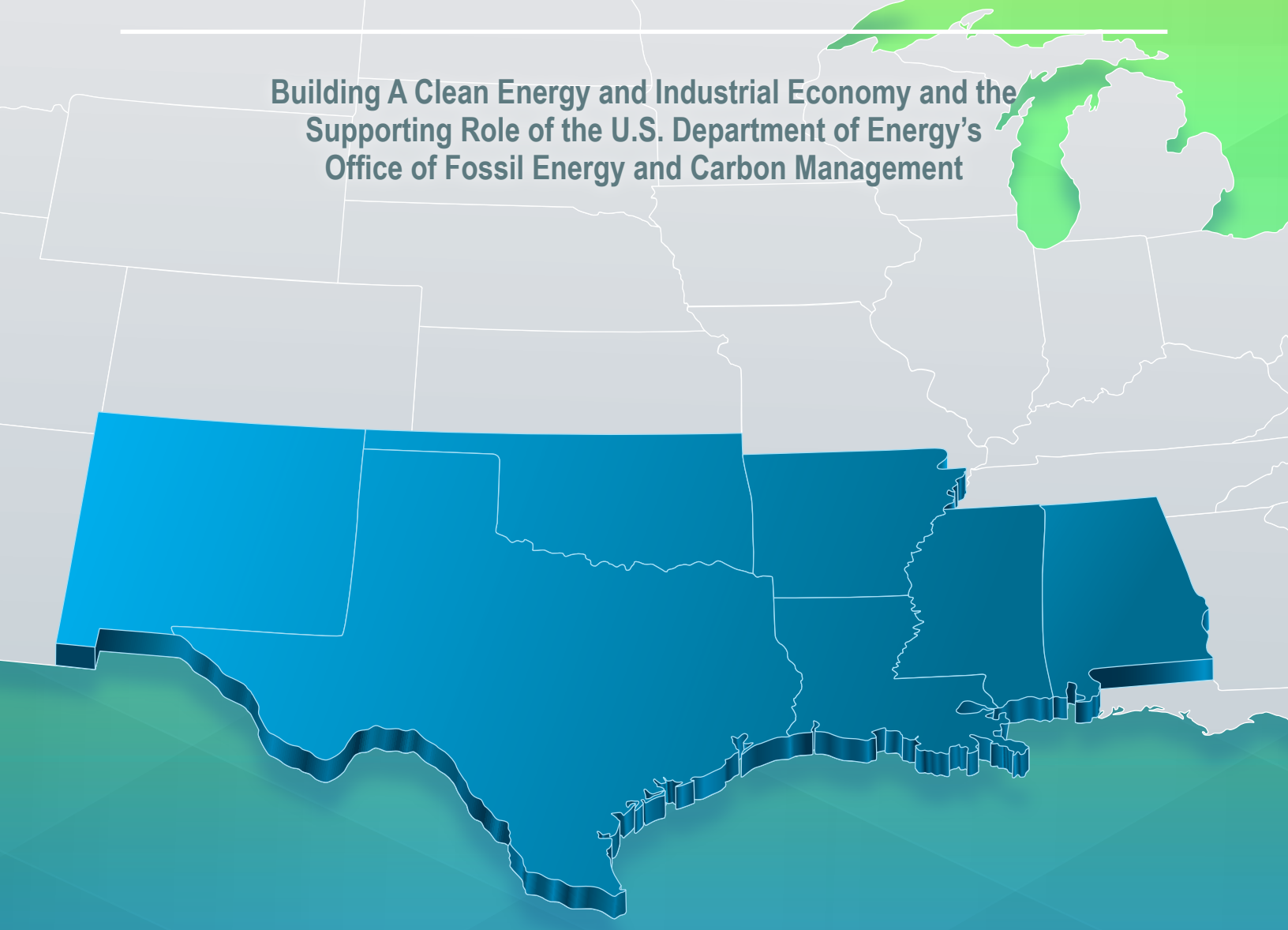
U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

GULF COAST AND SOUTH-CENTRAL REGIONAL REPORT

Building A Clean Energy and Industrial Economy and the Supporting Role of the U.S. Department of Energy's Office of Fossil Energy and Carbon Management



OCTOBER 2024

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Purpose of this Report

The "**Gulf Coast and South-Central Regional Report: Building a Clean Energy Economy and the Supporting Role of the U.S. Department of Energy's Office of Fossil Energy and Carbon Management**" aims to deepen the understanding of the decarbonization opportunities and challenges in the Gulf Coast and South-Central region, supporting broader efforts to achieve a clean energy and industrial future. The Gulf Coast and South-Central region, as defined in this report, includes New Mexico, Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Alabama. The region's significant energy resources and energy workforce, long history of energy development, and vast geological formations support current efforts to decarbonize and scale clean energy technologies. Additionally, by referencing the region's industry, energy mix, and energy activities, this report identifies priority areas for the Gulf Coast and South-Central region and aligns them with the research, development, and demonstration portfolio of the U.S. Department of Energy's (DOE's) Office of Fossil Energy and Carbon Management (FECM) to curate relevant solutions.

This report was developed by the Office of Fossil Energy and Carbon Management in collaboration with the National Energy and Technology Laboratory (NETL).

This report is being disseminated by the Department of Energy. As such, this document was prepared in compliance with Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) and information quality guidelines issued by the Department of Energy.

Introduction

The U.S. energy portfolio and economy currently depend heavily on fossil energy. It is crucial to advance clean energy solutions, such as carbon capture and storage, CO_2 removal, and other decarbonization pathways, to achieve a net-zero greenhouse gas emissions economy. FECM is dedicated to minimizing the environmental and climate impacts of fossil fuels while working to a clean energy and industrial future. Its portfolio encompasses the research, development, demonstration, and deployment of technologies that include carbon capture, carbon conversion, CO_2 removal, CO_2 transport and storage, hydrogen production with carbon management, methane emissions reduction, and critical minerals production.

As part of successfully implementing this portfolio, FECM is engaging with communities and stakeholders across the country, where significant project development is expected to occur, to ensure community and stakeholder participation, understand and address concerns, and increase awareness regarding FECM funding and available opportunities. FECM focuses on two-way engagement, in which communities and stakeholders are not only informed, but given the opportunity provide input and shape the design and development of projects and infrastructure that affect them. This aligns with DOE's broader priority of placing stakeholders and local communities at the center of project development efforts, ensuring that DOE's investments result in tangible benefits for communities.

