Council on Environmental Quality Report to Congress on Carbon Capture, Utilization, and Sequestration

Delivered to the Committee on Environment and Public Works of the Senate and the Committee on Energy and Commerce, the Committee on Natural Resources, and the Committee on Transportation and Infrastructure of the House of Representatives, as directed in Section 102 of Division S of the Consolidated Appropriations Act, 2021

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ANSI	American National Standards Institute
APA	Administrative Procedure Act
BECCS	Bioenergy carbon capture and sequestration
BLM	Bureau of Land Management
BOEM	Bureau of Ocean and Energy Management
CarbonSAFE	Carbon Storage Assurance Facility Enterprise
CCPI	Clean Coal Power Initiative
CCS	Carbon capture and sequestration/storage
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization, and sequestration/storage
CDR	Carbon dioxide removal
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CSA	Canadian Standards Association
DAC	Direct air capture
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EA	Environmental assessment
e-GGRT	EPA electronic Greenhouse Gas Reporting Tool
EGR	Enhanced gas recovery

EIS	Environmental impact statement
EOR	Enhanced oil recovery
EPA	U.S. Environmental Protection Agency
FAST-41	Fixing America's Surface Transportation Act, Title 41
FDA	U.S. Food and Drug Administration
FECM	Office of Fossil Energy and Carbon Management (DOE)
FEED	Front-End Engineering Design
FERC	Federal Energy Regulatory Commission
FY	Fiscal year
GCI	Global CO_2 Initiative
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
Gt	Gigaton
ICCS	Industrial Carbon Capture and Storage
IGCC	Integrated gasification combined cycle
IRS	Internal Revenue Service
ISO	International Organization for Standardization
Km	Kilometer
LCA	Life cycle analysis
LCFS	Low Carbon Fuel Standard
LPO	Loan Program Office (DOE)
MLA	Mineral Leasing Act
MPRSA	Marine Protection, Research and Sanctuaries Act
MVA	Monitoring, verification, and accounting
MWe	Megawatts electric
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NIST	National Institute of Standards and Technology
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
PHMSA	Pipeline and Hazardous Materials Safety Administration
R&D	Research and development
RAPID	Regulatory and Permitting Information Desktop toolkit
RCRA	Resource Conservation and Recovery Act
RCSP	Regional Carbon Sequestration Partnership
RD&D	Research, development, and demonstration
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
ROD	Record of Decision
RUS	Rural Utilities Service
RVO	Renewable Volume Obligation

SCALE Act	Storing CO_2 and Lowering Emissions Act
STB	Surface Transportation Board
STOMP	Subsurface Transport Over Multiple Phases
TEA	Techno-economic analysis
TELGP	Tribal Energy Loan Guarantee Program
U.S.C.	U.S. Code
UIC	Underground Injection Control
USDOT	U.S. Department of Transportation
USE IT Act	Utilizing Significant Emissions with Innovative Technologies Act
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WPCI	Wyoming Pipeline Corridor Initiative

1 Executive Summary

To reach the President's ambitious domestic climate goal of net-zero emissions economy-wide by 2050, the United States will likely have to capture, transport, and permanently sequester significant quantities of carbon dioxide (CO_2).[1] In addition, there is growing scientific consensus that carbon capture, utilization, and sequestration (CCUS) and carbon dioxide removal (CDR) will likely play an important role in decarbonization efforts globally; action in the United States can drive down technology costs, accelerating CCUS deployment around the world.[2]

Carbon capture technology can reduce emissions of other kinds of pollution (such as sulfur oxides) in addition to carbon pollution, and can provide well-paying union jobs. For CCUS to scale more widely, CCUS technology deployment must advance in the context of a strong regulatory regime informed by science and experience. Responsible CCUS projects should include meaningful public engagement and help address cumulative pollution for overburdened communities. In addition to the climate and equity imperatives for responsible CCUS deployment, there is an economic imperative to support these technological systems: CCUS can reduce the costs of meeting climate goals, and maintain and create well-paying union jobs nationwide and globally.[3]

The Administration is therefore committed to accelerating the responsible development and deployment of CCUS to make it a widely available, increasingly cost-effective, and rapidly scalable climate solution across all industrial sectors. To broadly scale CCUS in an manner that is efficient, orderly, and responsible, the President has committed to increasing support for CCUS research, development, demonstration, and deployment (RDD&D), enhancing the Section 45Q tax incentive for CCUS (Internal Revenue Code of 1986, as amended ("Section 45Q")), advancing a technology-inclusive Energy Efficiency and Clean Electricity Standard, ensuring a robust and effective regulatory regime, and supporting efforts to ensure that CCUS technologies are informed by community perspectives and deliver desired climate, public health, and economic goals, as outlined in this report.[4]

CCUS plays several critical roles in achieving climate goals. CCUS is likely to be especially important for decarbonizing the industrial sector, where high-temperature heat can be difficult and expensive to electrify and where there are significant emissions as a result of chemical processes.[5] CCUS may also play an important role in decarbonizing the global power sector. While the first priority for addressing climate change must be to reduce emissions rapidly, CDR technologies, such as direct air capture (DAC) and permanent sequestration, are likely needed to deliver on the Paris Agreement goals to hold warming well below 2 degrees Celsius and pursuing efforts to hold warming to 1.5 degrees Celsius, which is necessary to prevent the worst impacts of climate change. According to the Intergovernmental Panel on Climate Change, the scale of CDR required to stabilize global temperatures is on the order of 100-1,000 gigatons (Gt) of CO_2 over the 21st century.[6] Some CDR approaches, including DAC and bioenergy carbon capture and sequestration (BECCS), may incorporate geologic sequestration. CCUS is therefore an emission reduction strategy where it is applied to new and existing sources of emissions, and an enabler of CDR from the atmosphere.

