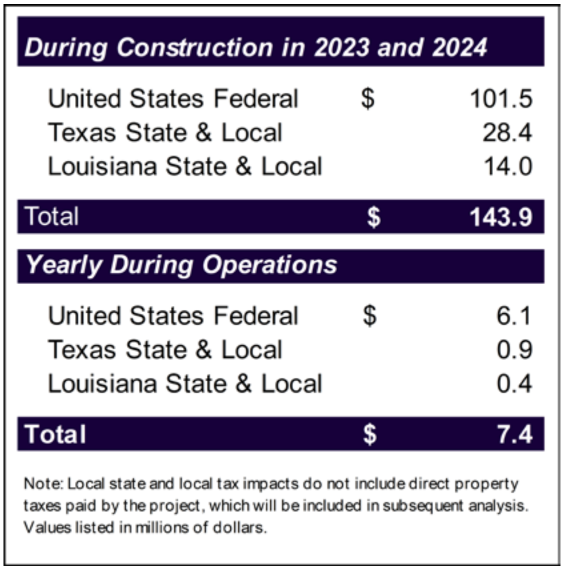
NPV over 30 Years from 2023 to 2053	Labor Income (Million $)	Gross Domestic (Million $)
United States		
2% Discount Rate	$ 883	$ 1,530
4% Discount Rate	698	1,213
8% Discount Rate	484	848
Regional (Louisiana & Texas)		
2% Discount Rate	$ 702	$ 1,223
4% Discount Rate	560	980
8% Discount Rate	395	698

Note: Includes constructon and yearly operations of facility.

5.2.2. Tax Impacts

Next, tax impacts are presented in Table 5. The construction of the project is anticipated to generate $143 million dollars in total tax revenues nationwide. This includes approximately $28 million in Texas state and local taxes, $14 million in Louisiana state and local taxes, and approximately $102 million in federal tax receipts. Table 5 also shows yearly tax impacts once the project has been completed. Nationwide, the project is associated with about $7.4 million in revenues per year, with approximately $900,000 and $400,000 per year of state and local taxes in Texas and Louisiana, respectively. Note that this does not include the direct property taxes associated with the project itself for Calcasieu Parish, which will be presented in the next section.

Table 5: Tax impacts by jurisdiction



During Construction in 2023 and 2024		
United States Federal	$	101.5
Texas State & Local		28.4
Louisiana State & Local		14.0
Total	**$**	**143.9**
Yearly During Operations		
United States Federal	$	6.1
Texas State & Local		0.9
Louisiana State & Local		0.4
Total	**$**	**7.4**

Note: Local state and local tax impacts do not include direct property taxes paid by the project, which will be included in subsequent analysis. Values listed in millions of dollars.

Table 6 shows the estimated tax revenues to Calcasieu parish over a 30-year period. Note that this includes tax impacts during the construction phase of the project, yearly tax impacts from economic activity generated while the facility is operational, as well as direct property taxes paid from the facility itself. Direct property tax estimates assume that the facility receives an 80 percent industrial tax exemption for 10 years.[76] Yearly O&M tax impacts assume that nominal wages increase by 4 percent per year. This is based on average U.S. wage growth historically.

Over 30 years, we estimate that this project will support $102 million in tax revenues to Calcasieu parish specifically. On a net present value basis, this ranges from $43 million (using an 8 percent discount rate) to $71 million (using a 2 percent discount rate).

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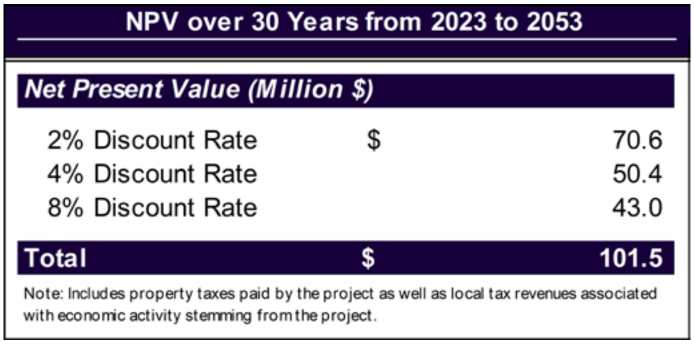
[76] Note there is a chance this policy will change when a new Louisiana Governor is elected. Analysis is based on existing policies.

Table 6: Calcasieu Parish local tax revenues over 30 years



NPV over 30 Years from 2023 to 2053		
Net Present Value (Million $)		
2% Discount Rate	$	70.6
4% Discount Rate		50.4
8% Discount Rate		43.0
Total	**$**	**101.5**

Note: Includes property taxes paid by the project as well as local tax revenues associated with economic activity stemming from the project.

5.3 Potential Decarbonized Jobs

All discussion in Sections 5.1 and 5.2 only includes the economic impacts of the construction and operations of the GCS facility itself. But importantly, these impacts do not consider the jobs that could potentially be decarbonized. These "decarbonized jobs" are addressed in this section. Note that no single job will be decarbonized in its entirety, but instead many thousands of jobs will have a reduced carbon intensity due to sequestration. Thus, we will define a "decarbonized job" as the percent reduction in carbon intensity of a job times the number of jobs with the reduced intensity. More details on the calculation are provided below.

Specifically, to estimate the number of decarbonized jobs we first identify the combustion and non-combustion CO_2 emissions in facilities within geographic proximity to the GCS location. To do so, we obtained the facility level emissions data from the EPA's Envirofacts System and FLIGHT Tool. Details on the specific methodology utilized are discussed in Appendix A. In summary, we selected all facilities in EPA's FLIGHT database within 200 miles of the GSC sequestration sites and reviewed the data reported from each facility. In total 575 individual facilities were reviewed. For each emission source, we classified CO_2 emissions as either "combustion" or "non-combustion" emissions.[77] An example of combustion emissions would include the CO_2 emitted from a fossil fuel-based power-plant after the fuel is combusted. Although there is certainly potential that such emissions could be captured and sequestered, these emissions are likely to have relatively high capture cost relative to non-combustion emissions. An example of non-combustion emissions is the CO_2 that is removed from a stream of methane before the methane is liquified into liquified natural gas (LNG) for LNG export. There are many petrochemical processes that generate CO_2 but that does not involve the combustion of a molecule. These "non-combustion" emissions are likely to have relatively lower capture costs.

After identifying and categorizing facility level emissions, next we estimated the total number of jobs at each of these individual facilities. Note that publicly available data is not available at individual facilities, as this is proprietary company information. But we can estimate employment at these facilities. To do so, we first identified total employment in Texas and Louisiana in three sectors. Refining (NAICS 211), Chemical Manufacturing (NAICS 213) and export of liquified natural gas (LNG export).[78] These three

---

[77] Note that one "facility" can have multiple emissions "sources."

[78] There are three such facilities within 200 miles of the GCS location, which we individually identify.

sectors are chosen, because they make up over 90 percent of the non-combustion emissions in the facilities within 200 miles of the GCS location. In total, there were 45 such facilities within 100 miles of the GCS location and 95 facilities within 200 miles.

Dividing total emissions within the entire state of Texas and Louisiana by the number of jobs in each respective sector, we obtain a sector and state specific emissions per job. Using this ratio, we then estimate facility level employment at each refining and chemical manufacturing facility within 200 miles of the GCS location.[79] For LNG exports, we utilize employment information submitted to Louisiana Economic Development for the Industrial Tax Exemption Program (ITEP) for the two LNG export facilities in Louisiana. We use the ratio of jobs per liquification capacity to estimate employment at the export facility in Texas.

Results of this exercise are shown in Table 7. There are approximately 51 thousand jobs within 100 miles of the GCS location, and approximately 95 thousand jobs within 200 miles of the GCS location in the refining, petrochemical manufacturing, and LNG export sectors. There are 45 such facilities within 100 miles and 95 such facilities within 200 miles. From these facilities, there are 81 million metric tons of CO_2 emissions within 100 miles and 144 million metric tons within 200 miles. Approximately 24 percent of the emissions at these facilities within 100 miles are non-combustion emissions. Next, the GCS sequestration potential is assessed. Once all three phases are completed, GCS will have a sequestration potential of approximately 10 million metric tons per year. Thus, it will have the ability to sequester approximately half of the non-combustion emissions from the refining, chemical manufacturing, and LNG export facilities within 100 miles, and approximately a quarter of the emissions within 200 miles. Multiplying the total jobs at these facilities times the percent of the emissions that could be sequestered, yields an estimated number of “decarbonized jobs” between approximately 6,300 and 6,600. Of course, no job will be 100 percent decarbonized, but this one facility has the potential to decarbonize an equivalent of over 6,000 jobs in the region. As discussed throughout this report, reduced carbon intensity of this sector will be an important factor when firms decide to locate in the Gulf Coast region, and also factor into the resilience of these sectors in a decarbonized future.