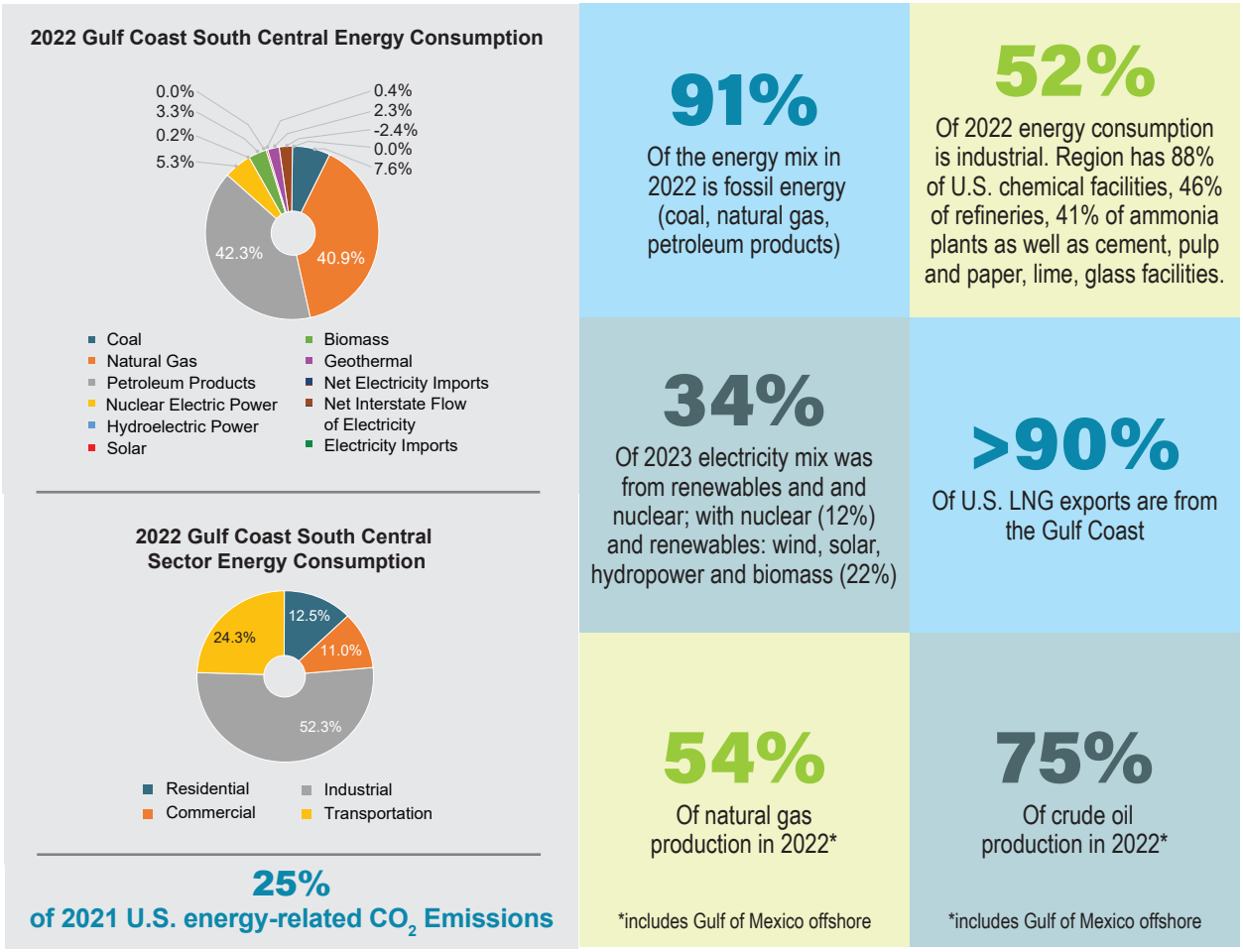
The Community Benefits Plan framework is one example of a significant initiative that aims to institutionalize this priority. This framework aims to ensure that projects receiving public funding, particularly from the Bipartisan Infrastructure Law and the Inflation Reduction Act, create economic, environmental, and societal benefits for the communities and workers where projects are located. Through close collaboration between developers and communities, Community Benefits Plans can evolve into Community Benefit Agreements, which are legally binding agreements between community groups and developers that stipulate the benefits a developer agrees to fund or furnish in exchange for community support of a project. DOE does not require Community Benefit Agreements but encourages them as an outcome of developing a Community Benefits Plan. Ideally, strong Community Benefits Plans result in formal agreements to create lasting benefits that will continue after DOE's involvement in a project ends.

As outlined throughout this report, FECM's focus areas and portfolio of technologies are well-aligned with the Gulf Coast and South-Central's energy mix, local infrastructure, and resources. These efforts will also help the region engage communities, create new jobs, build new supply chains and industry, and invest in private sector and university research and development and innovation. Further, through DOE's Community Benefits Plans, FECM illustrates how the design and scope of a project can maximize economic, environmental, and societal benefits for communities in the region, contributing to project success.

The Gulf Coast and South-Central Region – Domestic Center of Energy Production and Infrastructure with Major Role in Supporting Global Energy Security

The Gulf Coast and South-Central region is one of the most important regions globally for energy resources and infrastructure (Figure 1). In 2022, the region accounted for 75% of U.S. oil production and 54% of U.S. natural gas production. The Gulf Coast and South-Central region is also home to Erath, Louisiana-based Henry Hub (HH), used as a global benchmark for many natural gas contracts; as well as West Texas Intermediate (WTI), the main oil price benchmark for North America based in Cushing, Oklahoma. Much of the oil and gas exported from the Gulf Coast is produced from onshore operations across the South-Central region, including four out of the seven largest onshore oil and gas basins (Permian, Anadarko, Eagle Ford, and Haynesville). Located in Western Texas and eastern New Mexico, the Permian Formation is the largest oil producing formation in the United States, yielding more than 61% of U.S. tight oil in 2023; as well as the second largest dry shale gas producing formation, yielding almost 24% of U.S. dry natural gas. The U.S. is the world's largest oil producer, natural gas producer, and global exporter of liquefied natural gas (LNG), supplying almost 18% of the world's LNG in 2022. Over 90% of U.S. LNG exports come from the Gulf Coast.

Figure 1: Energy in the Gulf Coast and South-Central Region



Source: EIA. Energy consumption (also referred to as energy mix) includes fuels consumed and electricity exported (negative net interstate flow). Electricity mix includes electricity generated from fossil, nuclear, and renewable plants. See EIA glossary. Glossary - U.S. Energy Information Administration (EIA)

In 2022, industry, and primarily energy intensive industry, accounted for approximately 52% of energy consumption in the Gulf Coast and South-Central region compared to 33% within the total U.S. As a result, the total energy mix for this region, despite its significant renewables capacity, remains more than 90% fossil energy. Approximately one-quarter of the total U.S. energy-related GHG emissions come from this region.

The significant industrial activity has supported prosperity in the region. However, communities located adjacent to or nearby energy and industrial facilities have borne the brunt of pollution from this level of industrial activity. The pollution includes harmful criteria air pollutants such as nitrogen dioxide, sulfur dioxide, and particulate matter (fine, inhalable particles).

Additionally, a significant amount of water is used and produced in onshore oil and gas operations. “Produced water” is a term used in the oil and gas industry to refer to the water that comes out of a well during the oil and gas production process. In a few parts of the region (e.g., New Mexico, Texas, and Mississippi), access to water for agriculture and industry is an increasing consideration, making responsible water management and treatment of produced water increasingly important for operators in the region.

However, as we ramp up our efforts to deploy climate solutions, there is an opportunity to move toward cleaner and lower carbon energy, turn produced water into a resource, and develop an industrial economy that provides environmental and economic benefits for residents of these communities and within the broader region.

The Gulf Coast and South-Central region has evolved significantly over the last few decades. Companies in the region are increasing energy efficiency and productivity, reducing flaring and methane emissions, and integrating wind and solar power into operations and biofuels into fuels supply chains. In 2023, renewables and nuclear energy generated 34% percent of the region's electricity mix.

The portfolio of technologies being developed by FECM and other offices across DOE are well-suited to support the Gulf Coast and South-Central region's efforts to increase the share of clean energy technologies and decarbonize existing energy and industrial production while maintaining a leadership role in energy production. These efforts are further supported by the Bipartisan Infrastructure Law and the Inflation Reduction Act, which are helping to enable a robust market for clean energy and industrial projects through a comprehensive portfolio of funding, financing, and tax incentives.

As a part of the Bipartisan Infrastructure Law, DOE will deploy approximately $12 billion in new carbon management funding over five years, including $2.5 billion for six large commercial-scale carbon capture demonstrations and approximately $1.0 billion for large-scale pilot projects under the office of Office of Clean Energy Demonstrations; $2.1 billion for CO_2 transportation infrastructure; $2.5 billion for developing large-scale regional geologic storage sites; and $3.5 billion for regional direct air capture hubs. As part of the $2.1 billion in funding for CO_2 transport, FECM is working with the Loan Programs Office (LPO) to offer access to capital for large-capacity, common-carrier CO_2 transport projects (e.g., pipelines, rail, shipping, and other transport methods). Additionally, FECM is offering "Future Growth Grants" as part of the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) program to extend or enlarge planned carbon transport infrastructure to connect additional CO_2 sources.

Additionally, the federal 45Q tax credit provides up to $85 per metric ton of CO_2 captured from industry and power generation for dedicated storage in geologic formations; $60 per metric ton of CO_2 captured and geologically stored through the process of enhanced oil recovery; $60 per metric ton of CO_2 captured and converted into low carbon products or utilized (subject to the life cycle analysis and CO_2 reduction); and up to $180 per metric ton for direct air capture facilities with dedicated storage in geologic formations. Enhancements to the tax credit include: an authorization of the credit for a full ten years (i.e., all projects beginning construction by the end of 2032 are eligible); the ability to claim the credit for 12 years of operation, directly as a cash payment for the first five years of operation, and the option to transfer the credit to outside investors for the remaining seven years; and expanded eligibility for smaller industrial, power generation, and direct air capture facilities.

Since the Bipartisan Infrastructure Law and the Inflation Reduction Act, the number of U.S. carbon management projects announced annually by the private sector has more than doubled since 2019. Of the 219 cumulative projects in the Clean Air Task Force database, 92 (42%) are in the Gulf Coast South-Central region[1].