CCUS already plays an important and valuable role in the U.S. economy, and the technology continues to evolve. In the United States, there are 5,200 miles of dedicated CO_2 pipelines, and 52 million tons of CO_2 were supplied to EOR for injection underground in 2019.[7] And there are approximately 45 CCUS facilities in operation or in development in the United States today.[8] The costs of carbon capture have decreased by 35% between a first-of-a-kind power plant with carbon capture and the second facility using the

same technology.[9] The United States has more CCUS activities planned and proposed than any other country. But if the United States is to achieve its climate goals, research suggests that CCUS deployment should increase tenfold over the next decade.[10] Deploying CCUS at a larger scale will require robust governance to ensure these systems are delivering desired societal outcomes and have broad and deep public support. Successful widespread deployment of responsible CCUS will therefore require strong and effective permitting and regulatory regimes and meaningful public engagement early in the technological deployment process.

Incentives, structures, and policies, such as the Section 45Q tax credit, California's Low Carbon Fuel Standard (LCFS), and the Department of Energy's RDD&D funding opportunities, are likely to accelerate CCUS deployment. Still, incentives alone are not enough for successful and responsible technological deployment, which also requires standards that provide regulatory certainty and safeguard public health and the environment. As this report reveals, CCUS is progressing in the United States in part because such a framework is taking shape. The Environmental Protection Agency (EPA) has a regulatory framework that was finalized in 2010 under the authorities of the Safe Drinking Water Act and the Clean Air Act that ensures the long-term, safe and secure geologic sequestration of CO_2. The Utilizing Significant Emissions with Innovative Technologies (USE IT) Act made CCUS infrastructure eligible for the permitting review process created under Fixing America's Surface Transportation Act (FAST-41).[11] And the President's American Jobs Plan seeks to build on this momentum, all while reducing pollution for overburdened communities and maintaining and growing well-paying union jobs.

As part of the USE IT Act, included in H.R. 133 (116th Congress), Congress directed the Chair of the Council on Environmental Quality (CEQ) to prepare a report on CCUS, with a particular focus on identifying and inventorying existing permitting requirements, including best practices to advance the efficient, orderly, and responsible development of CCUS projects at increased scale. The USE IT Act defines "efficient, orderly, and responsible" as "a process that promotes environmental, health, and safety protections while maintaining a process that is completed in an expeditious manner." Like all technological systems, CCUS will only deliver desired societal and environmental benefits if it is well-designed and well-governed; CCUS must be deployed in the context of a strong and appropriate regulatory framework that protects public health, the environment, and workers, and addresses place-specific concerns and issues.

This report was drafted with input from the Environmental Protection Agency (EPA), the Department of Energy (DOE), the Department of the Interior (DOI), the Department of Transportation (DOT), the Federal Permitting Improvement Steering Council (Permitting Council), and other relevant agencies and components of the Executive Office of the President. A working group with representatives from these agencies reviewed Federal permitting processes and requirements, and compiled information as required.

Summary of Key Findings

1. President Biden is committed to accelerating the responsible development and deployment of carbon capture, utilization, and permanent sequestration as needed to decarbonize the U.S. economy by mid-century.
2. CCUS will only deliver desired societal and environmental benefits (climate-related and otherwise) if its deployment is well-designed and well-governed. The Administration is particularly focused on the role CCUS can play in maintaining and creating well-paying union

jobs and addressing cumulative impacts in historically disadvantaged and overburdened communities.

3. The scale of implementation of CCUS and carbon removal likely to be required to achieve climate goals understandably raises concerns about public health and environmental impacts, as well as questions about who stands to benefit from the deployment of these systems. Responsible CCUS projects should address cumulative pollution and should incorporate environmental justice and equity considerations.
4. CCUS has a critical role to play in decarbonizing the global economy. This is particularly true in the industrial sector, where high temperatures are required to drive industrial activity and where process emissions from chemical reactions are more difficult to address.
5. Combating climate change and meeting net-zero goals may ultimately require deployment of technologies capable of removing CO_2 from the ambient air, known as CDR. Responsible CCUS deployment enables future CDR deployment; irresponsible deployment can constrain it.
6. There is a wide array of carbon utilization options. Each technical approach for carbon utilization (pathway) has specific characteristics in terms of technical maturity, market potential, economics, and CO_2 reduction potential, and may have different societal and environmental impacts as well.
7. CO_2 pipelines are critical to the future nationwide deployment of CCUS. Extensive research identifies the priority pathways and necessary pipeline infrastructure required to achieve CCUS at a climate-relevant scale across all industries, but significant investments, planning, and community engagement and analysis will be required.
8. Key guidance documents and best practices have been developed by the Federal Government, industry, and non-governmental organizations to assist CCUS project developers in moving CCUS efforts forward responsibly and efficiently. As with any industrial activity, the applicable permits and reviews will depend on the characteristics of the particular project.
9. The Federal Government has an existing regulatory framework that is rigorous and capable of managing permitting and review actions while protecting the environment, public health, and safety as CCUS projects move forward.
10. The pathway for regulating CCUS projects is established, but given the nature of CCUS projects that combine several complex undertakings (capture, transport, and storage, for example), the precise mix of permits and reviews needed for a particular project will be determined by project-specific details. This report identifies where clarification and improvements could be made to the existing framework to ensure that CCUS is responsibly scaled in a timely manner that is aligned with climate goals.
11. Incentives are already driving CCUS investments that are being regulated according to the existing framework outlined in this report, and further efforts can help to accelerate CCUS deployment to achieve our climate goals while achieving other societal objectives.

2 Introduction

2.1 Background

On December 27, 2020, Congress enacted Division S, Innovation for the Environment, of the Consolidated Appropriations Act, 2021 (Pub. L. 116-260), which includes Section 102, cited as the Utilizing Significant Emissions with Innovative Technologies (USE IT) Act. Subsection (c) of the USE IT Act created a Carbon Utilization Program by amending the Energy Policy Act of 2005 (Pub. L. 109-58) to add a new Section 969. Subsection (d) of the USE IT Act directs the Chair of CEQ, in consultation with the Administrator of the EPA, the Secretary of Energy, the Secretary of the Interior, the Secretary of Transportation, the Executive Director of the Permitting Council, and the head of any other relevant Federal agency as determined by the President, to prepare a report on CCUS. Congress specified that, for the purposes of this report, CCUS is inclusive of direct air capture techniques, although there are important differences across these categories, and CO_2 removal will be addressed comprehensively in a forthcoming report.