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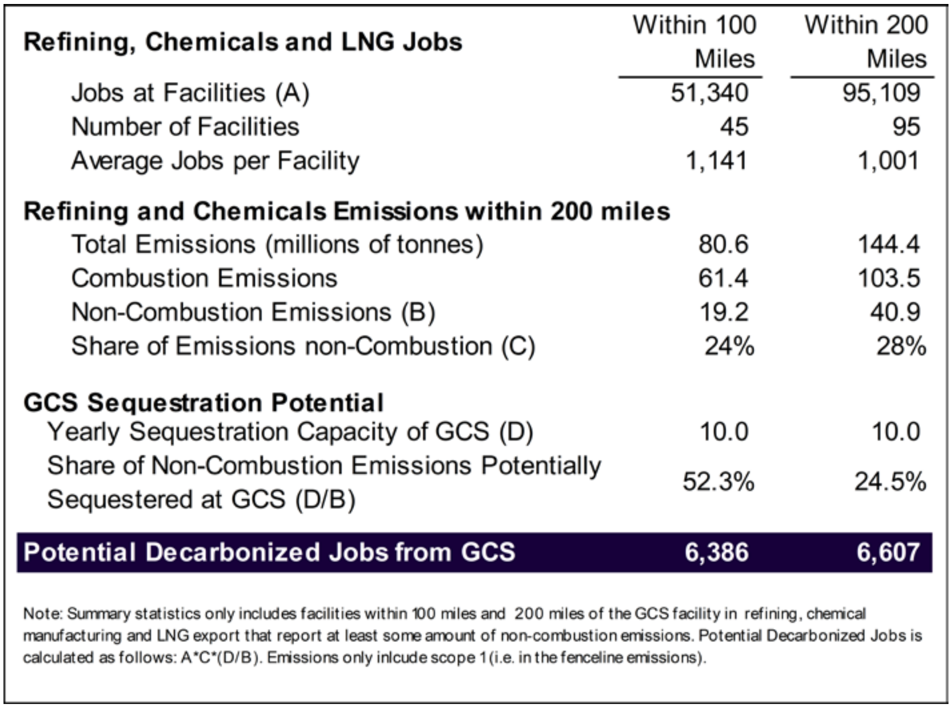
[79] We conducted several checks to assess whether this is a reasonable methodology for estimating employment at these facilities. First, we looked at specific facilities for which the authors have a reasonable estimate of the actual number of employees. Also, we estimated employment at the parish/county level for select counties and matched to publicly available data. Although there is likely a large margin of error for an *individual facility*, this methodology provided reasonable estimates of *groups of facilities*.

Table 7: Estimated decarbonized jobs from GCS



Refining, Chemicals and LNG Jobs	Within 100 Miles	Within 200 Miles
Jobs at Facilities (A)	51,340	95,109
Number of Facilities	45	95
Average Jobs per Facility	1,141	1,001
Refining and Chemicals Emissions within 200 miles		
Total Emissions (millions of tonnes)	80.6	144.4
Combustion Emissions	61.4	103.5
Non-Combustion Emissions (B)	19.2	40.9
Share of Emissions non-Combustion (C)	24%	28%
GCS Sequestration Potential		
Yearly Sequestration Capacity of GCS (D)	10.0	10.0
Share of Non-Combustion Emissions Potentially Sequestered at GCS (D/B)	52.3%	24.5%
Potential Decarbonized Jobs from GCS	**6,386**	**6,607**

Note: Summary statistics only includes facilities within 100 miles and 200 miles of the GCS facility in refining, chemical manufacturing and LNG export that report at least some amount of non-combustion emissions. Potential Decarbonized Jobs is calculated as follows: A*C*(D/B). Emissions only inlcude scope 1 (i.e. in the fenceline emissions).

5.4 Abated Climate Damages

Finally, we estimate the potentially abated climate damages from the GCS facility. To do so, we consider all three phases of the project, and the approximate timeline, shown in Table 2, for which they could begin sequestering CO_2. We utilize the social cost of carbon as published by the Interagency Working Group on Social cost of Greenhouse Gases.[80] Calculations include a total of 10 million metric tons sequestered per year for 30 years. Sequestration begins in 2025 at the rate of 2.7 million metric tons per year and ramps up to the total 10 million metric tons per year by 2027. We utilize the social cost of carbon in 2020 dollars per metric ton, utilizing 3 percent discount rate.[81] Net present value over 30 years presented utilizing 3 percent discount rate. Thus, the avoided social cost estimate is presented in 2020 dollars. The result is that the project has the potential to abate climate damages by $11.3 billion over its lifetime by sequestering a total of 300 million tons of CO_2.

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[80] Table ES-1 of "Technical Support Document: Social cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates under Executive Order 13990. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government." February 2021.

[81] Yearly social cost is then linearly extrapolated between five-year periods.

6 | Leveraging, De-risking, and the Evolution of a Gulf Coast Carbon Economy

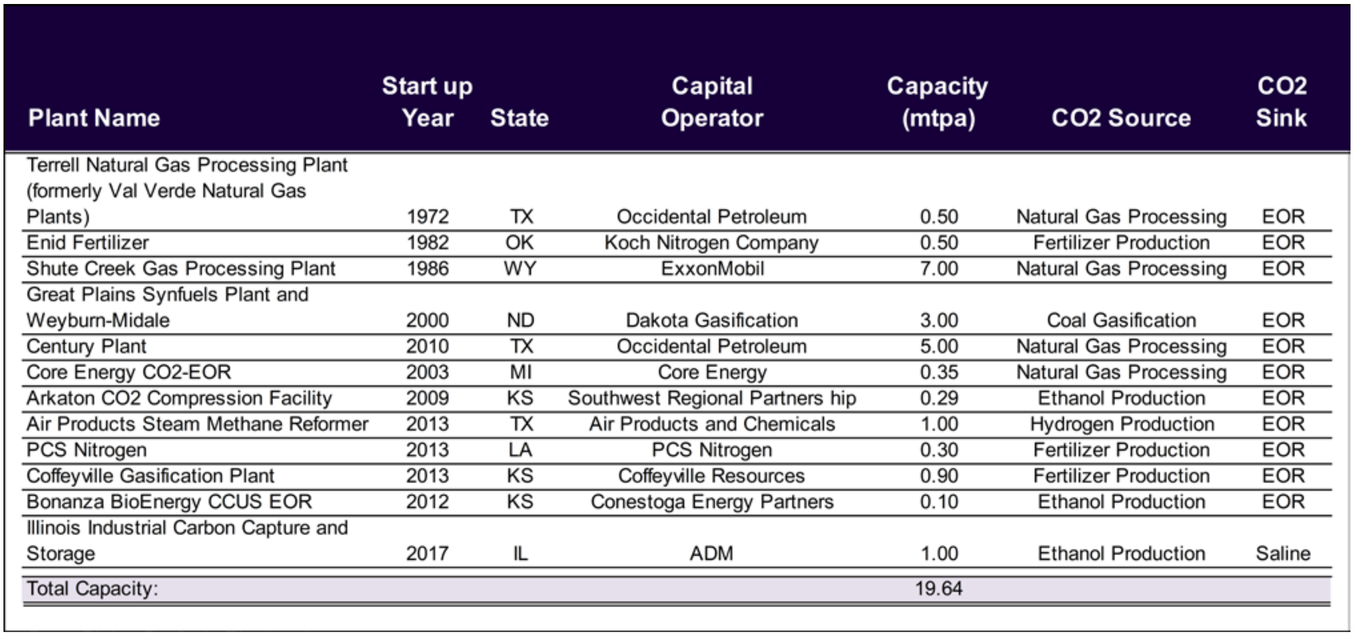
6.1 Overview

GCS will be a unique underground storage hub that will be precedent setting. In addition, at 80 Mt of storage capacity, the GCS facility will be one of the largest currently under development. Yet this is just a starting point since the GCS facility has the additional capability of expanding its overall storage capacity over time as market opportunities expand. GCS will prove that a large-scale facility, dedicated to the permanent storage of CO_2, can be developed in a timely and efficient fashion.

There are several risks associated with developing an underground CO_2 storage facility. Development risk being the first since no comparable permanent storage facility has ever been constructed and operated in Louisiana. There are, however, several underground storage/CCS projects that are active in the United States that include 12 active locations accounting for 19.6 Mtpa of capacity. Note that in all but one of these cases injection is for the purposes of EOR.

Table 8 identifies these facilities and shows that most of these CCS projects were developed in the 1970s and 1980s and are dedicated to enhanced oil recovery (EOR) activities. Further, a large number of legacy CCS projects are located outside the Gulf Coast region in places like the midcontinent region and the West. The GCS facility, along with many others that are likely to be developed over the next decade, will differ from these legacy facilities because the new underground storage facilities will be dedicated to permanent storage activities as opposed to facilitating EOR.