[1] CRES illustration with data from IEA, https://www.iea.org/data-and-statistics/data-product/ccus-projectsdatabase. Used in GPI presentation at 2024 NETL Annual Review meeting; U.S. Carbon Capture Project Map – Clean Air Task Force (catf.us) August 28, 2024

In 2023 alone, over $6.5 billion was invested in carbon management in the U.S., approximately half of which went to the Gulf Coast South-Central region.[2] The application queue for Class VI wells is another indicator of activity. At the time of this report, 152 well applications are under review by the EPA across the U.S., and several are located in the Gulf Coast South-Central region. Of those in the region, applications for Oklahoma and Texas are currently under review and Louisiana has been granted Underground Injection Control primacy.[3]

There are a variety of other tax credits as well. The 45X tax credit provides a 10% credit for the production of 50 different critical minerals that are essential to our clean energy economy and national security. The 45V tax credit creates a new 10-year incentive for clean hydrogen production of up to $3.00/kilogram. The level of the 45V credit provided is based on carbon intensity (i.e., the lower the carbon intensity, the higher the credit), with a maximum of four kilograms of CO_2-equivalent per kilogram of hydrogen eligible for the tax credit.

[2] https://www.cleaninvestmentmonitor.org/database as of August 28th, 2024

[3] U.S. EPA Class VI Permit Tracker as of August 16, 2024. (Current Class VI Projects under Review at EPA | US EPA)

Industry

The concentration of petrochemicals, refineries, and natural gas processing facilities creates a significant opportunity to share carbon management infrastructure that could also be leveraged by other industries with facilities in close proximity.

As shown on Map 1, there are more than 220 energy intensive facilities in this region, including 62 refineries (46% of U.S.), 67 petrochemical plants (88% of U.S.), and 94 facilities across ammonia, cement, lime, glass, pulp and paper, and bioethanol. Carbon capture is important for industrial processes that cannot be decarbonized more economically through other carbon-free methods, including chemicals, refining, and cement. If carbon management infrastructure is made available to smaller emitters at a lower cost, it could present an opportunity for industries such as glass and pulp and paper. DOE is funding projects in the region to develop technologies capable of capturing at least 95% of CO_2 emissions generated from diverse industrial sectors. For example, FECM is currently funding three Front-End Engineering Design (FEED) studies in this region: (i) carbon capture on Air Liquide's United States Gulf Coast steam methane reformer; (ii) carbon capture from the CEMEX Balcones cement plant flue gas; and (iii) carbon capture from a hot briquetted iron manufacturing facility.

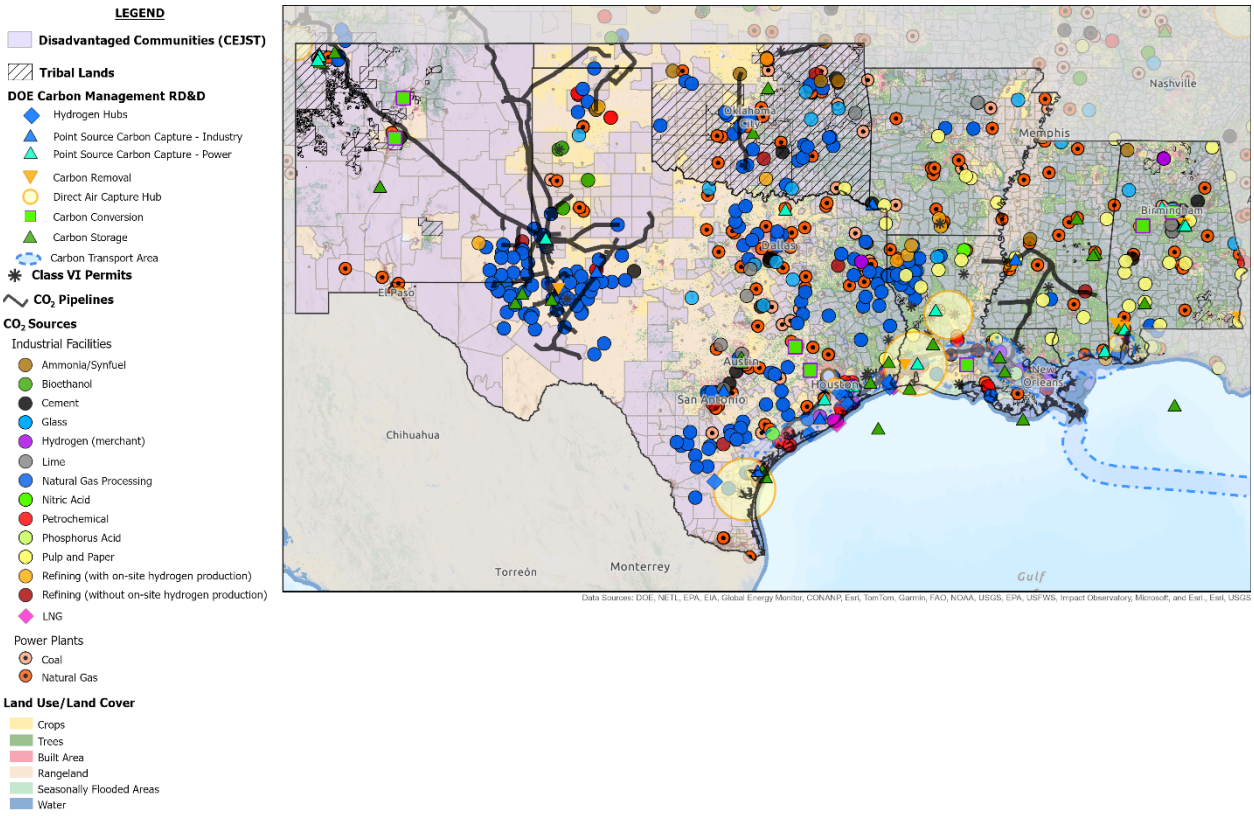
The large number of chemical plants (and refineries and cement plants) in the region are also an opportunity for captured CO_2 to be used as a feedstock for lower carbon chemicals, fuels, building materials, plastics, and bioproducts. For example, methanol can be produced by combining clean hydrogen with captured CO_2 and existing process technology can convert methanol into gasoline, diesel, and jet fuel. The first approved vendor under the Utilization Procurement Grant program is producing low-carbon methanol using carbon conversion at their facility located in Pasadena, Texas and is now eligible to sell their product as part of that program. Industrial emissions also offer other utilization opportunities. CarbonBuilt, a startup which CO_2 emissions captured from power plants and industrial facilities, successfully tested their technology and manufactured concrete blocks as part of a demonstration with the National Carbon Capture Center in Alabama. Importantly, this process mineralizes the CO_2 in the concrete blocks and offers a long duration storage opportunity.

Clean hydrogen production through initiatives like HyVelocity Hub, selected by the DOE's Office of Clean Energy Demonstrations (OCED) for the Regional Clean Hydrogen Hubs Program, will also support industry decarbonization, for example, by replacing the unabated hydrogen currently used in refineries and ammonia plants with clean hydrogen produced by capturing the CO_2 released when hydrogen is produced from natural gas. Clean hydrogen production in the region will also require CO_2 capture, transport, and storage or use of the CO_2 in the manufacture of products, thus providing anchor CO_2 infrastructure that could be leveraged by nearby industrial facilities.

DOE is investing in bold industrial decarbonization technologies at each stage of the innovation pipeline to help manufacturers and businesses use clean energy, increase efficiency, and integrate new, innovative processes and technologies.

Map 1: Industrial Activity in the Gulf Coast and South-Central U.S.

Over 220 energy intensive facilities, current and future sites for clean hydrogen production, and future direct air capture plants, are often clustered together and have an opportunity to share CO_2 transport and storage infrastructure and resources to reduce decarbonization investment costs and risks.



Source: National Energy and Technology Lab (NETL) developed map using publicly available data sets (e.g., EPA, USGS).

Carbon management also offers the opportunity for dispatchable natural gas power generation to continue to support the growth of wind and solar in the region by capturing and storing the CO_2 from natural gas power plants. Over 22% of the electricity in the region is already generated from renewable sources. In 2023, the share of renewables in the electricity mix reached 46% in New Mexico and 44% in Oklahoma. Meanwhile, Texas has the largest installed capacity of wind and solar of any state in the U.S.[4] Natural gas power plants have played a key role in supporting high wind penetration: electricity generated from natural gas increases when wind energy output is low and decreases when it is high. Other markets are planning to implement models like the Dispatchable Power Agreement CCS business model in the United Kingdom to enable natural gas with carbon capture to support further growth in wind and solar. However, carbon capture and storage technologies need to be compatible with this flexible operation. DOE is investing in such technologies through the Advanced Research Projects Agency-Energy's (ARPA-E) FLExible Carbon Capture and Storage program (FLECCS). Supported by the program, researchers in Texas completed a research project to improve the design and processes of carbon capture and storage-equipped plants to reduce their dispatch cost in environments with a high share of variable renewable energy.[5]

[4] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

[5] Southwest Research Institute (SwRI) | arpa-e.energy.gov

The examples so far reflect many of the DOE assisted carbon management projects. However, as referenced earlier in this report, private investment, supported by the 45Q tax incentive, particularly for ammonia, ethanol, and waste-to-energy in this region exceeds government assistance. There are 87 industrial carbon capture, power carbon capture, and CO_2 storage projects in the region, and in 2023 alone, there was over $3 billion of actual investment. Although the projects are at various stages of development, e.g. front-end engineering and design (Pre-FEED, FEED), final investment decision (FID), construction, operations), most are FEED studies.