These entities were tasked with drafting a report that "compiles all existing relevant Federal permitting and review information and resources for project applicants, agencies, and other stakeholders interested in the deployment and impact of carbon capture, utilization, and sequestration projects and carbon dioxide pipelines"; "inventories current or emerging activities that transform captured carbon dioxide into a product of commercial value, or as an input to products of commercial value"; "inventories existing initiatives and recent publications that analyze or identify priority carbon dioxide pipelines needed to enable efficient, orderly, and responsible development of carbon capture, utilization, and sequestration projects at increased scale"; "identifies gaps in the current Federal regulatory framework for the deployment of carbon capture, utilization, and sequestration projects and carbon dioxide pipelines"; "identifies Federal financing mechanisms available to project developers"; and "identifies public engagement opportunities through existing laws." In response, this report was written to address these topics.

It is worth noting that this is one in a series of reports on CCUS requested by Congress as part of the Consolidated Appropriations Act, 2021.[12] To the extent that there are issues not addressed comprehensively in this report, they may be addressed in forthcoming reports. Relevant Congressionally mandated reports include:

- Department of the Interior, Environment, and Related Agencies Appropriations Act, 2021 (Division G):
    - A report to Congress on recommendations to improve the Class VI permitting procedures for geologic sequestration
- USE IT Act (Division S):
    - A report to Congress on deep saline formations focusing on the risks and benefits of geologic sequestration with recommendations for risk management and mitigation
    - A National Academies of Sciences, Engineering and Medicine study to assess the barriers and opportunities relating to the commercial application of CO_2
- Energy Act of 2020 (Division Z):
    - A National Academies of Sciences, Engineering and Medicine study to assess any barriers and opportunities relating to commercializing carbon, coal-derived carbon, and CO_2

- A Government Accountability Office report on the successes, failures, practices and improvements of DOE in carrying out commercial-scale carbon capture demonstrations
- A report to Congress on the carbon capture technology program
- A report to Congress that assesses the progress of all regional carbon sequestration partnerships, identifies the remaining challenges in achieving large-scale carbon sequestration, and creates a roadmap for carbon storage
- A report to Congress examining the opportunities for research and development in integrating blue hydrogen technology in the industrial power sector, and how that could enhance the deployment and adoption of CCUS
- A report to Congress on CO_2 removal methods

2.2 What is CCUS?

Carbon capture, utilization, and permanent sequestration refers to a set of technologies that remove CO_2 from the emissions of point sources or the atmosphere, and either transport it, compress it, and inject it deep in the earth's crust (and monitor sites to verify safe and secure storage operations), or transform it for utilization in industrial processes or as feedstock for useful commercial products.[13] Safe and secure geologic sequestration requires a deep rock formation (thousands of feet underground) with pore space that can trap the CO_2, and a dense caprock overlying it. CO_2 can also dissolve and, over time, combine with minerals to become a solid. In many cases, the geological conditions for safe and secure storage do not precisely overlap geographically with point sources of CO_2, so the CO_2 must be transported, usually by pipeline (although truck, train, and ship transportation of CO_2 is common for other purposes). Because these systems vary significantly (e.g., a carbon capture project at a natural gas plant in one place versus a carbon capture project at a cement facility in another), careful attention to the conditions under which specific projects can be implemented, while protecting people and the environment, is critical.

The technologies for CCUS already exist, with a reported 26 commercial-scale projects in operation globally,[14] and an estimated 45 CCUS facilities in operation or in development in the United States today.[15] These projects are by their nature complex – marrying carbon capture with transportation and sequestration – and therefore the applicable local, state and Federal permits and reviews will depend on the characteristics of the particular project.

The "U" in CCUS (or, more accurately, carbon capture and utilization (CCU)) refers to the potential for using captured CO_2 to make products, like concrete or plastics. CCU is a broad term used to describe the many different ways that captured CO_2 can be used or "recycled" to produce economically valuable products or services.

There are different types of point sources of CO_2. CCUS can apply to the power sector (e.g., coal- and natural gas-fired power plants), as well as the industrial sector (e.g., cement, steel, paper mills). There are some industrial processes that already capture CO_2 as part of normal operations (e.g., natural gas processing or fossil-fuel based hydrogen production) and others that yield a high purity stream of CO_2 (e.g., ethanol or nitrogenous fertilizer production). Some of these CO_2 streams have been captured and used by the oil industry for enhanced oil recovery since the 1970s, resulting in incidental geologic sequestration of CO_2 with business-as-usual operations, although quantifying the amount of CO_2 sequestered requires monitoring and verification.[16,17]

Combating climate change and meeting net-zero goals will likely ultimately require deployment of technologies capable of removing CO_2 from the ambient air, known as CDR. CDR is different from CCUS, in that CO_2 is captured from the ambient air and permanently stored, either in geologic formations or as useful commercial products. CDR can also include techniques to remove CO_2 from the atmosphere through enhancement of terrestrial or ocean sinks. Direct air capture (DAC) and sequestration, enhanced mineralization, and bioenergy carbon capture and sequestration (BECCS) are among the CDR approaches being explored. CDR systems share some technologies and infrastructure with CCUS. For example, BECCS approaches can include conventional carbon capture technologies, typically used in large point source applications. Additionally, carbon sequestration[18] is applicable for any source of CO_2, be it from a large point source or the atmosphere. Utilization concepts can also be applied to CDR systems, such as DAC. A DAC system with a utilization technology that converts the CO_2 into a product, such as concrete, could durably store CO_2. The key difference between CDR and CCUS is that the former aims for a net reduction of CO_2, whereas the latter aims to avoid new emissions.