Table 8: Active U.S. CO_2 capture and storage projects



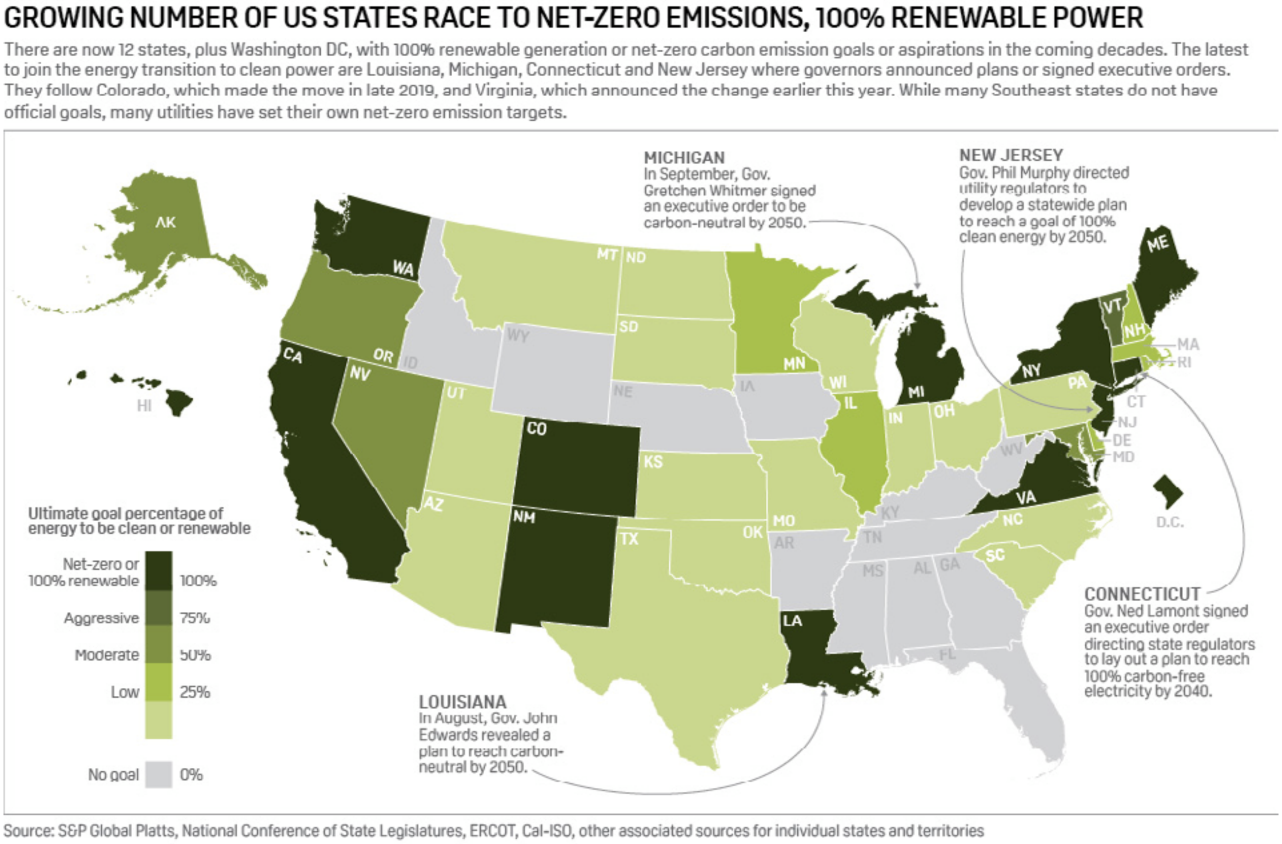
Plant Name	Start up Year	State	Capital Operator	Capacity (mtpa)	CO2 Source	CO2 Sink
Terrell Natural Gas Processing Plant (formerly Val Verde Natural Gas Plants)	1972	TX	Occidental Petroleum	0.50	Natural Gas Processing	EOR
Enid Fertilizer	1982	OK	Koch Nitrogen Company	0.50	Fertilizer Production	EOR
Shute Creek Gas Processing Plant	1986	WY	ExxonMobil	7.00	Natural Gas Processing	EOR
Great Plains Synfuels Plant and Weyburn-Midale	2000	ND	Dakota Gasification	3.00	Coal Gasification	EOR
Century Plant	2010	TX	Occidental Petroleum	5.00	Natural Gas Processing	EOR
Core Energy CO2-EOR	2003	MI	Core Energy	0.35	Natural Gas Processing	EOR
Arkaton CO2 Compression Facility	2009	KS	Southwest Regional Partners hip	0.29	Ethanol Production	EOR
Air Products Steam Methane Reformer	2013	TX	Air Products and Chemicals	1.00	Hydrogen Production	EOR
PCS Nitrogen	2013	LA	PCS Nitrogen	0.30	Fertilizer Production	EOR
Coffeyville Gasification Plant	2013	KS	Coffeyville Resources	0.90	Fertilizer Production	EOR
Bonanza BioEnergy CCUS EOR	2012	KS	Conestoga Energy Partners	0.10	Ethanol Production	EOR
Illinois Industrial Carbon Capture and Storage	2017	IL	ADM	1.00	Ethanol Production	Saline
Total Capacity:				19.64		

Source: Global CCS Institute, Global Status Report 2021.

Thus, the development of a new underground carbon storage project, that in turn will support future capture facilities, will be critical to meeting the carbon neutrality proposals that policymakers are proposing at the national and state level.

However, despite the development challenge, there is a considerable emerging policy support for underground CO_2 storage. There are a large number of individual states that are proposing or adopting policies that substantially reduce, if not attempt to eliminate their overall GHG emissions (on a net emissions basis) by a certain date.

Figure 12: State climate goals and initiatives



GROWING NUMBER OF US STATES RACE TO NET-ZERO EMISSIONS, 100% RENEWABLE POWER

There are now 12 states, plus Washington DC, with 100% renewable generation or net-zero carbon emission goals or aspirations in the coming decades. The latest to join the energy transition to clean power are Louisiana, Michigan, Connecticut and New Jersey where governors announced plans or signed executive orders. They follow Colorado, which made the move in late 2019, and Virginia, which announced the change earlier this year. While many Southeast states do not have official goals, many utilities have set their own net-zero emission targets.

MICHIGAN
In September, Gov. Gretchen Whitmer signed an executive order to be carbon-neutral by 2050.

NEW JERSEY
Gov. Phil Murphy directed utility regulators to develop a statewide plan to reach a goal of 100% clean energy by 2050.

CONNECTICUT
Gov. Ned Lamont signed an executive order directing state regulators to lay out a plan to reach 100% carbon-free electricity by 2040.

LOUISIANA
In August, Gov. John Edwards revealed a plan to reach carbon-neutral by 2050.

Source: S&P Global Platts, National Conference of State Legislatures, ERCOT, Cal-ISO, other associated sources for individual states and territories

Source: S&P Global; available at: https://www.spglobal.com/commodity-insights/en/market-insights/latest-news/electric-power/122420-commodities-2021-states-racing-to-set-goals-toward-net-zero-emission-100-renewable-electricity.

However, there are some states pursuing carbon neutrality policies that are heavily invested in fossil fuels such as Louisiana and New Mexico. A map of state climate goals and initiatives is shown in Figure 12. Louisiana, the location of the GCS project, targets 2050 as the date at which it aspires to reach net zero carbon emissions, something that will be difficult to purse without major investment in carbon capture and permanent underground CO_2 storage facilities.

As noted earlier, Louisiana has a large level of GHG emissions that are highly concentrated in one economic sector (industry). Meeting the state's aggressive emissions reduction goals, therefore, will require very rapid and targeted strategies that focus heavily on reducing industrial emissions. The clean energy/climate strategies that are utilized to reduce industrial carbon emissions are often commonly referred to as “industrial decarbonization” measures and include such activities as: (1) the use of renewable energy; (2) CCS; (3) fuel switching to electricity (called “electrification”) and fuel switching to other resources.

Before discussing these decarbonization measures, it is important to understand how Louisiana industry uses energy. Louisiana industrial energy use is multifaceted because most chemical production and refinery processes use considerable pressure and heat. Process heat, usually generated with furnaces through the combustion of fossil fuels, is an important industrial energy use. Most Louisiana industrial facilities require considerable amounts of high temperature/high pressure steam created by boilers, which also combust fossil fuels. Most Louisiana industrial facilities utilize a considerable amount of electricity and often have their own on-site power generators that are primarily run by the combustion of natural gas. Lastly, many Louisiana industrial facilities use various hydrocarbons as feedstocks, and while they are not directly combusted, certain GHG releases may arise in the reformation process including methane (CH_4) and nitrous oxide (N_2O).

Thus, many of the industrial decarbonization strategies that could be effective for other manufacturing and industrial facilities around the United States may be less effective for Louisiana given the unique, large, and highly concentrated nature of the state’s industrial energy use. For instance, while the use of renewable energy can be an important on-site supplement for many Louisiana industrial facilities, these facilities’ electricity requirements are simply too large, and are around-the-clock and do not match well with the intermittency of renewable power generation.

Likewise, Louisiana industry, has been increasingly converting many on-site energy uses to electricity to avoid on-site emissions of all types. However, at this point in time, it is highly unlikely that high pressure/high temperature heat or steam can be generated using utility grid-provided electricity including from a renewable energy resource. Cost effective technologies for industrial electrification is not commercially available, making CCS, and projects like GCS, increasingly important as a means of mitigating near-term GHG emissions and meeting the ambitious schedule set out for the state’s net zero GHG emission goals.