Direct air capture is also an opportunity in the region. Two-commercial-scale direct air capture facilities in Texas and Louisiana will be funded by OCED for DOE's Regional Direct Air Capture (DAC) Hubs program; and a non-DOE-affiliated project is underway which will include carbon and storage infrastructure that may be leveraged by nearby industries. Three feasibility studies (Texas, Louisiana, and Alabama) were also selected by FECM for award negotiation under the program.

Additionally, although New Mexico has less industrial activity for some industries (with only two refineries and one cement plant) and has among the lowest emissions in the U.S. (ranking 37/50 states in emissions), there are 24 natural gas processing plants and significant oil and gas activity in the Permian Basin. Given the oil and gas activity; rich wind and solar resources available to power direct air capture; and the growing emissions offset market, New Mexico presents an opportunity to explore renewables powered direct air capture coupled with carbon capture and CO_2 storage.

There is significant potential in the region for carbon capture from industry, hydrogen production, natural gas and coal power plants, and carbon removed through direct air capture to share carbon management infrastructure and reduce the costs. Many of these facilities are clustered together and in close proximity to existing CO_2 pipelines and storage options, and they are attracting the interest of CO_2 pipeline and geologic storage project developers where there is an opportunity to build new infrastructure to service future decarbonization and carbon removal needs. The region has a long history of transporting CO_2 via existing CO_2 pipelines, particularly from natural CO_2 producing domes for enhanced oil recovery. Clean hydrogen production could also provide anchor demand for pipelines that could be leveraged by smaller emitters. A recent study suggests that the average transport costs could be reduced by two-thirds when CO_2 pipelines are shared rather than dedicated to individual capture facilities.[6]

As project developers begin to develop these CO_2 transport and storage hubs in the region, they have an opportunity to facilitate project success by prioritizing project development that engages local community and stakeholder groups to better understand their concerns and identify benefits that are important to them. For example, the potential of capture technologies to also manage and reduce harmful criteria air pollutants is important to energy and industry-adjacent communities that have experienced significant environmental and health burdens due to their long-term exposure to these non-GHG emissions. To further support co-pollutant reduction, DOE is developing monitoring approaches to stay ahead of the risks like amine degradation, as well as investing in a broad suite of additional capture technologies such as solid sorbents, membranes, and cryogenic separation that do not rely on amines.

[6] Shared CO_2 capture, transport, and storage for decarbonizing industrial clusters - ScienceDirect

Another benefit that developers should consider, in consultation with communities, labor organizations, and local community and technical colleges, is how to support local economic development through workforce development, reskilling opportunities, and other means. For example, the HyVelocity Hub, selected by OCED for the Regional Clean Hydrogen Hubs program, alone is expected to create approximately 45,000 direct jobs[7] and the two OCED funded commercial scale Direct Air Capture Hubs in Louisiana and Texas estimate the creation of 2,300 and 2,500 jobs, respectively. Developers whose projects proceed with or without federal funding can refer to FECM's "Responsible Carbon Management Initiative" as a guide for how to pursue the highest levels of safety, environmental stewardship, transparency, and community engagement and benefits in project development.

[7] Regional Clean Hydrogen Hubs Selections for Award Negotiations | Department of Energy

Energy and Resources

The region's high quality geological storage, dense concentration of energy and industrial production, extensive energy infrastructure, experienced energy workforce, and available fiscal incentives result in cost competitive abatement of CO_2 on a per metric ton basis.

Carbon transport and storage is not new to the Gulf Coast and South-Central region. As shown in Map 2, the Gulf Coast and South-Central region has existing CO_2 pipelines that could, depending on existing contracts terms, provide carbon transport opportunities to surrounding industries. Additionally, the region's robust saline and oil and gas formations, as well as the Jackson and Bravo CO_2 domes, offer the potential to store billions of metric tons of CO_2 from power plants and industrial facilities, as well as CO_2 removed from the atmosphere via direct air capture.

CO_2 domes are underground formations where naturally occurring CO_2 has been contained for more than a million years. In the early 1980s, the oil and gas industry began extracting and transporting CO_2 from the Bravo dome for enhanced oil recovery in the Permian Basin. As of 2019, Cumulative production for the Bravo dome amounted to 3.3 trillion cubic feet (tcf) (121 million metric tons) of CO_2, with about 5.5-10 tcf (202- 367 million metric tons) of recoverable CO_2 in reserves.[8] The CO_2 from the Jackson Dome in Mississippi has also been used for enhanced oil recovery over the past decade and represents an estimated 5-9 tcf (183- 330 million metric tons) of recoverable CO_2 supply.[9] In 2022, the Bravo and Jackson domes produced a combined 9.07 million metric tons of CO_2; and 3.21 and 5.86 million metric tons of CO_2, respectively.[10] Two additional CO_2 domes in Colorado, McElmo and Sheep Mountain, supply CO_2 for enhanced oil recovery in West Texas. As a result of this production, there is existing infrastructure in place to possibly transport and store captured CO_2 in these domes and provide an early foundation for future CO_2 transport and storage hub development.

In 2003, DOE embarked on a series of regional research and development projects on carbon storage in the Gulf Coast and South-Central region. In 2016, the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) program was launched to support the commercial development of geologic storage and provide crucial resources and information necessary for large-scale geologic storage facilities or carbon management hubs. As shown on Map 2, there are a number of Phase III- Site Characterization and Permitting CarbonSAFE projects in the region. The national network of CarbonSAFE projects is on track for targeted commercial injectivity of 100 million metric tons per year and to identify contingent storage resources[11] of 6 billion metric tons by 2035. In addition to geologic resource characterization, modeling, permitting, and ultimately construction and commercial operations, projects incorporate public engagement and provide technical assistance and resources to communities. As described earlier, the BIL provisions for geologic storage and CO_2 transport (CIFIA) are examples of incentives that support these storage opportunities.

[8] https://nmgs.nmt.edu/publications/guidebooks/downloads/70/70_p0101_p0108.pdf

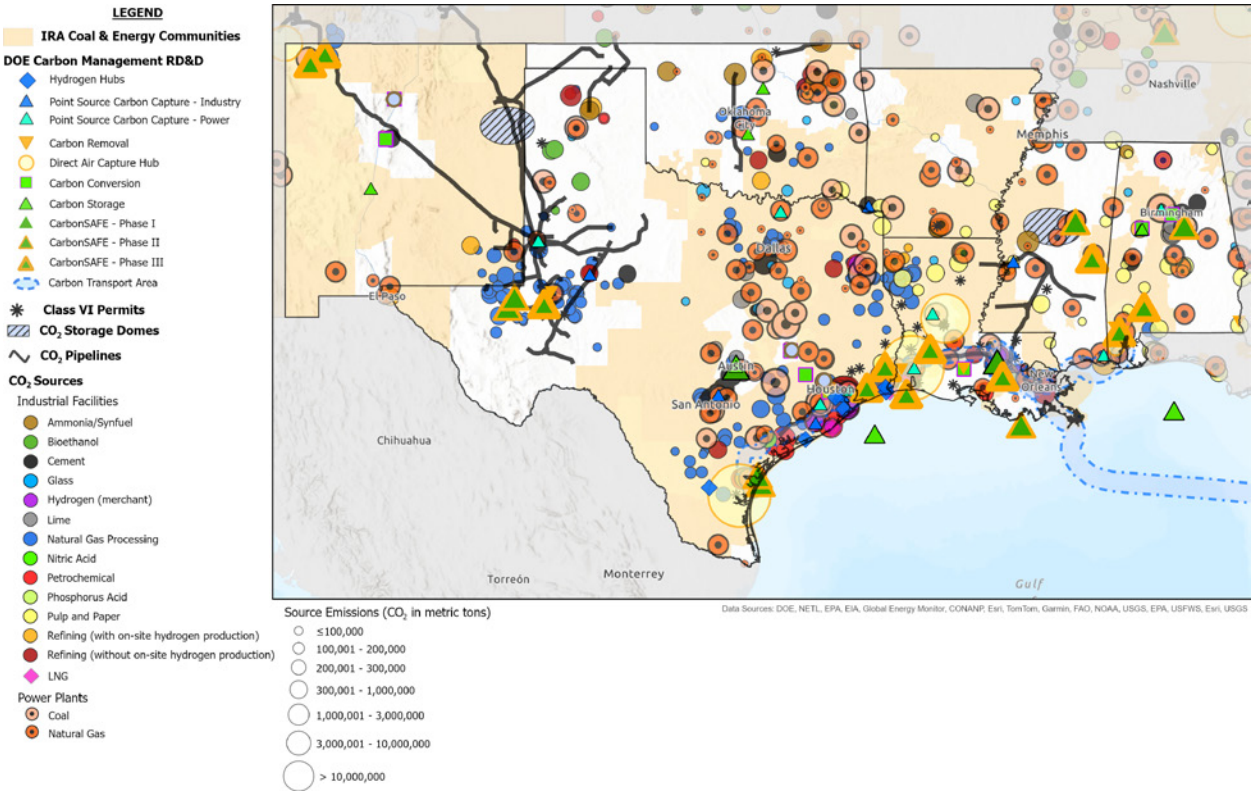
[9] Denbury Demonstrates Feasibility Of CO_2 EOR In Mature Fields (aogr.com)