More details on CDR technologies will be included in an accompanying Report to Congress as requested in Division Z, Title V, Section 5001, Carbon Removal, of the Energy Act of 2020. This report will include an inventory of current and emerging CO_2 removal technologies, and more specific recommendations on policy tools that the Federal Government can use to advance deployment of CO_2 removal technologies, including direct air capture.

2.3 Role of CCUS in Addressing Climate Pollution

To mitigate the most severe impacts of climate change, the world must reach net-zero greenhouse gas emissions by mid-century, and net-negative emissions shortly thereafter. Removing CO_2 from the ambient air will be necessary. The Intergovernmental Panel on Climate Change has noted that limiting temperature rise to less than 1.5 degrees Celsius above pre-industrial levels may require geologic sequestration at a scale of 350 billion metric tons to one trillion metric tons of CO_2 cumulatively by 2050.[19]

The following recent analyses suggest a role for CCUS in meeting climate goals, domestically and globally:

- Intergovernmental Panel on Climate Change: In the Special Report on Global Warming of 1.5 degrees Celsius, all scenarios included CDR. One scenario (PI) excluded BECCS. In this scenario, a globally downsized energy system enables meeting targets with afforestation as the only CDR option.[20]
- International Energy Agency: In the Net Zero Emissions Scenario, CCUS and CDR are estimated at 7.5 Gigatons (Gt) and 1.9 Gt per year by 2050. Enabling CCUS and CDR at this level will require prioritization and increased research and development (R&D) spending by governments globally.[21]
- National Academies of Sciences Engineering and Medicine: To put the United States on a path to net-zero emissions by 2050, the report states that the United States should build out a national CO_2 capture, transport, and disposal network, and in the next decade, carbon capture and storage should increase by a factor of ten above current levels.[22]
- Net Zero America Project: In the Net Zero America Project, CCUS is deployed at a large scale in all scenarios, except RE+. CCUS is especially important for cement production,

gas- and biomass-fired power generation, natural gas reforming, biomass-derived fuels, and DAC. Biomass with CCUS contributes significantly to hydrogen production starting in 2035. The scale of geologic sequestration is 1,000 facilities capturing and sequestering 1 to 1.7 billion tons of CO_2 per year with 110,000 km of new CO_2 pipelines, a scale which is 1.3 to 2.4 times the United States' current oil production on a volume-equivalent basis.[23]

3 Carbon Utilization

This section of the report is being developed in response to the Congressional mandate to compile:

> *"inventories current or emerging activities that transform captured carbon dioxide into a product of commercial value, or as an input to products of commercial value."*

Carbon utilization is a broad term used to describe the many different ways that captured carbon oxides – principally CO_2, and in some cases carbon monoxide (CO) – can be used or to produce economically valuable products or services. Current uses for CO_2 in commercial markets are summarized in Figure 1. Ethanol is the largest source (36%) of CO_2 produced from industrial sources and used for commercial applications in the U.S.[24] These commercial applications do not result in permanent sequestration of CO_2. Note that although CO_2 is captured via photosynthesis, carbon storage via increased net biomass stocks and conversion of plant-based biomass for fuels and other uses without subsequent carbon capture and sequestration were considered outside the scope of the report.

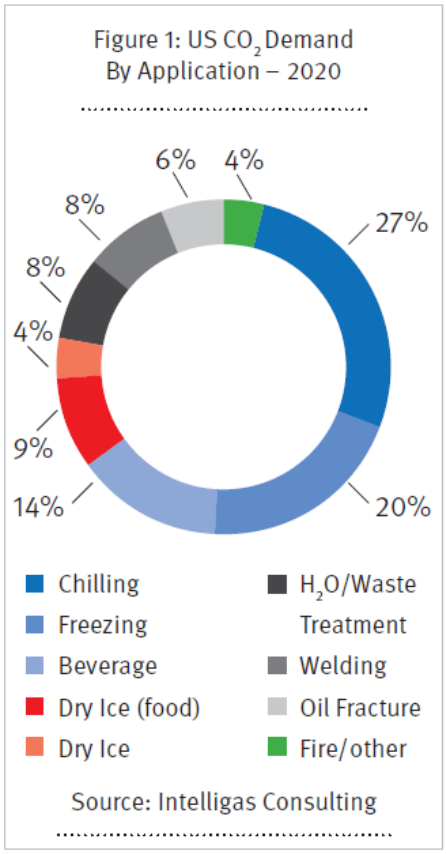
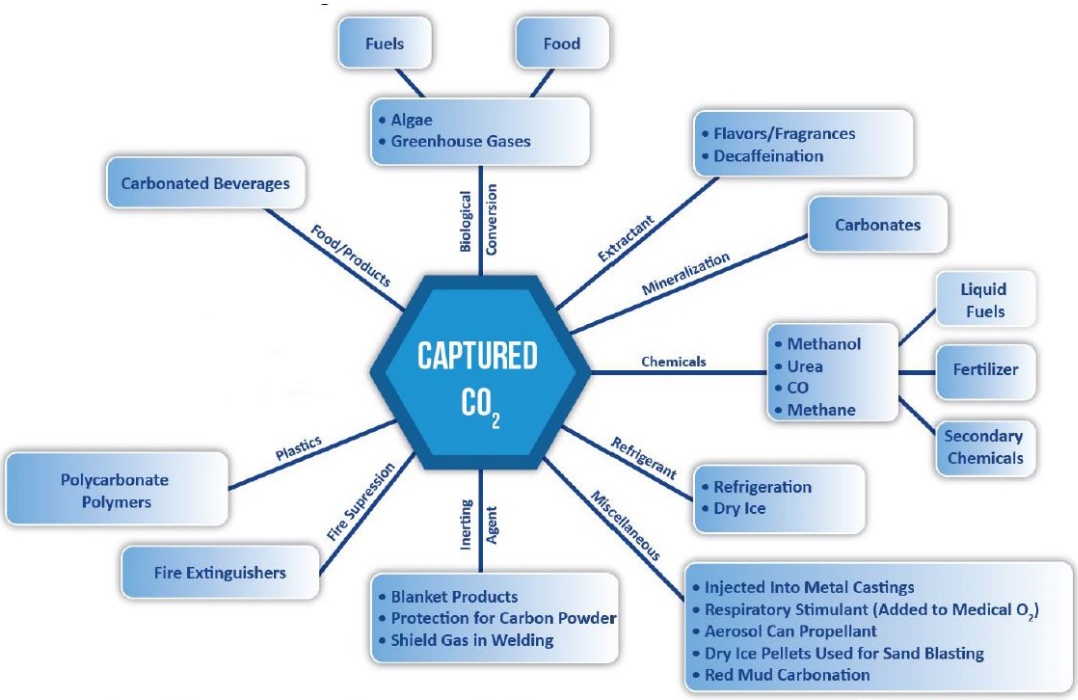