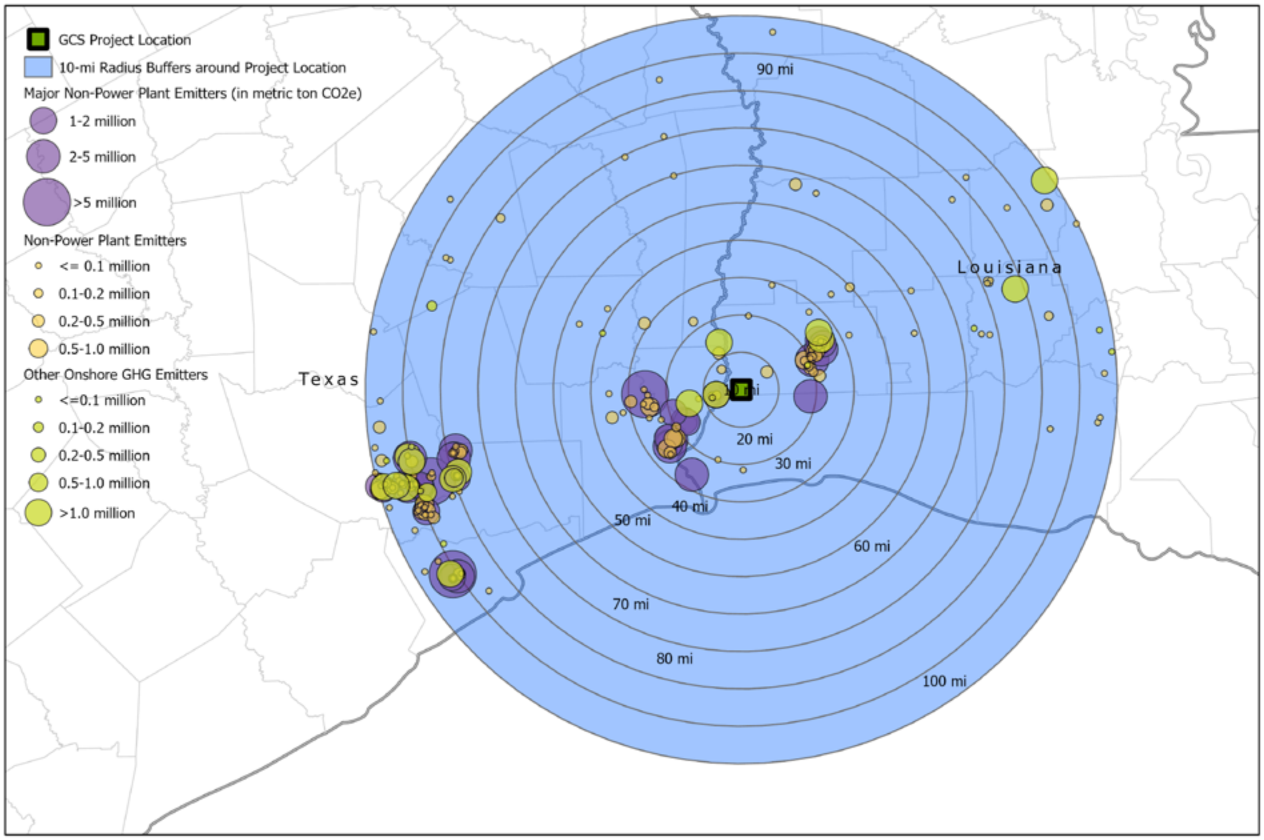
6.2 De-risking Permanent and Underground CO_2 Storage

Volume and scale are important in making underground carbon storage productive and profitable (or at least, less cost prohibitive). Like many other types of energy infrastructure, CCS requires large capital and capacity investments, where unit cost (cost per capacity of underground storage) falls as captured/stored volumes decrease (i.e., the cost per ton captured and stored falls as volume increases). Thus, having access to many large, varied GHG emission sources is important for a CCS project, or one limited to just underground storage alone.

A large number of potential industrial CO_2 storage service “customers” are located in southwestern Louisiana and east Texas, in close proximity to the proposed GCS facility. Figure 13 maps these large sources by their geographic proximity to the GCS facility in concentric distance-measured rings. Most of these large emitters in proximity to the GCS project are located (a) in the Lake Charles, Louisiana, industrial area, (b) the Beaumont/Port Arthur industrial area, or (c) east of Houston. This map also shows the potential for a larger carbon hub connecting these emitting locations with storage sites.

The map shows there are as many as 29 "large" (greater than 1 Mtpa) CO_2 emission sources that are within 100 miles of the proposed GCS facility. These industrial point CO_2 emission point sources total as much as 79.2 Mtpa in CO_2 capture potential.[82] Close to half of this volume, 38.9 Mtpa, is emitted by 15 locations, all of which are within 30 miles of GCS.

Figure 13: Industrial GHG emission sources



Source: U.S. Environmental Protection Agency, Facility Level Information on GreenHouse gases Tool (FLIGHT), 2020 Greenhouse Gas Emissions from Large Facilities

Louisiana specifically has a large number of high purity CO_2 streams that can be captured from existing chemical reformation processes. These high purity streams need less treatment, and often have lower capture costs, than more expensive post-combustion processes like those associated with power generation. Many of these higher purity streams have CO_2 concentrations at the 90 percent level or better and, as such, can have lower capture costs. The higher the purity, the better the capture candidate from a cost perspective. Louisiana currently has 86 separate high purity emission sources totaling to as much as 21 Mtpa: a level comparable to all currently active U.S. CCS projects (highlighted below at around 19 to 20 Mtpa).

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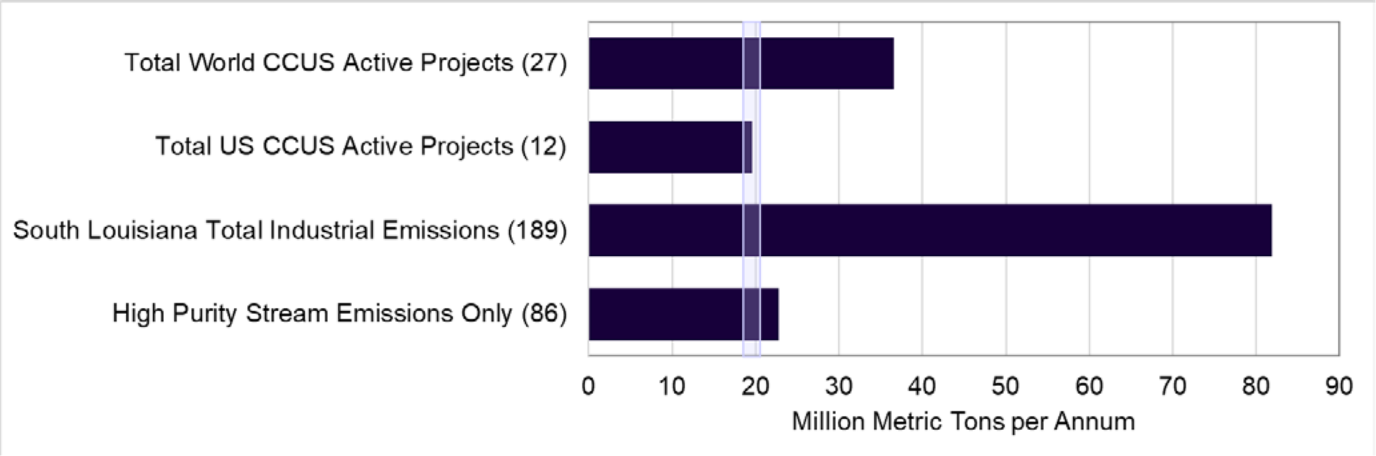
[82] 2019 data, industrial locations only, excludes power generation emitters. Note, there are 226 total GHG emission point sources in the 100-mile radius, with emissions totaling 136.7 Mtpa (power generation and industrial combined). Total industrial emissions alone, including smaller less than 1 Mtpa sources, sums to 103.8 Mtpa (194 locations).

Figure 14: Louisiana potential CCS capabilities



Source: Dismukes, "Louisiana carbon capture: sinks; sources; and the role of transportation in industrial applications." Pollution Solutions: LSU Journal of Energy Law & Resources Symposium on Carbon Capture and Solutions. (2021)

Thus, the large number of potential CO_2 industrial sources that are in close proximity to GCS will help to reduce some of the risks associated with the project given the potentially large "market" for CO_2 storage services. GCS' success will help pave the way for additional types of comparable underground storage facilities by proving the concept, not just from an engineering and geological perspective, but from a business case perspective.

6.3 Facilitating the Development of More Sustainable Fuels

Projects like GCS will also facilitate the ability of Louisiana to leverage its abundant natural gas resources in an environmentally sustainable fashion. Underground CO_2 storage, like the GCS proposal, facilitates the development of two important emerging (and related) fuels: hydrogen and ammonia.

Hydrogen is the simplest and most abundant element in the universe. However, pure hydrogen is rarely found and is often part of other common elements such as hydrocarbons, acids, and hydroxides. Hydrogen is widely used in South Louisiana across industrial production processes.