[10] https://ghgdata.epa.gov/ghgp/main.do

[11] Contingent storage resources are storage resources estimated to be accessible in known geologic formations, but the applied project(s) are not yet considered mature enough for commercial development, as a result of one or more contingencies. srms_sep2022_w_errata.pdf (spe.org)

Map 2: Energy Infrastructure and Resources in the Gulf Coast and South-Central U.S.

Abundant CO_2 storage resources, well-understood geology, existing energy infrastructure close to emitting industries, and an extensive skilled energy workforce can be leveraged to make this one of the most competitive regions to decarbonize on a cost per metric ton basis.



Source: National Energy and Technology Lab (NETL) developed map using publicly available data sets (e.g., EPA, USGS).

Beyond CO_2 storage, the region's diverse geology could further provide energy storage options through infrastructure development for underground hydrogen storage (UHS). Three of the four domestically operating UHS facilities operate within engineered salt caverns in Texas. Beyond salt cavern storage, the region's abundant depleted oil and natural gas reservoirs may be suitable for large-volume hydrogen storage within the subsurface. Workforce knowledge and community familiarity with gas storage operations could further accelerate the deployment of low carbon energy storage in the region. DOE's Subsurface Hydrogen Assessment, Storage, and Technology Acceleration (SHASTA) Project is assessing the Gulf Coast and South-Central region for geologic suitability for UHS demonstration and deployment.[12]

As shown on Map 2, there are a significant number of coal and energy communities in this region with a long history of experience living and working alongside the energy industry. This skilled energy workforce can be trained to support the deployment of new technologies in their communities. DOE's University Training and Research program is funding projects focused on science, technology, engineering, and mathematics (STEM)

[12] Enhancing Site Screening for Underground Hydrogen Storage: Qualitative Site Quality Assessment - SHASTA: Subsurface Hydrogen Assessment, Storage, and Technology Acceleration Project (Technical Report) | OSTI.GOV)

fields that consider the human impacts of technologies during development and student training. For example, the University of Texas at El Paso will investigate the community barriers to adopting gasification technologies.

The infrastructure and energy workforce that makes the region attractive for carbon management is a result of the region's long history of oil and gas production that will continue to be the region's biggest industry for the foreseeable future. Reducing emissions and the environmental impact of the oil and gas industry through new technologies and practices will support the region's future competitiveness as markets and buyers start to consider emissions and environmental impact in oil and gas supply sources. FECM programs to support these efforts include the Methane Emissions Reduction Program, Methane Mitigation Technologies, and Advanced Remediation, which are described in the subsequent paragraphs.

FECM is working with EPA to implement $1.36 billion in technical and financial assistance through the Methane Emissions Reduction Program that was established under the Inflation Reduction Act to target methane emissions across the oil and natural gas supply chain. The program will provide funding to undertake a wide range of measures, including monitoring methane emissions; voluntarily plugging high-emitting, low-producing marginal wells and reducing emissions at other operating wells and infrastructure; and providing financial assistance for installing technology to reduce emissions from equipment such as valves, tanks, and compressors. In December 2023, the Biden-Harris Administration announced the first round of funding of $350 million to 14 states. Texas, Louisiana, and New Mexico are the three states from the Gulf Coast and South-Central region that received these formula grants in the amounts of $134.1 million, $15.7 million, and $14.7 million, respectively. In June 2024, DOE and EPA made a joint announcement that $850 million in federal grant funding will be made available competitively to industry, research and technical organizations, tribes, communities, and others for projects that monitor, measure, quantify, and reduce oil and gas sector methane emissions.

FECM's Methane Mitigation Technologies program focuses on achieving near-elimination of emissions from the oil and gas supply chain—from production to processing, transportation, storage, and end use—by 2030, including:

- Advanced sensors to increase the efficiency, reliability, and resiliency of methane detection, measurement, and monitoring to facilitate elimination of methane emissions across the natural gas infrastructure
- New control systems to optimize operation and eliminate fugitive emissions
- Materials, equipment, and processes to enable currently flared, vented, or otherwise stranded natural gas to be converted to products with a higher market value

Additionally, LongPath Technologies received a conditional commitment from the DOE's Loan Program Office (LPO) for an up to $189 million loan guarantee to support the fabrication and installation of a real-time methane emissions monitoring network in the region. LongPath's Active Emissions Overwatch System project aims to cover 25 million acres of land with large-area remote methane monitors, providing emissions detection, location, and quantification services for tens of thousands of oil and gas sites through a subscription service.

Under the Advanced Remediation Technologies Research and Development portfolio, FECM has invested over $55 million in six Gulf Coast Field Test Sites that have helped accelerate the development of new technologies, tools, and processes for optimizing oil and gas operational efficiency and environmental stewardship. These projects have also generated valuable geotechnical data for improved characterization of unconventional oil and gas reservoirs as potential future geological storage sites for any type of fluid storage, including both CO_2 and hydrogen.

Treatment and beneficial reuse of produced water is also a priority in regions of Texas, Mississippi, and New Mexico that are water stressed areas.[13] Produced waters that move back through the wellhead with the gas from drilling, fracturing, and production operations represent a stream that must be managed. State governments, local governments, and shale gas operators seek to manage produced water in a way that protects surface and ground water resources, and if possible, reduces future demands for fresh water. Under the Advanced Remediation Technologies portfolio, DOE will fund a $3.2 million produced water treatment project.[14] Using treated wastewater not only reduces freshwater needs in regions with limited freshwater resources, but it also decreases wastewater volumes disposed of in deep water wells, which has been linked to a recent increase in minor earthquakes in the Permian Basin. Produced water also contains valuable critical minerals, and recovering these critical minerals is a potential opportunity that will be discussed in the next section.

The Gulf Coast and South-Central region has the dual opportunity and challenge of improving the sustainability of existing operations and transitioning its core oil and gas industry and workforce to support industrial decarbonization, particularly through carbon management and clean hydrogen production. There is a significant opportunity to build upon the oil and gas and petrochemical industry expertise and workforce in the Gulf Coast and South-Central U.S. to preserve and create high-wage jobs. According to the Rhodium Group and Great Plains Institute, the carbon capture and storage industry has the potential to create almost 39,752 annual jobs across New Mexico, Texas, Louisiana, Arkansas, Oklahoma, and Mississippi. When hydrogen and related supply chains are considered, this number will be even more significant.

[13] Map: Where ongoing water crises are happening in the US right now - ABC News

[14] DOE Invests $10 Million to Increase Domestic Supplies of Water and Critical Minerals | Department of Energy

Recovery of Critical Minerals from Produced Water

Many of the USGS priority critical minerals are present in the produced water of the region's oil and gas operations, creating another opportunity to turn waste into a resource.

The Gulf Coast and South-Central region has an opportunity to play a key role in developing domestic sources of critical minerals and materials and rare earth elements. Critical minerals and rare earth elements are key to our national defense and to manufacturing clean energy technologies—such as solar panels, wind turbines, electric vehicles, and hydrogen fuel cells—that will help the U.S. achieve a net-zero emissions economy. Demand for critical minerals and materials and rare earth elements is growing in the U.S. and globally, and the U.S. currently imports greater than 80% of its rare earth elements from non-domestic suppliers. DOE is pursuing research to recover rare earth elements and critical minerals from energy and mining waste streams to develop a domestic supply chain of critical minerals and rare earth elements that will reduce U.S. dependence on foreign sources.

FECM is investing in research and development projects to advance water treatment and management technologies while also recovering critical minerals from produced water. Like oil and gas, this non-potable water exists naturally underground. Depending on the chemistry of the rocks, it may contain many different chemical constituents, including mineral salts, organic compounds, heavy metals, naturally occurring radioactive materials, critical minerals, and other minerals.