Figure 1. United States CO_2 utilization demand by market

The wide array of potential carbon utilization options (including those that result in emissions upon use, or emissive uses) is illustrated in Figure 2. Each carbon utilization pathway has specific characteristics in terms of technical maturity, market potential, economics, societal impact, and lifecycle impact. For example, there are some carbon mineralization technologies that are currently used commercially for the production of construction materials. Similarly, there are biological conversion technologies that economically generate nutraceuticals at relatively small scale. Utilization pathways differ in permanence

for removing CO_2 from the atmosphere. Ongoing research seeks to improve cost and performance in existing markets, as well as to develop technologies capable of expanding into new markets. Technologies that produce fuels and chemicals are generally at earlier stages of development and require additional research and development to improve process efficiencies and drive down costs.



Adapted from National Energy Technology Laboratory (www.doe.netl.gov)

Figure 2. Carbon utilization pathways

A wide range of climate stakeholders are increasingly focused on carbon utilization where that carbon is permanently sequestered. Prominent examples include:

- In 2016, the Global CO_2 Initiative (GCI) released *A Roadmap for the Global Implementation of Carbon Utilization Technologies,*[25] which estimated the potential market size and emissions reduction associated with non-geologic carbon utilization. More recently, they have developed extensive guidelines regarding life cycle analysis (LCA) and techno-economic analysis (TEA) for carbon utilization technologies.[26]
- In 2017, the Innovation for Cool Earth Forum generated a carbon utilization roadmap focused on three distinct categories of CO_2-based products, the technologies that can be used to convert CO_2 to these products, and the associated research and development needs. The roadmap also addresses LCA for carbon utilization technologies, as well as policy tools that could be used to promote CO_2-based products.[27]
- The XPRIZE Foundation recently completed a competition with $20 million in total prize money, funded by utility company NRG and Canada's Oil Sands Innovation Alliance, in which teams from multiple countries tested and demonstrated breakthrough technologies that convert CO_2

emissions into valuable products like building materials and fuels. Teams were scored based on how much CO_2 they converted and the net value of their products. Two winners were selected that utilized CO_2 in construction materials.[28]

- In 2019, the National Academies of Sciences, Engineering, and Medicine developed a report titled *Gaseous Carbon Waste Streams Utilization: Status and Research Needs*. The report defines a research agenda to address the principal challenges associated with commercializing carbon utilization technologies. The report also identifies improvements needed in tools used for evaluating the economic and environmental attributes of carbon utilization technologies.[29,30]
- The US Department of Energy's Office of Fossil Energy and Carbon Management (FECM) supports a Carbon Utilization Research and Development program focused on early-stage R&D to develop novel ways to transform waste carbon streams into value-added products. The program also supports development of enabling technologies such as LCA, as well as analyses of integration of carbon utilization with hydrogen production and carbon capture and storage. The program is focused on three technology pathways: biological uptake, conversion to fuels and chemicals, and mineralization. The R&D portfolio spans private-public partnerships, university research grants, collaborative work with national laboratories, and research conducted through the National Energy Technology Laboratory's (NETL) Research and Innovation Center.[31]
- Several organizations have developed catalogues of carbon utilization efforts. For example, Smart CO_2 Transformation has developed a database with of over 200 carbon utilization projects globally.[32] Similarly, the Washington, DC-based think tank Third Way has developed a database and map of carbon capture and utilization projects globally.[33]
- Finally, a variety of organizations have developed estimates of total available market and emissions reduction potential for carbon utilization technologies. These include GCI, as noted above, as well as the Center for Climate and Energy Solutions[34] and Carbon180.[35] The estimates generated tend to be based on projections of market penetration and timing, and valuations vary considerably, ranging between $800 million and $1.2 trillion.

In the sections below, the technologies used for carbon utilization are summarized, along with current status, opportunities, and challenges.

3.1 Inventory of Current & Emerging Technologies that Transform Carbon Dioxide

It is possible to produce a wide variety of unique materials, including commodities, from the reaction of CO_2 with other chemical compounds. As a practical matter, products made from CO_2 will displace other products in the marketplace if they are cost-competitive and have other positive characteristics that differentiate them from existing products.

Figure 3 illustrates different classes of products that could utilize CO_2 as a feedstock or working fluid. Note that the values in Figure 3 are in $ per ton of carbon, rather than $ per ton CO_2 (each $ per ton of carbon equates to 0.273 $ per ton of CO_2). Potential approaches include targeting the top of the pyramid at small market scale, targeting the bottom of the pyramid at large market scale, or targeting any scale by providing tangible benefits through product differentiation, such as improved durability, reliability, safety, sustainability, etc. Policy and regulatory drivers, such as the Section 45Q Federal tax credit and California's LCFS, can also incentivize the development of products derived from recycled CO_2. Additional information about the Section 45Q Federal tax credit can be found in Section 7.4.

Different carbon utilization technology developers and practitioners are considering approaches at all levels of the pyramid. A key component illustrated by the pyramid is that a product's market value and market size are inversely correlated; in general, as value goes up, market size decreases. For example, lower profit margins are more closely associated with commodities than with fine or specialty products. It can be difficult to commercialize new technologies for producing commodities due to the low profit margins. One strategy for commercialization is to focus on higher-value specialty and fine products early in the development process, and then pivot toward larger-volume commodity markets as the technology matures.