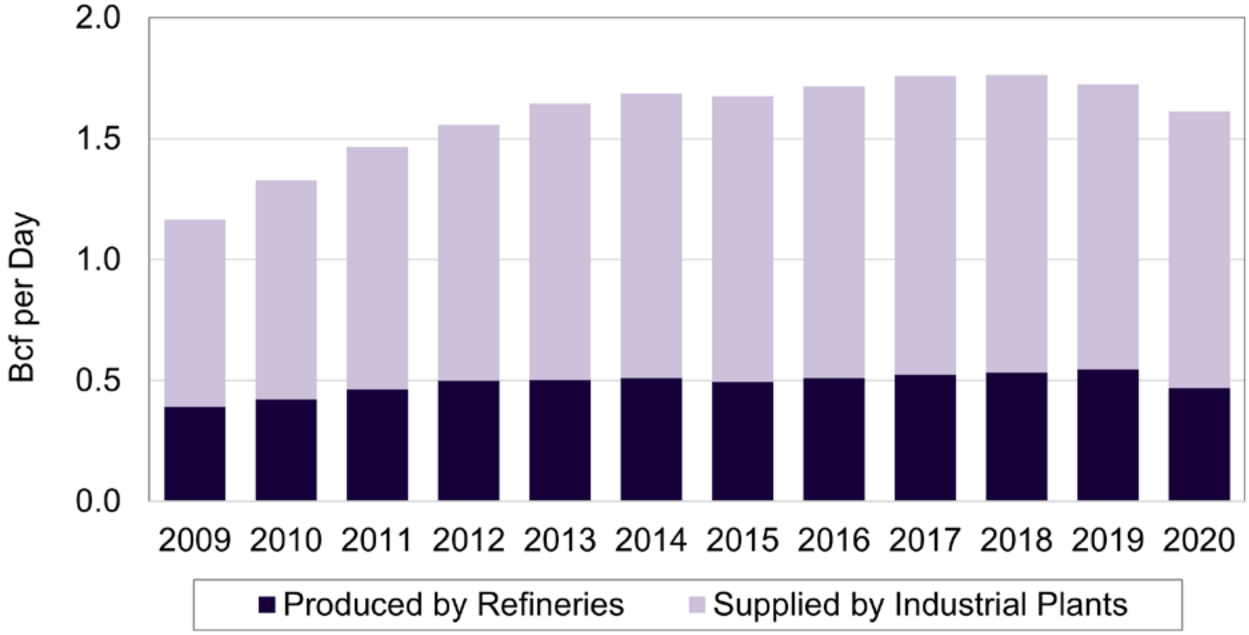
First, hydrogen is an important component in ammonia production. In order to produce ammonia (NH_3), one nitrogen atom is bonded with hydrogen. Various chemical processes developed over the early twentieth century and forward have been used to produce ammonia, mostly using hydrocarbons, like natural gas, as a feedstock. Louisiana's historic abundance of natural gas production, therefore, has served as a reliable and usually low-cost feedstock for the region's ammonia producers.

However, there are other methods by which ammonia can be produced, the second being through an electrolysis process that uses water and electricity to derive the necessary hydrogen to formulate ammonia. While electrolysis can be more expensive than reformation processes using natural gas, electrolysis is often considered to be more environmentally sustainable, particularly if the electricity used in the process is generated by renewable energy.

Hydrogen is also important in refinery operations in order to produce clean fuels that meet current clean air emissions standards. This refinery demand for hydrogen has increased as sulfur content regulations have become more stringent, and as those regulations have spread to a wide range of refined fuels, including clean burning diesel used around the globe for transportation.

U.S. hydrogen production that is supplied to refineries alone has been growing over the past several years, particularly production that originates at industrial plants (ammonia, methanol). Figure 15, for instance, shows that while total U.S. onsite refinery hydrogen production has remained relatively constant, industrial hydrogen production used to serve refineries' clean fuel production requirements has grown by as much as 4.3 percent on an annual average basis.

Figure 15: U.S. hydrogen supplied to refineries



Source: U.S. Energy Information Administration, https://www.eia.gov/todayinenergy/detail.php?id=24612

As noted earlier, ammonia is a large feedstock user of Louisiana natural gas, and an important source of hydrogen use in the state and region. Given the commodity nature of its production, global competition, and the small margins, ammonia production and investment are highly dependent upon feedstock costs. If those feedstock costs increase dramatically, much as they did during the natural gas price volatility of the 2000s, these industries suffer.

The advent of the shale revolution reversed what was otherwise a dismal outlook for ammonia production along the Gulf Coast. Today, ammonia and methanol production are growing significantly and are expected to continue to grow as the post-pandemic global economic expansion continues, particularly in the developing world.

Table 9 identifies U.S. ammonia production facilities and their capacities, and highlights those along the Gulf Coast.

Table 9: U.S. ammonia facilities (2021)

Company/Location	Capacity (MM tons per year)	Company/Location	Capacity (MM tons per year)
CF Industries Holdings, Inc		**J.R. Simplot Co.**	
Donaldsonville, LA (5 plants)	**3.90**	Rock Springs, WY	0.19
Port Neal, IA	1.09	**Koch Industries**	
Verdigris, OK (2 plants)	1.02	Beatrice, NE	0.27
Woodward, OK	0.44	Dodge City, KS	0.28
Yazoo City, MS	**0.51**	Enid, OK	0.93
Coffeyville Resources Nitrogen Fertilizers, LLC		Fort Dodge, IA	0.35
Coffeyville, KS	0.38	**LSB Industries**	
Dakota Gasification Co.		**Cherokee, AL**	**0.16**
Beulah, ND	0.36	El Dorado, AR	0.40
Dyno Nobel Inc.		Pryor, OK	0.21
Cheyenne, WY	0.18	**The Mosaic Company**	
St. Helens, OR	0.10	**Faustina (Donaldsonville), LA**	**0.51**
Dyno Nobel Louisiana Ammonia, LLC		**Nutrien Ltd.**	
Waggaman, LA	**0.80**	Augusta, GA	0.79
East Dubuque Nitrogen Fetilizer, LLC		**Borger, TX**	**0.49**
East Dubuque, IL	0.34	**Geismar, LA**	**0.45**
Fortigen Geneva, LLC		Kenai, AK	**0.28**
Geneva, NE	0.03	Kennewick, WA	0.18
Green Valley Chemical Corp.		Lima, OH	0.61
Creston, IA	0.03	**OCI North America**	
Honeywell International Inc.		**Beaumont, TX**	**0.33**
Hopewell, VA	0.53	**Yara Freeport**	
Iowa Fertilizer Co.		**Freeport, TX**	**0.75**
Wever, VA	0.77		
Total Gulf Coast Capacity:	**7.57**	**Total U.S. Capacity:**	**17.6**

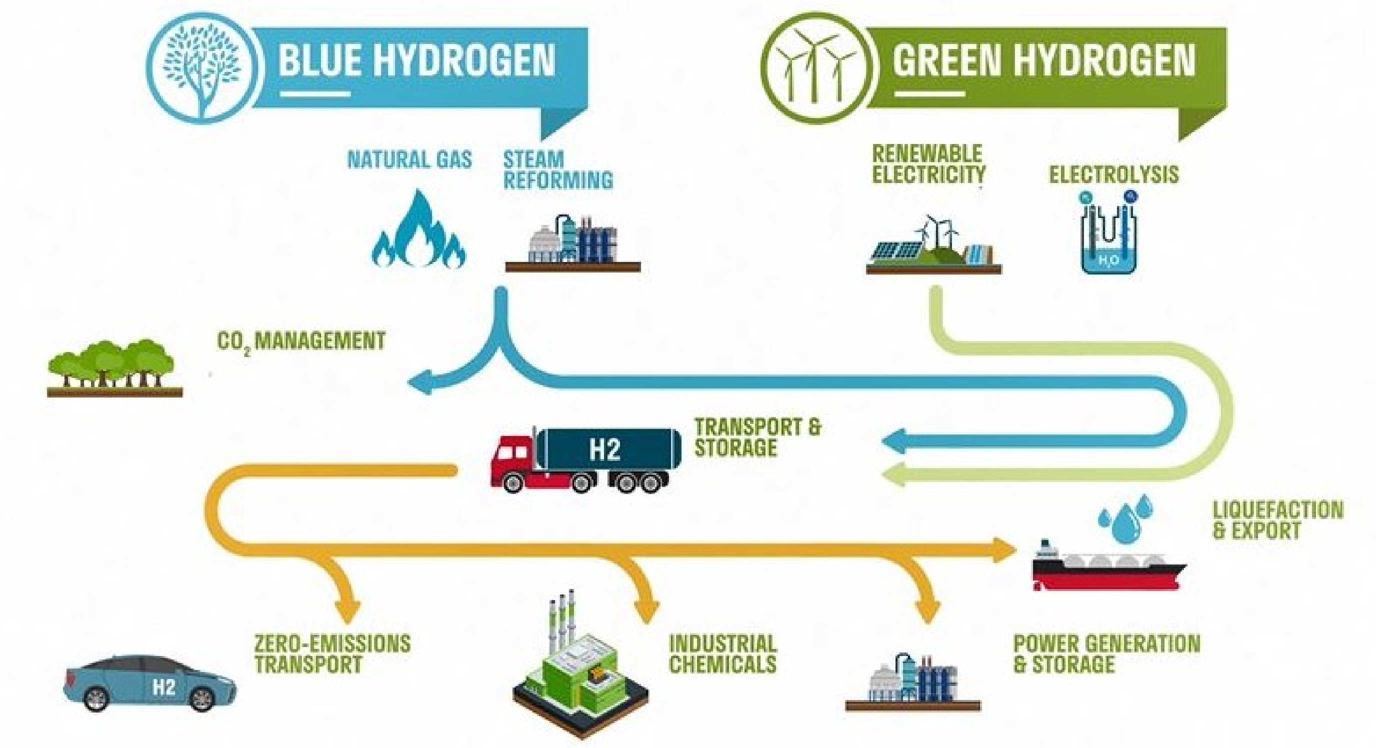
Source: U.S. Geological Survey, U.S. Department of the Interior.

There is currently over 17.6 million tons per year of U.S. ammonia production capacity. Several of these facilities, totaling nearly 7.6 million tons per year in capacity, are located along the Gulf Coast, which accounts for 42.9 percent of all U.S. ammonia production.