The volume of water produced per well during oil and gas development and production can vary greatly depending on geological factors. However, as the number of wells and production increases, so does the volume of produced water. The Permian Basin, which spans western Texas and New Mexico, represents about half of U.S. oil production and an oversized share of produced water production. Albeit in low concentrations, critical minerals like barium, lithium, manganese, and magnesium can be found in Permian-produced water. Because of the high volumes, even low concentrations can be material. For example, the Permian Basin's produced water volume is about 20,000,000 barrels per day. In a simplistic calculation, using the median concentration of lithium in Permian-produced water from tight oil wells of 18 ppm, the theoretical lithium present in the produced water is over 15,500 metric tons per year. Comparably, U.S. consumption of lithium reached 3,000 metric tons in 2022.[15]

In addition to the Permian, the Eagle Ford, Haynesville, and the Anadarko development areas are also in the Gulf Coast and South-Central region.[16] In addition to existing operations' production of water, these development areas offer the possibility of drilling into underground brine deposits rich in critical minerals. For example, in the Haynesville Shale, the Smackover formation is known to contain high concentrations of lithium in the brine, and multiple developers are applying their geological and drilling expertise to extract lithium.[17]

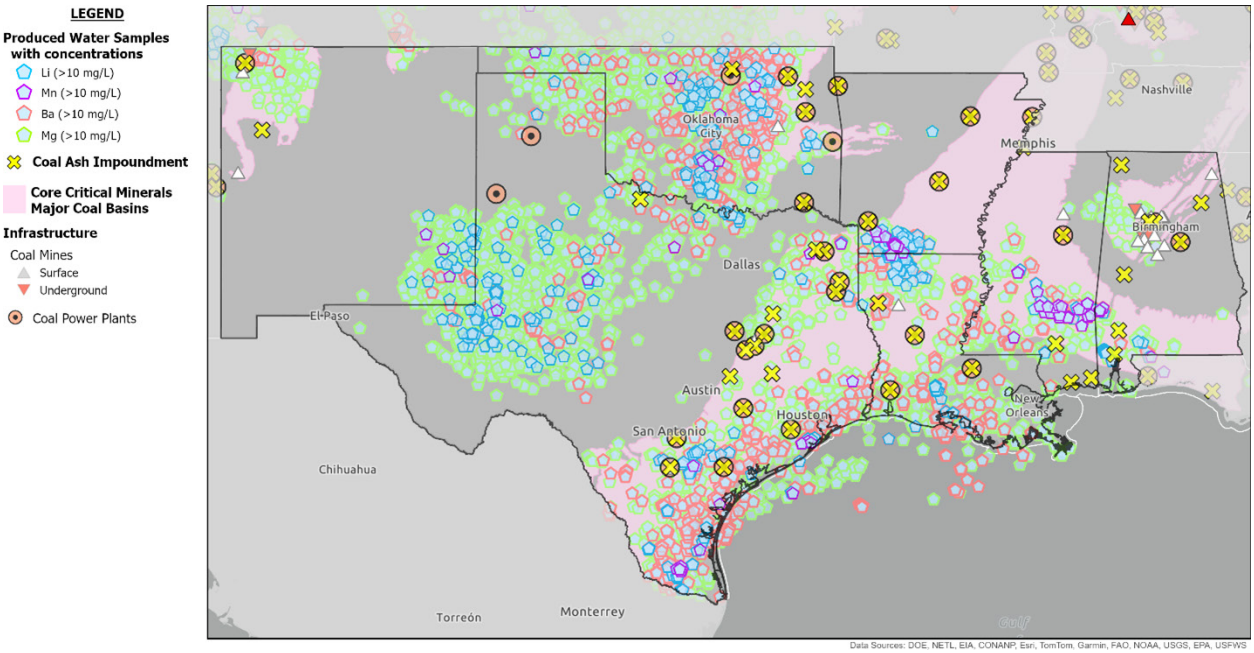
[15] U.S. annual lithium consumption | Statista

[16] Drilling Productivity Report - U.S. Energy Information Administration (EIA)

[17] Arkansas' Huge Lithium Reserves go Unexploited, Until Now (prnewswire.com)

Map 3: Critical Mineral and Rare Earth Element Resource Potential

With 54% of natural gas production and 75% of oil production, the region accounts for the vast majority of produced water from U.S. oil and gas operations. Recovering critical minerals and remediating that produced water thus presents an important opportunity. Oil and gas operators have a particular opportunity to apply their geological and drilling expertise to extract lithium in the region's unconventional oil and gas formations.



Source: National Energy and Technology Lab (NETL) developed map using publicly available data sets (e.g., EPA, USGS).

However, the economics to recover the critical minerals from produced water is challenging, given the small concentrations, high cost of separations, and large water volumes. Further research and development of extraction technologies that can accommodate varying produced water qualities (e.g., very high salinity and total dissolved solids) and compositions are needed. The extraction process will depend on the produced water composition, and there are many technology options[18] that need to be tested and evaluated for their effectiveness, economics, and environmental impacts. Some examples include electrocoagulation, chemical precipitation, thermal distillation, adsorption, advanced oxidation, membrane filtration, flotation, solvent extraction, and biological technologies. FECM is funding research to develop these technologies. A $1.9 million project with the New Mexico Institute of Mining and Technology will comprehensively characterize produced water from the Permian and San Juan Basins in New Mexico and develop a scalable and highly efficient membrane distillation-crystallization and adsorption process for simultaneous water and critical elements recovery from produced water. A $2.2 million project with Texas Tech University will develop a system engineering approach for produced water resource extraction and management involving vacuum membrane distillation integrated with vapor compression to extract water, selectively recovering elements of interest using staged precipitation, and developing an optimization framework for managing produced water and identifying infrastructure needs. Additionally, innovative business models that leverage shared water treatment infrastructure at the basin level could be an opportunity.

[18] Standard Water Treatment Techniques and their Applicability to Oil & Gas Produced Brines of Varied Compositions (Book) | OSTI.GOV

Liquefied Natural Gas and Hydrogen/ Ammonia Export

Growing LNG production and associated infrastructure and efforts to reduce methane and CO_2 emissions can also be leveraged to develop the clean ammonia and hydrogen market.

As a hub of crude, natural gas, and petroleum product production, storage, marketing, and trading, the Gulf Coast and South-Central region has historically played an important national and global energy security role, especially during times of energy supply crises. During the onset of the Russia-Ukraine war, the refineries in the region were asked to increase refining runs to reduce fuel prices. The region is also home to the U.S. Strategic Petroleum Reserve which has been used to mitigate oil supply disruptions . Additionally, as Europe sought to reduce its reliance on Russian natural gas supplies, the Gulf Coast and South-Central region supported Europe's and the Biden Administration's efforts to replace Russian gas with U.S. LNG. As a result, the U.S. is now the primary supplier of LNG to Europe and the number one global exporter, with most of those exports coming from this region.[19]

DOE has a regulatory role authorizing U.S. LNG exports and has a robust export posture. The cumulative amount of LNG exports that DOE has approved to non-free trade agreement countries now stands at over 48 billion cubic feet per day (Bcf/d). This approved amount represents approximately 45% of total current U.S. domestic dry natural gas production, and according to the U.S. Energy Information Administration's 2023 Annual Energy Outlook, it is near the highest levels foreseen in the most robust LNG export scenarios. This cumulative amount approved by DOE for export is also approximately four times the current LNG export levels, which average approximately 12 Bcf/d, an amount that already makes the U.S. the top global exporter of LNG. In addition, based on export capacity approved by DOE and now under construction, the total amount of U.S.-sourced natural gas export capacity is set to nearly double, reaching 26 Bcf/d by 2030. This means that the U.S. will remain the top exporter of LNG in the world by a large measure, surpassing second-ranked Qatar by over 40% at the end of this decade once capacity under construction in both countries is complete. Accordingly, with this dramatic growth in LNG exports from the Gulf Coast, DOE is focused on opportunities to reduce methane and CO_2 emissions related to LNG across the natural gas supply chain.