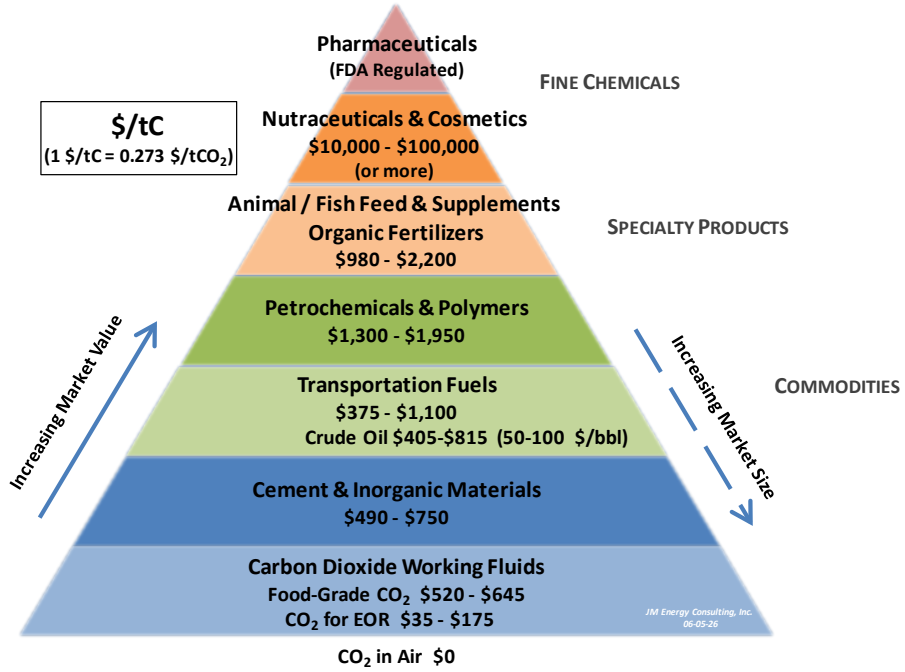


Figure 3. Market value of various carbon-based goods and services

The bottom of the pyramid—Carbon Dioxide Working Fluids—represents the lowest-cost approach to the utilization of CO_2 and is practiced at industrial scale. Enhanced oil recovery using CO_2 (CO_2-EOR) has been commercially viable since the early 1970s. Incidental geologic sequestration occurs associated with standard CO_2-EOR practices.[36] In the United States, approximately 22 million metric tons of CO_2 were captured from industrial sources for supply into the economy in 2019, of which approximately 15 million metric tons of CO_2 were supplied to CO_2-EOR. This is only a portion of the total amount of CO_2 that is supplied to CO_2-EOR (approximately 52 million metric tons in 2019). The remaining CO_2 required for the EOR industry is extracted from naturally occurring underground sources of CO_2.[37] Because it is a mature and widely practiced technique, and because climate goals require the capture and removal of CO_2 at scales greater than what EOR can accommodate alone,[38] CO_2-EOR is not addressed further in this section of the report.

Energetics of Transforming CO_2 into Organic & Inorganic Compounds

The energy required to produce the goods and services illustrated in Figure 3 varies by use. Generally, the use of CO_2 as a working fluid requires the least amount of energy—the CO_2 molecule remains unchanged throughout the process. Transformation of CO_2 into other products, typically through

reaction with other compounds, can either consume or produce energy. Due to the stability of the carbon-oxygen bonds in CO_2, the vast majority of reactions involving CO_2 require input of significant quantities of energy.

Figure 4 shows relative reaction energies for various classes of compounds that can be produced using CO_2 as a feedstock. The numeric values shown are approximate ranges for the enthalpy change of the various reaction classes shown. Negative values (red) reflect exothermic reactions that produce energy during reaction, and positive values (blue) reflect endothermic reactions that consume energy. The production of inorganic carbonate compounds is thermodynamically favorable and releases energy. The production of organic compounds (transportation fuels and above in Figure 3) requires energy to be supplied. Energy requirements to produce organic materials are particularly high when starting with thermodynamically stable molecules like CO_2 and water (H_2O) as feedstocks. Energy requirements are minimized by carefully selecting the target product and the best available CO_2 co-reactant for the synthesis. Co-reactants derived from petroleum, natural gas, or waste materials may provide the least energetic penalty for converting CO_2 into beneficial products.

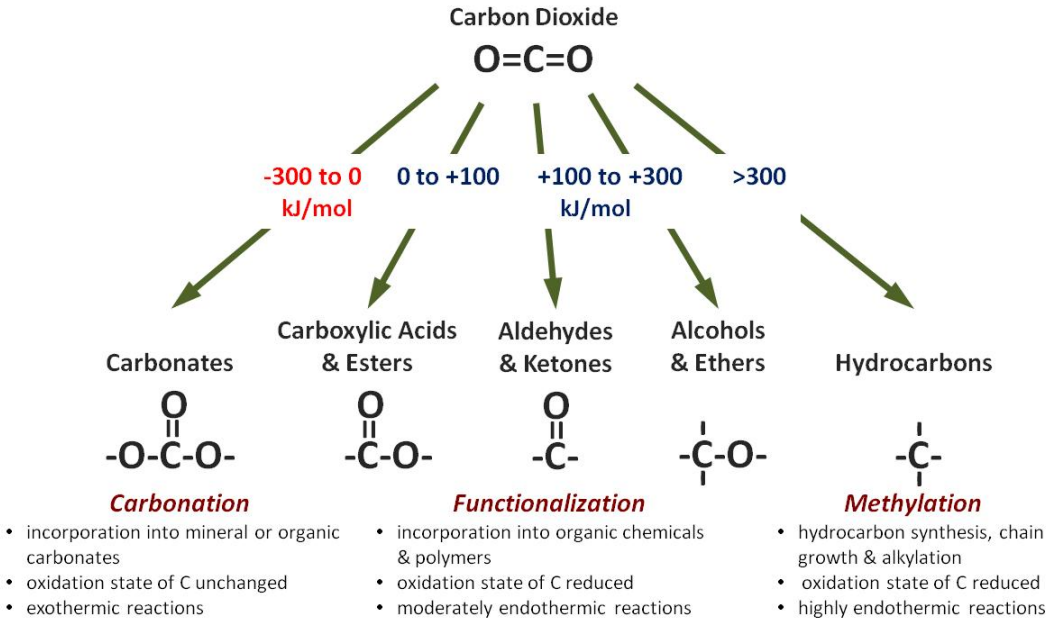


Figure 4. Energetics of CO_2 conversion to various classes of organic and inorganic compounds