Thus, there are continued opportunities to maintain and even leverage current hydrogen and ammonia production, from a position that is already considerable to one that is potentially higher, as the interest in using hydrogen and ammonia as alternative fuels—rather than inputs in chemical processes like agricultural chemicals--changes. The key will be to do so in a fashion that is economically and environmentally sustainable. There are a number of arguments to increase the utilization and production of hydrogen and ammonia using "green" methods. These green methods utilize electrolysis and power generation from renewable energy. The challenge with the green approach is that renewable energy-based approaches are more expensive and require a large amount of power generation capacity that could be difficult to develop in the near term.

Thus, a "bridge" approach will be needed to meet the scale of production of both hydrogen and ammonia necessary for Louisiana industrial decarbonization. One such bridge approach, shown in Figure 16, is through a process of developing "blue" methods for producing hydrogen and ammonia. These blue methods use traditional hydrocarbon feedstocks (natural gas), and traditional chemical reformation techniques, but capture carbon in this reformation process and inject that carbon into permanent underground storage facilities. Thus, underground CO_2 storage facilities like the one being proposed by GCS will be critical during the energy transition period needed to assure large scale and immediate industrial decarbonization activities.

Figure 16: Blue versus green hydrogen production



Source: Energy Tracker Asia. https://energytracker.asia/hydrogen-oil-green-vs-blue-whats-the-difference/

Blue and green hydrogen can be used in applications other than chemical manufacturing. Co-blending hydrogen with natural gas, for instance, can be used as a low GHG emissions fuel for a variety of combustion purposes. This can occur with natural gas local distribution companies (LDCs) that are now considering injecting as much as 20 percent hydrogen into their distribution gas streams for retail customers.

In addition, these co-blending opportunities could leverage the use of cleaner burning fuel in Louisiana's significant fleet of natural gas power generators, at both the utility and industrial level. In fact, a recent announcement was made for a new state-of-the-art power generator in Iberville Parish that, once constructed, will have the ability to burn up to 50 percent hydrogen as a fuel source for power generation purposes.[83]

These opportunities are already arising in Louisiana. Table 10 identifies several recent project announcements for Louisiana clean energy projects that include blue and green hydrogen and ammonia facilities.

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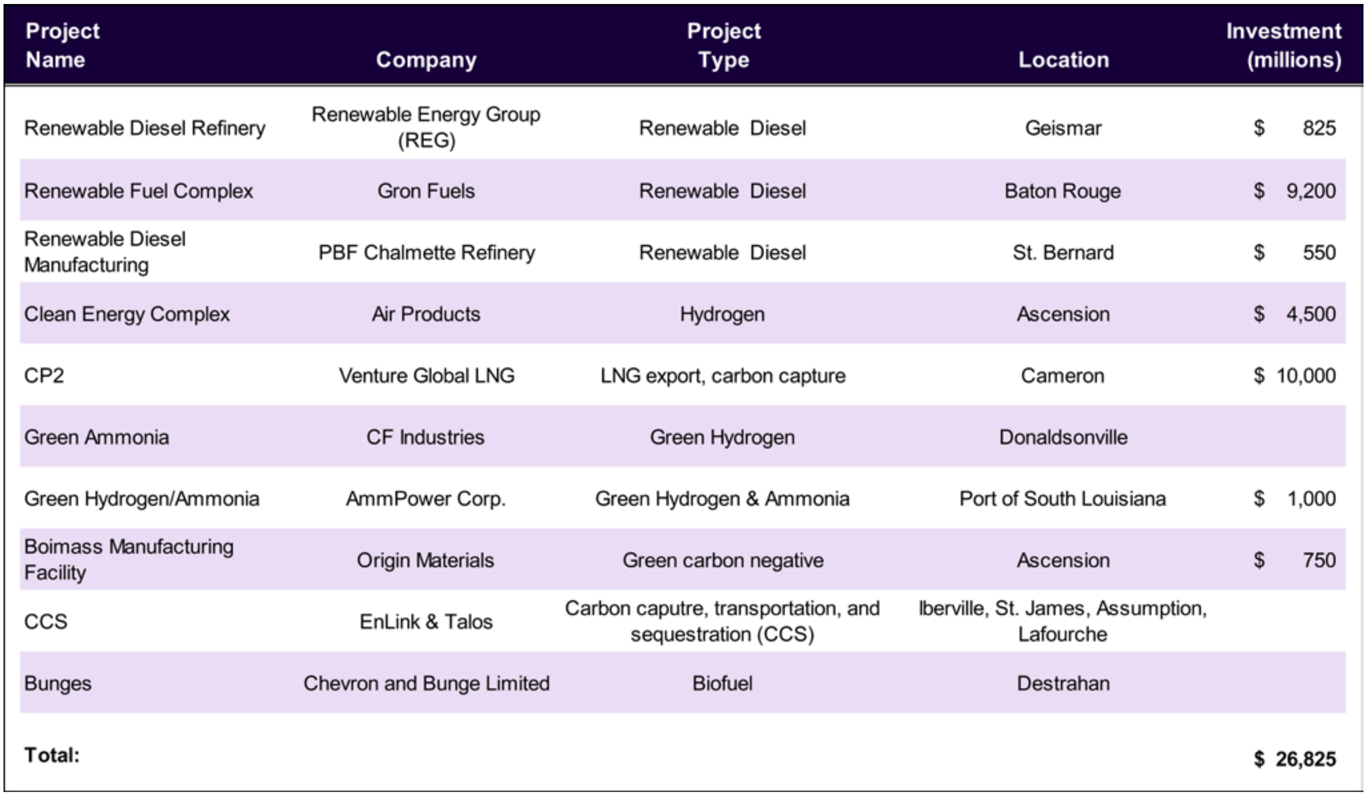
[83] BIC Magazine. "PSC Paves the way for $740 Million Power Plant." February 9, 2022.

Table 10: Recently proposed Louisiana clean energy projects



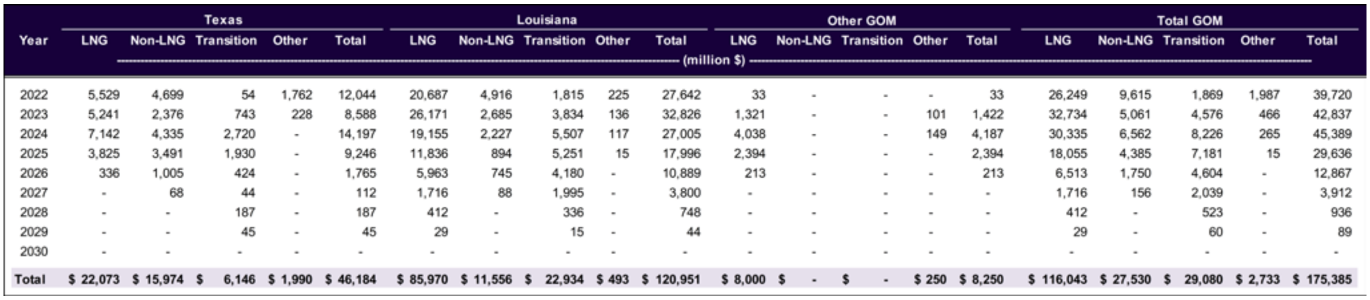
Project Name	Company	Project Type	Location	Investment (millions)
Renewable Diesel Refinery	Renewable Energy Group (REG)	Renewable Diesel	Geismar	$ 825
Renewable Fuel Complex	Gron Fuels	Renewable Diesel	Baton Rouge	$ 9,200
Renewable Diesel Manufacturing	PBF Chalmette Refinery	Renewable Diesel	St. Bernard	$ 550
Clean Energy Complex	Air Products	Hydrogen	Ascension	$ 4,500
CP2	Venture Global LNG	LNG export, carbon capture	Cameron	$ 10,000
Green Ammonia	CF Industries	Green Hydrogen	Donaldsonville	
Green Hydrogen/Ammonia	AmmPower Corp.	Green Hydrogen & Ammonia	Port of South Louisiana	$ 1,000
Boimass Manufacturing Facility	Origin Materials	Green carbon negative	Ascension	$ 750
CCS	EnLink & Talos	Carbon caputre, transportation, and sequestration (CCS)	Iberville, St. James, Assumption, Lafourche	
Bunges	Chevron and Bunge Limited	Biofuel	Destrahan	
Total:				**$ 26,825**

Source: Authors' construct.

6.4 Leveraging Natural Gas Production and Exports

Lastly, underground storage projects like GCS will also be needed to sustain existing and potentially new LNG export facilities located along the central Gulf Coast. The potential for extensive LNG investments still exists and given recent geopolitical tensions in Europe, the opportunity of moving more U.S. natural gas into international trade has increased considerably. Table 11, taken from the most recent *Gulf Coast Energy Outlook* (GCEO), published by the LSU Center for Energy Studies, estimates as much as $116 billion in continued regional LNG investment.