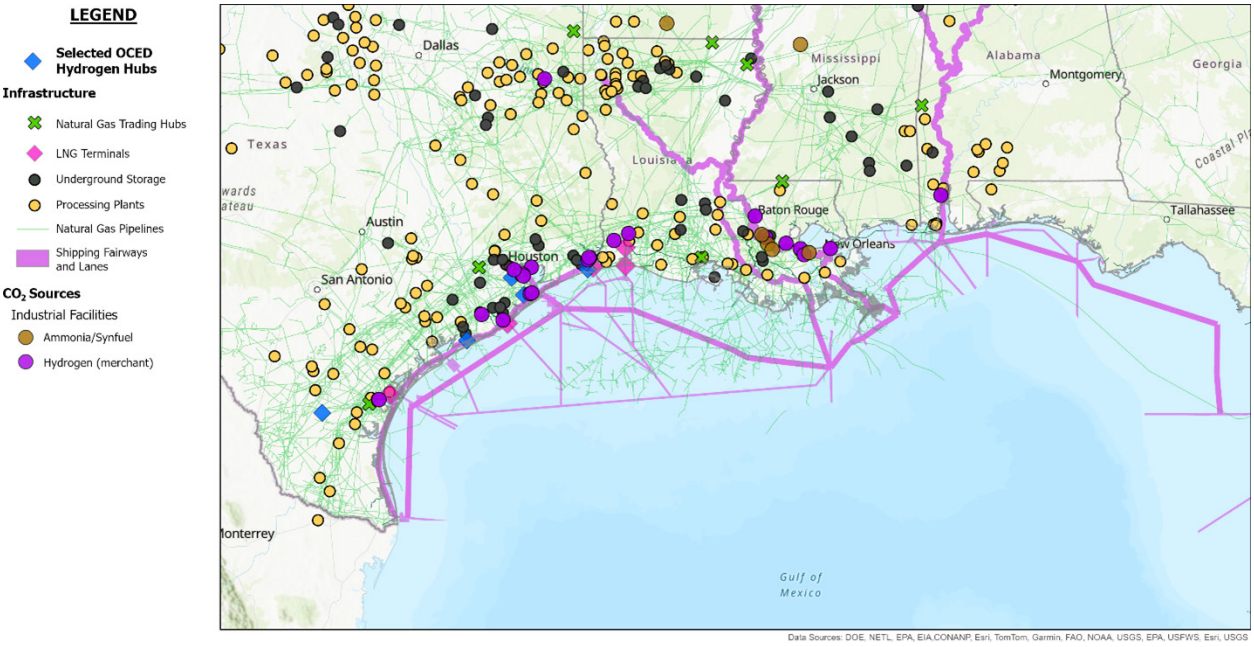
The Gulf Coast's role in the global market, and its existing broader natural gas ecosystem, gives the Gulf Coast a comparative advantage in building the global clean hydrogen economy of the future. Momentum in the development of hydrogen and ammonia as a replacement for natural gas has been growing globally as countries progress on their energy transitions. Initiatives like the OCED selected HyVelocity Hub have identified clean hydrogen export as a key opportunity and the capabilities and infrastructure of the Gulf Coast as an advantage in exporting hydrogen. In another example in Louisiana, in April 2024, CF Industries and JERA entered into

[19] https://www.eia.gov/todayinenergy/detail.php?id=57000

a Joint Development Agreement (JDA) to evaluate building an approximately 1.4 million metric ton capacity low-carbon ammonia plant in Louisiana that would also supply more than 500,000 metric tons of low-carbon ammonia annually to Japan to meet its demand for low-carbon fuels.[20] In addition to the presence of the international traders, marketers, and storage companies in the Gulf Coast that would likely play a role in the global trade of hydrogen and ammonia, the region's LNG-related infrastructure (as shown on Map 3) and experience in market formation, quality assurance and standards, export contracting and insurance, and port, shipping, and storage operations can also potentially be leveraged for clean hydrogen and ammonia.

Map 4: LNG and Clean Hydrogen and Ammonia Export

Reducing methane emissions from the natural gas supply chain is critical to LNG trade and to clean hydrogen and ammonia production in the Gulf Coast. The existing LNG export and international trade infrastructure will enable the global trade of clean hydrogen and ammonia.



Source: National Energy and Technology Lab (NETL) developed map using publicly available data sets (e.g., EPA, USGS).

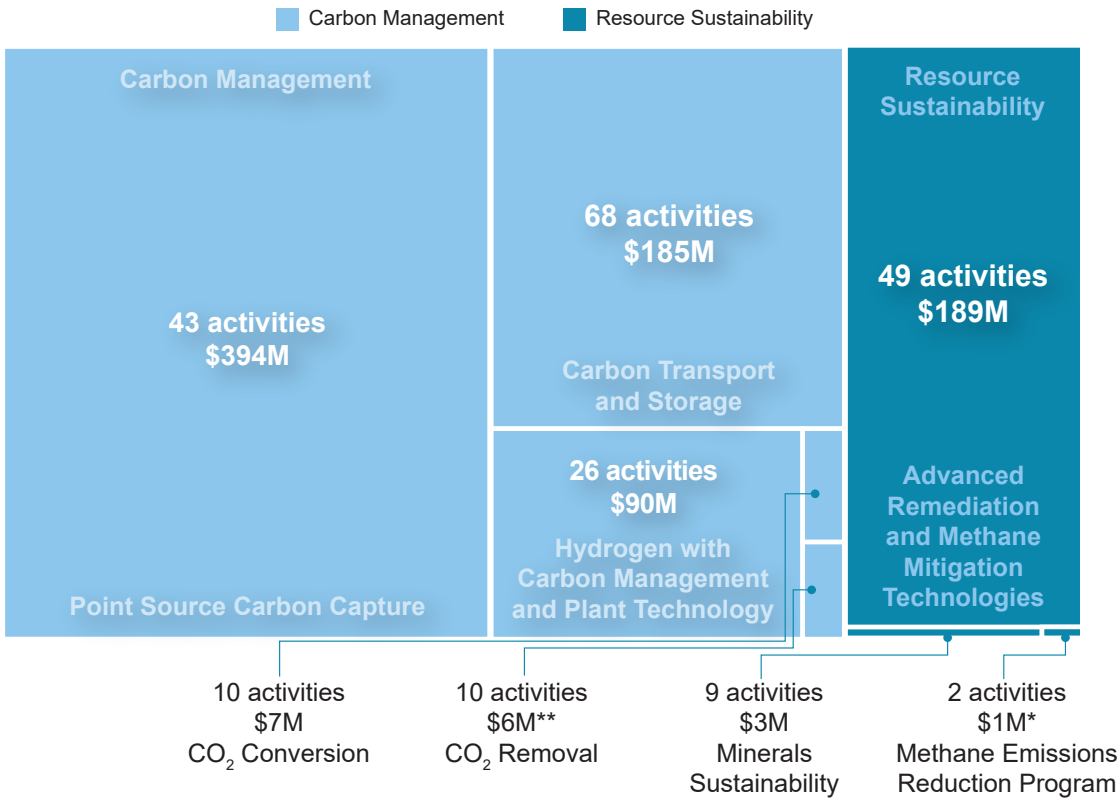
DOE's goal is to bring transparency, improved technology, and best practices to the production, processing, transport, liquefaction, and end uses of natural gas across the U.S. gas supply chain, which can, in turn, help the U.S. achieve among the lowest emissions profiles of any natural gas in the world. FECM is supporting the development of a global framework for measurement, monitoring, reporting, and verification of the greenhouse gas intensity of natural gas —both methane and CO_2 emissions— across the international supply chain. In line with the DOE's U.S. Methane Emissions Reduction Action Plan, which reflects an overall global goal to cut methane emissions by 30% from 2020 levels by 2030, FECM announced the creation of an International Working Group to establish the Greenhouse Gas Supply Chain Emissions Measurement, Monitoring, Reporting, and Verification (MMRV) Framework in November 2023.

[20] CF Industries and JERA Announce JDA to Develop Greenfield Low-Carbon Ammonia Production Capacity in U.S. | CF Industries

Spotlight on Investment and Support in the Gulf Coast and South-Central Region

FECM has long supported the Gulf Coast and South-Central region, a global energy leader and hub for innovation and deployment of energy technology and infrastructure. As of August 2024, FECM has invested more than $870 million into active and awarded projects, supporting over 215 activities with organizations in the region. This includes $383 million for 116 activities in Texas; $370 million for 36 activities in Alabama; $66 million for 38 activities in New Mexico; $40 million for 20 activities in Oklahoma; $15 million for five activities in Louisiana; and $0.5 million for two activities in Mississippi. Organizations to receive FECM funding include industry, academic institutions, not- for-profit entities, and government entities. Figure 2 illustrates the total regional investments for each of FECM's research programs.

Figure 2: Gulf Coast and South-Central Region Projects and Investments by FECM Program Areas
(Includes value of awards to companies/organizations based in the region, both prime and sub-contracted, with active projects[21])



* The share of the $850 million funding awarded with EPA in the Methane Emissions Reduction Program is not included in the numbers because funding comes from the EPA.