Low-carbon energy sources (e.g., solar, wind, geothermal, nuclear, and fossil with carbon capture and storage) or energy carriers derived from these sources (e.g., hydrogen) may also be exploited to reduce the carbon footprint of CO_2 utilization. For example, algae and terrestrial plants use CO_2 and solar energy to biologically produce a wide range of organic and inorganic chemicals through photosynthesis. In other carbon utilization approaches, such as when the CO_2 co-reactant is water, using low-carbon energy is essential because use of unabated fossil-based energy to meet the high energy requirements discussed above would lead to net increases in the carbon footprint.

Carbon utilization technologies that are currently being pursued can be broadly lumped in to three categories:

- Chemical utilization of CO_2 into chemicals and fuels
- Biological utilization of CO_2 into chemicals, fuels, and agricultural products
- Mineral carbonation to produce construction materials

Each of these categories is described in the sections below.

3.2 Chemical Utilization of CO_2 into Chemicals & Fuels

At a very basic level, conversion of CO_2 to fuels and chemicals entails adding hydrogen (either in molecular form or from other reaction partners) to the carbon in CO_2. The two primary routes for doing this are direct hydrogenation of CO_2, and indirect production (Figure 5), which involves conversion of CO_2 to CO followed by synthesis of specific products.

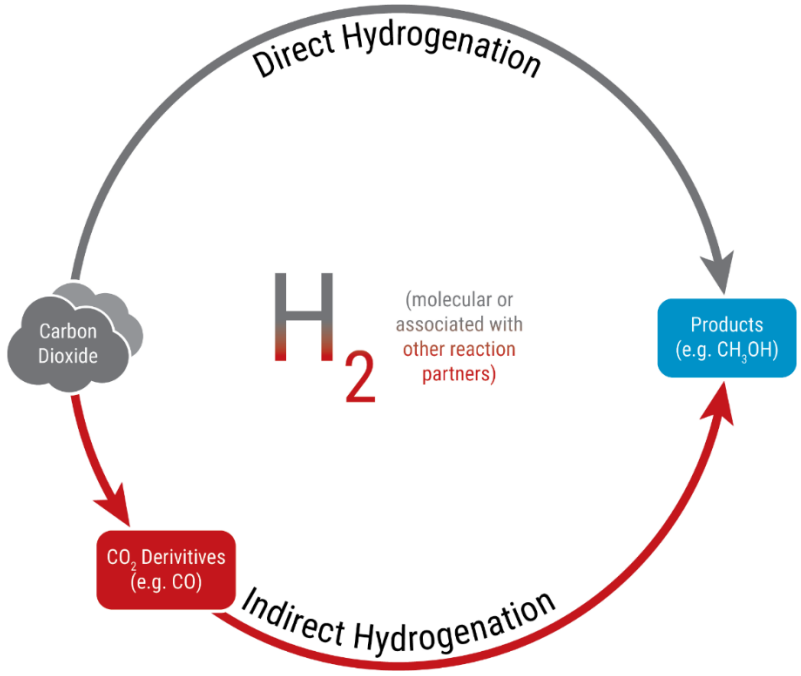


Figure 5. Primary routes for production of fuels and chemicals from CO_2[39]

There are several pathways to produce clean hydrogen that could be used for CO_2 utilization. As a feedstock for many pathways that convert CO_2 into fuels and chemicals, the availability of inexpensive, low-carbon hydrogen is an important component to the commercial viability of CO_2 utilization.

3.2.1 Chemical CO_2 Conversion Pathways

Pathways for converting CO_2 into chemicals and fuels fall into the following categories:

- Thermocatalytic: where energy is provided in the form of heat (and pressure) and the reaction is driven by a catalyst that activates CO_2 so that it can react with hydrogen;
- Electrochemical: where energy is provided in the form of electricity and reactions take place in an electrochemical cell;

- Biochemical: where living organisms or the unique products they generate (e.g., enzymes) convert CO_2 to products;
- Photochemical: where solar energy provides the heat or electricity needed to drive catalytic conversion reactions; and,
- Hybrid approaches: where the approaches noted above are combined (e.g., electrolysis coupled with thermocatalytic approaches, electrochemical reactions driven by microbes, etc.).[40]

Technology for direct hydrogenation exists and has been commercialized for the production of methane, methanol, and other chemicals. Methanol is an attractive product for CO_2 utilization because commercial processes exist to convert methanol to gasoline and other chemicals that are used in multiple industrial processes. Production of methanol from CO_2 has been tested at pilot scale, and a 5-million-liter-per-year CO_2-to-methanol plant is currently operating in Iceland, which enjoys the benefit of inexpensive hydroelectric power generation and geothermal heat that can be used for hydrogen production and process heating.

However, due to high costs associated with direct hydrogenation of CO_2 to methanol and other products, significant deployment of direct hydrogenation is not anticipated in the near term. The two components of the process needed for conversion—catalytically activated CO_2 and hydrogen – both have extremely high costs associated with them. R&D to develop better catalysts and more efficient separation processes is essential to drive down costs for the CO_2 activation step.