Table 11: 2023 GCEO projected regional investment



	Texas					Louisiana					Other GOM					Total GOM				
Year	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total
										(million $)										
2022	5,529	4,699	54	1,762	12,044	20,687	4,916	1,815	225	27,642	33	-	-	-	33	26,249	9,615	1,869	1,987	39,720
2023	5,241	2,376	743	228	8,588	26,171	2,685	3,834	136	32,826	1,321	-	-	101	1,422	32,734	5,061	4,576	466	42,837
2024	7,142	4,335	2,720	-	14,197	19,155	2,227	5,507	117	27,005	4,038	-	-	149	4,187	30,335	6,562	8,226	265	45,389
2025	3,825	3,491	1,930	-	9,246	11,836	894	5,251	15	17,996	2,394	-	-	-	2,394	18,055	4,385	7,181	15	29,636
2026	336	1,005	424	-	1,765	5,963	745	4,180	-	10,889	213	-	-	-	213	6,513	1,750	4,604	-	12,867
2027	-	68	44	-	112	1,716	88	1,995	-	3,800	-	-	-	-	-	1,716	156	2,039	-	3,912
2028	-	-	187	-	187	412	-	336	-	748	-	-	-	-	-	412	-	523	-	936
2029	-	-	45	-	45	29	-	15	-	44	-	-	-	-	-	29	-	60	-	89
2030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**$ 22,073**	**$ 15,974**	**$ 6,146**	**$ 1,990**	**$ 46,184**	**$ 85,970**	**$ 11,556**	**$ 22,934**	**$ 493**	**$ 120,951**	**$ 8,000**	**$ -**	**$ -**	**$ 250**	**$ 8,250**	**$ 116,043**	**$ 27,530**	**$ 29,080**	**$ 2,733**	**$ 175,385**

Source: LSU Center for Energy Studies, 2022 GCEO.

Projects like GCS help to leverage LNG in important ways. First, many countries that import considerable volumes of LNG annually are looking for ways to maintain their energy security as well as reduce their overall carbon footprint. The emphasis on reducing carbon emissions has only increased given recent international accords such as the COP21 and later agreements. Many nations are now, in the short run, attempting to couple responsibly sourced natural gas (RSG) with their LNG exports.[84] Many producers, including those in Louisiana, are likewise looking for ways to further differentiate the higher environmental quality of their own natural gas through RSG techniques.

Projects like GCS can take the concept of more environmentally friendly natural gas further by coupling underground storage with LNG exports to further differentiate the quality of U.S. and South Louisiana natural gas production. According to Wood McKenzie, CCS has the ability to reduce more than 25 percent of the overall carbon emissions depending upon the LNG project itself and the natural gas tied to that project.[85]

There are two commonly cited methods for capturing LNG emissions, one is pre-combustion, the other post-combustion.[86] The pre-combustion process removes CO_2 from the gas stream that can include reservoir activities (like RSG approaches above) as well as removal of CO_2 in the liquefaction process itself (in order to reduce both the Scope 1 and Scope 2 emissions). The post-combustion process is more costly and requires removing CO_2 from the flue gas stream much like a traditional power generation application.

This opportunity has not gone unnoticed by LNG developers. Recently Venture Global LNG announced plans to couple CCS with two of its announced projects: Calcasieu Pass ("CP") and Plaquemines LNG. Venture Global notes that, to date, it has already concluded its engineering and geotechnical analysis and has what it refers to as a "shovel ready" CCS project pending regulatory approvals only. Once all phases of the projects are completed, Venture Global anticipates sequestering as much as 1Mtpa. The projects would be the first of their kind in the United States.

6.5 Implications of the Inflation Reduction Act of 2022

The opportunities for continued expansive clean energy-related capital expenditures in the study region will be greatly expanded by the recent passage of the Inflation Reduction Act of 2022 ("IRA"). Over half of the financial incentives and provisions included in the IRA ($369 million out of $738 billion) are dedicated to helping households, businesses, and industries combat climate change and transition to a new energy future. Table 12 highlights the major investment and tax expenditures (i.e., tax incentive) components of the IRA, focusing on several clean energy initiatives that will be particularly attractive in the GCS study area.

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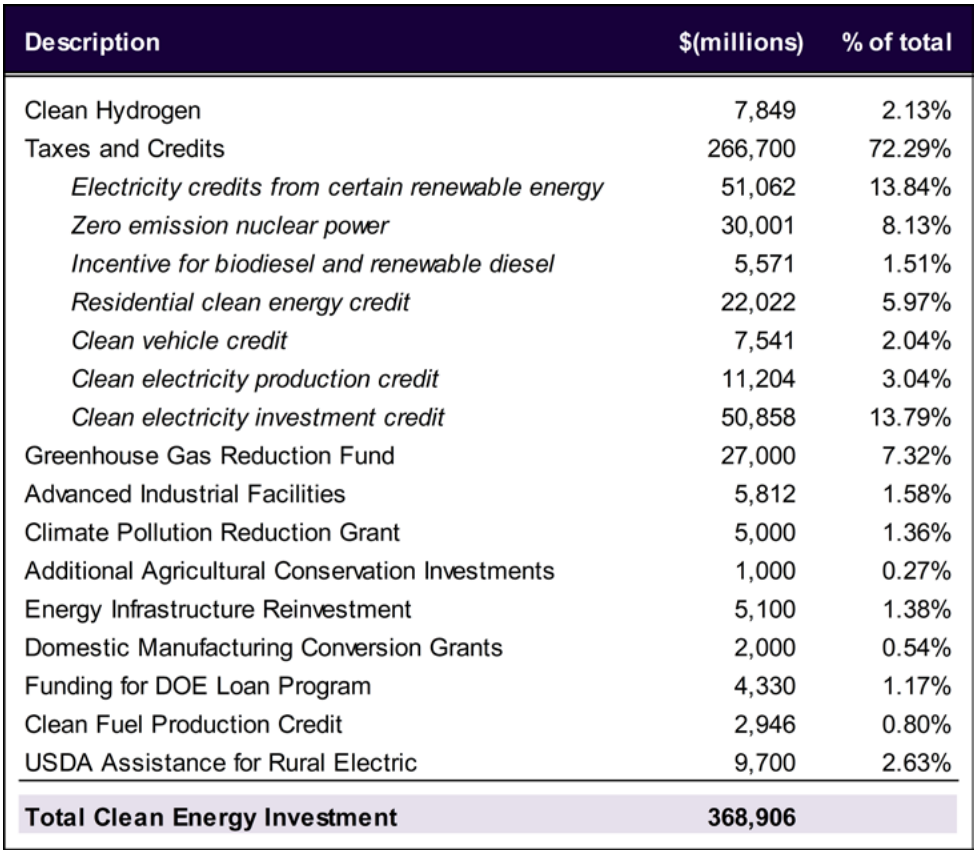
[84] Thomas Russo (2021). "Responsibly Sourced Gas: Time to Change the Natural Gas Industry's Narrative." *Climate and Energy*. February.

[85] Wood McKenzie (2021). "CCS could have material impact on carbon emissions of LNG projects." August 25.

[86] Ibid.

Table 12: Summary of IRA Clean Energy Provisions



Description	$(millions)	% of total
Clean Hydrogen	7,849	2.13%
Taxes and Credits	266,700	72.29%
Electricity credits from certain renewable energy	51,062	13.84%
Zero emission nuclear power	30,001	8.13%
Incentive for biodiesel and renewable diesel	5,571	1.51%
Residential clean energy credit	22,022	5.97%
Clean vehicle credit	7,541	2.04%
Clean electricity production credit	11,204	3.04%
Clean electricity investment credit	50,858	13.79%
Greenhouse Gas Reduction Fund	27,000	7.32%
Advanced Industrial Facilities	5,812	1.58%
Climate Pollution Reduction Grant	5,000	1.36%
Additional Agricultural Conservation Investments	1,000	0.27%
Energy Infrastructure Reinvestment	5,100	1.38%
Domestic Manufacturing Conversion Grants	2,000	0.54%
Funding for DOE Loan Program	4,330	1.17%
Clean Fuel Production Credit	2,946	0.80%
USDA Assistance for Rural Electric	9,700	2.63%
Total Clean Energy Investment	**368,906**	

Source: Congressional Budget Office

There are a number of clean energy provisions included in the IRA that will influence industrial development in the GCS region over the next five years, if not longer. This will be particularly true for the region's chemical sector and its LNG export sector. An important aspect of the IRA is the modification and expansion of what are known as the Section 45Q tax credits that have been available to CCS projects over the past several years. These credits, outlined in Section 45Q of the Internal Revenue Code, give qualifying facilities a fixed dollar per ton tax credit or rebate for sequestering carbon in either a permanent underground storage facility, or through the use of enhanced oil recovery ("EOR") applications. The IRA greatly expands these credits as well as modifies their applicability to remove certain regulatory and tax barriers that limited or created uncertainties for past CCS development projects.

The IRA will increase the dollar credit for CO_2 storage from its prior level of $50 per ton to $85 per ton, provided certain wage and employment qualifications are met. the IRA includes very lucrative tax incentives for "direct air capture" (or "DAC") technologies that uses chemical reactions to extract CO_2 directly out of the air. It is likely that many DAC technologies will be co-located at underground storage locations, like GCS, to minimize the transportation cost of moving CO_2 to permanent underground storage facilities. In fact, GCS has recently announced that it has entered into a Memorandum of Understanding (MOU) with Climeworks to collocate a DAC facility at the GCS site that, by 2030, will remove as much as one million tons of CO_2 from the atmosphere. The IRA increases the credits available to these DACs from a prior level of $85 per ton to as high as $180 per ton, provided certain prevailing wage and employment requirements are met. Congress estimated that taxpayers will claim $3.2 billion in tax credits pursuant to these provisions. Availability of the tax credit, however, is unlimited, and if more facilities are constructed and operated than anticipated, the overall value of the tax credits awarded for CCS could be higher than the estimate.