** The Regional Direct Air Capture Hub funding for Project Cypress and South Texas DAC Hubs are not included because the funding comes from OCED

Source: FECM and NETL database

[21] Active and awarded projects as of August 2024. Completed, and selected but not awarded, projects are not included.

By fostering collaboration across various sectors and driving transformative research, development, and deployment of technologies and infrastructure, the Gulf Coast and South-Central region is helping to shape the future of energy and setting a model for successful collaboration between academia, industry, and governments to deploy new low carbon technologies, as evidenced by the sheer number of projects in this region and their relative maturity.

Figure 3 highlights the DOE-funded projects referenced throughout the FECM Regional Report, as well as several other select projects in the region, including:

- Multiple carbon capture projects at cement, iron, hydrogen, and power plants
- Hydrogen production with carbon management
- Carbon transport and storage, including CO_2 pipelines and geologic storage sites
- Continuous monitoring of methane emissions from oil and gas production sites
- Reduction of methane emissions from wells on nonfederal lands and environmental restoration of well sites
- Multiple University Training and Research projects to prepare future energy workforce
- HyVelocity Hub in Texas (selected for OCED Regional Clean Hydrogen Hub Program)
- Direct Air Capture Hubs in Louisiana and Texas (funded by OCED Regional Direct Air Capture Hub Program)

The projects underway are not merely technological milestones: they represent the economic and intellectual vitality of the region and contribute to a sustainable and prosperous future for itself, the nation, and the world at large. Importantly, although often in early stages, many of these projects have Community Benefit Plans to ensure that projects receiving public funding, particularly from the Bipartisan Infrastructure Law and the Inflation Reduction Act, create economic, environmental, and societal benefits for the communities and workers where projects are located. As the Gulf Coast and South-Central region continues to evolve, the partnership between FECM, industry, universities and research institutions, state, local and tribal governments, and communities will undoubtedly play a pivotal role in shaping a sustainable and technologically advanced future.

Figure 3: Selection of Key Projects

Point Source Carbon Capture Industrial Sources | Power Sources

- $4M for pre-FEED studies to capture carbon dioxide from hydrogen production in Texas at Linde's facilities to Port Arthur and Sweeny and Air Liquide's Rodeo Plant
- $5M for FEED/pre-FEED studies for carbon capture at CEMEX's Balcones Cement Plant in New Braunfels. TX
- $4M for a FEED study for carbon capture at ArcelorMittal's hot briquetted iron facility in Texas
- $14M for FEED studies for carbon capture retrofits at power plants in Texas at Calphine's Deer Park Energy Center and in Louisiana at Cleco Power's Madison Power Plant Unit 3

Hydrogen with Carbon Management Hydrogen Fuel | Gasification | Solid Oxide Fuel Cells & Gas Turbines

- $6M for a FEED study to capture carbon dioxide from hydrogen production in La Porte, Texas
- $3M for Pre-FEED studies to capture carbon dioxide using Linde-BASF advanced aqueous amine or Svante VeloxoTherm™ solid adsorbent technology at steam methane reforming hydrogen plants in the Gulf Coast region
- Up to $1.2B for the HyVelocity Hub to produce hydrogen using natural gas with carbon capture and renewables-powered electrolysis* (OCED selected)

Carbon Dioxide Removal Direct Air Capture | Mineralization

- $1.1B for regional direct air capture hubs in Kleberg County, Texas and Calcasieu Parish, Louisiana. Each hub will remove up to 1 million metric tons of carbon dioxide annually and store it permanently deep underground* (*OCED funded)
- $2.5M for a pre-feasibility study for a direct air capture hub in the greater Houston area using a clean power source (renewable or nuclear energy)
- $3M to evaluate the feasibility or building a direct air capture hub in Louisiana

Carbon Transport and Storage Monitoring, Verification, Accounting, & Assessment of Long-Term Storage | Storage Infrastructure Demonstration | Accelerating Regional Initiatives | CarbonSAFE

- $12M for Coastal Bend Carbon Management Project: CarbonSAFE Phase II
- $9M to evaluate the feasibility of deploying carbon capture and storage in the Coastal Bend region of the Texas Gulf Coast
- $48M to demonstrate the feasibility of converting a mature oil and gas field in the Permian Basin into a dedicated carbon dioxide storage facility
- $1.4M for integrated carbon capture and storage pre-feasibility in the Northwest Gulf of Mexico

Advanced Remediation Environment Impacts of Development | Reducing Land and Water Impacts through Improved Recovery Efficiency | Produced Water Management | Repurposing Existing Infrastructure

- $29.3M for Hydraulic Fracturing Test Sites 1 & 2 to improve resource recovery efficiency and minimize current and future air and water quality impacts
- $7.8M for Field Evaluation of the Caney Shale as an Emerging Unconventional Play
- $7.8M for The Austin Chalk/Eagle Ford Field Laboratory
- $4.1M for technologies to extract critical minerals from produced water in New Mexico and Texas
- $7.9M for Engineered Water for Improvement of Oil Recovery for Fractured Reservoirs

Methane Mitigation Advanced Materials | Date Management Tools | Dynamic Compressor R&D | Direct & Remote Sensors

$4M to expand, improve, and document an existing network that is testing the capabilities of continuous monitoring of methane emissions from oil and gas production sites in the Permian Basin. The project will extend the Project Astra network to a basin-wide platform and advance detection and quantification capabilities.

$164.5M to cut methane emissions from wells on nonfederal lands and support environmental restoration of well sites on Texas, Louisiana, and New Mexico* (*EPA funded).

University Training and Research Education & Training | Novel, Early-stage R&D | Building R&D Capacity | Preparing the Future Workforce

Seven active projects with total award value over $4.5M and least 39 students trained:
Oklahoma State University, Prairie View A&M University, Texas State University, University of Texas at El Paso, University of Texas at San Antonio, University of Texas, Rio Grande Valley

Five additional institutions involved in projects selected for negotiation in FY24:
Angelo State University, Dillard University, Texas A&M University, Texas Tech University, University of Houston

Conclusion

FECM is committed to minimizing the environmental and climate impacts of fossil fuels and industrial processes to achieve net-zero emissions across the U.S. economy. The Gulf Coast and South-Central region's industrial and energy dominance make it one of the most important regions to decarbonize—one quarter of the U.S. energy-related greenhouse gas emissions comes from the seven states in this region. Additionally, 28% of the total U.S. refining, petrochemical, ammonia, lime, cement, glass, pulp and paper, and ethanol facilities are in this region.[22] Over the last few decades, companies in the region have increased energy efficiency and productivity, reduced methane emissions, and integrated wind and solar into operations and biofuels into supply chains.

As the region continues to deploy climate solutions, there is an opportunity to build a clean energy and industrial economy that provides environmental and economic benefits for residents of communities and the broader region. The region's energy, industry, infrastructure, and resources are well-suited for FECM's portfolio of technologies as described in this report. For example, the region's concentration of industries lends itself to creating economies of scale in carbon management, in which multiple facilities within close proximity to each other can deploy carbon capture technologies to reduce CO_2 emissions at the source and share CO_2 pipelines and storage infrastructure to reduce costs. The region's extensive LNG export infrastructure can help lay a foundation to advance the clean hydrogen and ammonia economy, and the oil and gas industry can improve and optimize its operations to reduce methane emissions and turn wastewater into a resource. One of the biggest advantages of the region is its highly skilled energy workforce capable of supporting the new technologies.

The Gulf Coast and South-Central region is entering the next chapter of its energy and industrial evolution. It will undoubtedly continue to play a key role as a leading energy producer and in ensuring energy security as the world moves to implement new low carbon fuels, technologies, and infrastructure creating jobs for its local communities and advancing industry innovation.

[22] There are 802 refining, petrochemicals, ammonia, lime, cement, pulp and paper, glass, soda ash, bioethanol, BF/BOF-steel in the EPA Flight database, and 223 are in the Gulf Coast South-Central region.

The Gulf Coast and South-Central Regional Report is one of six regional reports that highlight resource sustainability and decarbonization solutions in fossil energy-producing and industrial regions. Given the rapidly evolving market, technology, and policy environment, the regional reports are intended to be "living documents" and will be updated as the outlook on each region evolves. Please note these reports and regional decarbonization workshops do not represent DOE policy or strategy, but rather are a representation of DOE's current understanding based on a synthesis of available facts.

FECM welcomes input and feedback on content for each of the reports. Please direct all inquiries and input to FECMRegionalReport@hq.doe.gov. Input and feedback should not include business-sensitive information, trade secrets, proprietary, or otherwise confidential information. Please note that input and feedback provided is subject to the Freedom of Information Act.

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