Collectively, the incentives for CCS and DACs could help to support considerable additional clean energy/energy transition investments in the GCS study area. It is not unreasonable to assume that at least half, if not more, of the eligible CCS projects that will apply for these financial incentives will be along the Gulf Coast. This would entail as much as $1.6 billion in additional tax incentives to support as many as 38 new additional CCS facilities, assuming a 1 Mtpa "typical" (or "average") facility design. The total capital investment to support these 38 facilities, if comparable to GCS on a unitized basis, could be around $1 billion.

Note that under this hypothetical, the additional investment is assumed to be for the primary storage aspect of the tax-eligible projects. The amount, while impressive, does not include any additional capital investment that is associated with industrial capture, does not include any mid-stream investments (pipelines, processing, compression), nor any additional supporting investments which could easily double the $1 billion storage-only investment estimate.

The IRA also creates considerable financial incentives for hydrogen development. The IRA will provide as much as $7.8 billion in mostly direct tax credits for hydrogen development, more than the amounts discussed earlier included for CCS. The IRA creates section "45V" to the Internal Revenue Code that, like the earlier noted 45Q provisions, provides developers with a technology-neutral per unit of hydrogen produced financial incentive for a ten-year period. A qualified clean hydrogen production facility will be eligible for credits as high as $3.00 per kilogram ("kg") if it meets certain lifecycle emissions and prevailing wage and employment standards. In addition, the IRA creates what is known as a "direct pay option" for the tax credits for projects that are developed within an immediate five-year period.

An equally enticing aspect of the IRA is how it allows clean energy projects to leverage multiple tax benefits. For instance, the IRA will allow green hydrogen developers to utilize multiple tax credits, rather than individual tax credits. So, a green hydrogen developer can take advantage of both production tax credits and investment tax credits from the renewable portion of their development, and the new 45V credits for the hydrogen component of the project.

Lastly, and equally important for the GCS study region, the IRA creates a 30 percent credit for energy storage technology constructed before January 1, 2025. At this point, the text of the legislation is not precise on what sorts of infrastructure this might cover, it clearly does apply to hydrogen-related storage. This is important for the GCS region since it is very likely that salt-cavern storage will be the preferred medium for a significant share if not all near-term hydrogen production, particularly hydrogen produced to meet demand that is tied to end-use combustion for boilers, furnaces, and power generation. It is very likely that a considerable amount of this salt-cavern storage will be developed along the Gulf Coast in the GCS study region given the long-standing history and experience with these types of storage facilities and their high availability for near-term commercial development.

Like CCS, there is a very significant probability that most of the financial support afforded for clean hydrogen development will be located in the Gulf Coast region, likely the GCS study region. Estimating the number of facilities that could be developed in the GCS study area, given the IRA provisions, is a challenge since the scale of many existing projects are a pilot or demonstration levels that are around 1 megawatt ("MW") per electrolyzer.

There are some commercial development announcements, for instance, that in the 10 MW and 20 MW size. Assuming these capacities as being the preferred near-term scale results in an estimate of around 650 to 700 total clean hydrogen projects, assuming half of the IRA's funding makes it to the central Gulf Coast. This could result in as much as $5 billion to $6 billion in capital investment assuming installations in the 10 MW to 20 MW range. Note, as before, that this is a conservative regional capital investment estimate since additional infrastructure will be needed to support these initial investments, particularly in storage and pipelines.

6.6 Summary

Louisiana has a unique opportunity to transform its existing energy manufacturing infrastructure to production techniques that minimize, if not become exclusively neutral in GHG emissions. However, given the size and scope of industry's GHG emissions, and the urgency in taking action on these emissions to meet emissions reductions goals over the next decade, Louisiana and the Gulf Coast region will need GHG emissions abatement strategies and applications that bridge the use of natural gas to those that rely more heavily on renewables.

The use of blue strategies, in the production of hydrogen, ammonia, and LNG, therefore, will be important over the next decade in order to reduce Louisiana's and the Gulf Coast's industrial GHG footprint. The key linking these alternative and cleaner burning blue strategies is permanent underground storage like the GCS project. Underground storage captures and sequesters carbon emissions that otherwise would arise from the chemical reformation processes producing hydrogen and ammonia, or through the combustion of natural gas that arises in the liquefaction process at LNG facilities.

Underground storage provides an immediate and cost-effective strategy for industrial facilities to (a) fuel switch to hydrogen or ammonia for combustion purposes for heat and steam and/or (b) use hydrogen, or syngas as a fuel for power generation to facilitate greater levels of industrial electrification. While green approaches offer promise, and should be pursued in conjunction with blue approaches, widespread use of green applications will likely be cost-prohibitive at the scales needed to meet Louisiana's industrial GHG emissions reduction goals.

7 | Conclusions

Countries around the world have made significant commitments and are implementing policies aimed at reducing greenhouse gas emissions across their economies. Simultaneously, private companies are similarly making commitments and investments to reduce their carbon footprints across their global value chains. Although some progress has been made to reduce emissions, globally anthropogenic greenhouse gas emissions continue along an upward trajectory. This poses both a significant challenge and an opportunity for the Gulf Coast region, specifically southern Louisiana and Texas. The region employs more than 150,000 workers directly in the hydrocarbon-based manufacturing sectors that are responsible for significant greenhouse gas emissions.

The purpose of this report is to provide context on one strategy that the region might utilize to reduce its greenhouse gas footprint: carbon capture and sequestration (CCS). The creation of a "carbon hub" can facilitate a market for carbon, where companies can have a viable strategy for reducing emissions from industrial sources.

Economic impacts of the construction and operation of the project are also presented for both the regional economy (including Louisiana and Texas) as well as for the U.S. as a whole. Utilizing EPA's social cost of CO_2, the project has the potential to abate climate damages by $11.3 billion over its lifetime by sequestering a total of 300 million tons of CO_2. Considering the construction and approximately 30 years of operations, the facility will pay a net present value (utilizing 4 percent discount rate) of $560 million in earnings and $980 million in Gross State Product regionally, which includes the states of Louisiana and Texas. Nationally, the project will support an estimated $698 million in net present value (again utilizing 4 percent discount rate) earnings and $1.2 billion in U.S. Gross Domestic Product. During the approximately five years of construction, the project will support an estimated 977 jobs regionally and 1,149 jobs nationally. Once fully completed, on an annual basis the project itself will support approximately 375 jobs nationally paying $21 million in earnings. Regionally, it will support an estimated 286 jobs and $16 million in earnings annually.

Finally, we identify approximately 51 thousand jobs in the refining, chemical manufacturing, and LNG export sectors within 100 miles of the GCS facility that have non-combustion emissions that are candidates for sequestration. There are over 95 thousand such jobs within 200 miles of the GCS facility. Considering the share of emissions that are "non-combustion," the sequestration capacity of the GCS facility once all three phases are fully operational, and the jobs at these facilities, we estimate that this one facility can facilitate the decarbonization of approximately 6,500 high paying jobs.

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9 | Appendix – Identifying Non-Combustion Emissions

To estimate combustion and non-combustion CO_2 emissions by location, we used data from EPA's Envirofacts System and FLIGHT tool. Envirofacts reports total CO_2 emissions at the facility level as well as CO_2 emissions by "Subpart", where Subparts correspond to industrial processes (e.g. stationary combustion, electrical generation, petroleum refining, etc.). Only CO_2 emissions were included. EPA also reports CO_2 emissions data through its FLIGHT tool. These data are also reported in total and by subpart, but data are also provided for every individual emissions source at each facility (e.g.. every flare, boiler, cracker, etc.). We categorized emissions into emissions from combustion sources and emissions from non-combustion sources. Non-combustion sources included all emissions from Subpart G: Ammonia Production and Subpart W, Petroleum and Natural Gas Systems. Ammonia production produces a highly pure stream of CO_2 while the emissions from Subpart W are composed of CO_2 stripped from natural gas processing facilities, either associated with LNG or natural gas production. Non-combustion emissions also included emissions from hydrogen production (Subpart P) as well as the non-combustion emissions associated with petrochemical production (Subpart X). Hydrogen production produces a CO_2 stream that is approximately 45% (Herron et al. 2014). Petrochemical (Subpart X) emissions are more difficult to categorize. For every facility with Subpart X emissions, we used FLIGHT to separate each individual emission source into combustion and non-combustion sources. Non-combustion emissions included those from petrochemical processes while combustion emissions were mostly composed of flares. Similarly, we used FLIGHT data to separate refinery (Subpart Y) emissions into combustion and non-combustion sources. We included all emissions from catalytic cracking units or a sulfur recovery unit as non-combustion emissions and all other emissions (mostly flares).

Combustion emissions were those associated with General Stationary Combustion (Subpart C), electrical generation (Subpart D), and the combustion sources from petrochemical and refinery sectors, as described above. Note that nearly every facility produces Subpart C emissions to produce process heat for the other industrial processes. Note that not all non-combustion sources will be economic to capture with currently available technology and CO_2 concentrations from non-combustions sources will range from about 5 to over 99%. Ammonia production and natural gas processing represent the most significant "low-hanging fruit" followed by hydrogen production and some petrochemical production (especially ethylene oxide). But capture from other sources including refinery sour gas units (Abdollahi et al. 2017) is plausible.

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