Direct electrochemical processes that convert CO_2 to fuels and chemicals have been demonstrated at laboratory-scale to generate a variety of products, including formic acid, methanol, methane, and ethylene. Challenges associated with direct electrochemical conversion processes include low selectivity in transferring charge (Faradaic efficiency), low current density that limits production rates, and poor stability of the electrodes. R&D is needed to develop improved electrode materials and structures and improved process designs for practical applications. One other promising area of active research is "hybrid" microbial electrolysis cells, in which microbial communities living in the electrochemical cell convert CO_2 to chemicals.

The indirect production pathway involving conversion of CO_2 to CO prior to processing to generate fuels and chemicals is similar to direct conversion, but with a defined CO intermediate product. It is attractive because CO is much more chemically active than CO_2. The conversion of CO and hydrogen (i.e., syngas) into methanol and into hydrocarbons via Fischer-Tropsch synthesis is very well known.

The principal challenge for this approach is the CO_2-to-CO conversion step. Options include catalytically driven processes, such as reverse water gas shift to generate CO from CO_2; various forms of reforming, which use methane (or other light hydrocarbons) to convert CO_2 to CO; and electrochemical approaches, such as polymer electrolyte membranes or solid oxide electrochemical cells. Fundamental advances such as catalysts that operate at lower temperatures and advanced gas separation techniques are required to commercialize these processes.

Another example of the indirect conversion pathway is provided by technology in which engineered microbes convert CO into ethanol. The technology has been demonstrated at commercial scale using waste gas from steel production, which is high in CO content. The availability of CO was a critical component that allowed for the development of a successful utilization technology. Inexpensive,

widespread availability of more chemically active CO generated from CO_2 could result in the advancement of multiple technologies to generate fuels and chemicals from CO_2.

3.3 Biological Utilization of CO_2 into Chemicals, Fuels, & Agricultural Products

Biological conversion of CO_2 involves using photosynthetic and other metabolic processes embodied in plants, algae, bacteria, and fungi to produce higher-value products. Several factors contribute to the variety of bio-based products that can be synthesized from CO_2, including the large number of microorganisms that utilize CO_2, genetic modification of microorganisms, and tailoring of enzymatic properties through protein engineering. Biological utilization has the potential to generate a range of commercial products, including various biofuels, chemicals, fertilizers, and fish and animal feeds.

3.3.1 Biological CO_2 Conversion Pathways

The principal pathways for biological conversion of CO_2 into products are photosynthetic and non-photosynthetic. Both offer significant opportunities and challenges.

Photosynthetic conversion pathways typically include the use of algae. Algae are extremely efficient photosynthetic organisms. There are several advantages to algae-based carbon utilization, although it is worth noting that the water requirements for these approaches can be significant:[41,42]

- High purity CO_2 is not required to support algal growth.
- Flue gas containing varying amounts of CO_2 can be fed directly to the microalgae, reducing or eliminating the need for CO_2 capture systems.
- Some combustion products such as NO or SO_x can be used as nutrients for microalgae.
- Microalgae could yield high-value commercial products. The sale of these high-value products could offset the capital and operating costs of the process.
- Algae can be grown in open raceway pond systems and closed photobioreactor systems, as well as on land not suited for agriculture and in brackish or wastewater.
- Algae absorb atmospheric CO_2 and are relatively easy to convert into fuels and products.

One of the most attractive features of algae-based utilization approaches is the wide range of potential products that can be generated, as noted in Table 2.[43,44] A significant product pathway associated with algal uptake of CO_2 is the production of fuels – which is similar in some respects to the fuels production pathways described above. Fuels can be produced from algae through whole biomass conversion techniques such as hydrothermal liquefaction, through lipid extraction, or through fermentation of carbohydrates. Some strains of algae, including certain cyanobacteria, are capable of excreting fuel or fuel pre-cursors, eliminating the need for extraction or conversion.

Table 2. Potential microalgae products and prices

Product	Substitutes	Price	Unit[a]
Biodiesel	Diesel	$2.27	USD/gal
Bio-ethanol	Gasoline	$3.96	USD/gal
Bio-methane (fuel)	Liquified petroleum gas	$1.92	USD/gal
Jet fuel (bio-jet)	Jet fuel	$2.49	USD/gal
Electricity	Fossil energy	$0.13–$0.21	USD/kWh
Bio-methane (electricity)	Natural gas	$0.05–$0.06	USD/kWh
Biofertilizers	Synthetic fertilizers	$0.25–$0.63	USD/kg
Biostimulants	Growth promoters	$37.50–$312.50	USD/kg
Biopesticides	Synthetic pesticides	$5.00	USD/acre
Bioplastics	Fossil based plastics	$1.75	USD/kg
Food	Proteins, carbohydrates, oils	$50.00	USD/kg
Beta-carotene	Synthetic/natural	$275.00–$2,750.00	USD/kg
Omega-3 polyunsaturated fatty acids	Fish	$50.00	USD/g
Aquaculture	Fishmeal/fish oil	$68.75–$625.00	USD/kg
Livestock feed	Soybean meal	$300.00	USD/tonne
Feed additives	Botanicals, antibiotics	$20.00	USD/kg

Source: Adapted from https://bioenergykdf.net/billionton2016/overview

In addition, several very high-value algae-derived nutraceuticals, such as astaxanthin and betacarotene, already have small but well-established and growing markets, with values that can exceed $1 million per ton.

Animal feed and feed ingredients are also significant markets for algae-based products – particularly aquafeeds for fish and shellfish. CO_2-based algae can serve as effective substitutes for the nutrients traditionally obtained from wild fish because they can serve as the base of the marine food chain that many fish meal species rely on. The potential market size for fish feed is $9 billion, and for livestock feed, the market is estimated to be $370 billion and is expected to grow up to 40% in the next 20 years.[45]

Nonphotosynthetic biological systems are at an earlier developmental stage than photosynthetic systems but offer some potential advantages. These include a wide variety of organisms, a larger range of potential target chemicals, and the ability to avoid inefficiencies associated with photosynthesis. Aerobic systems also have the advantage of high productivity, capacity for continuous cultivation, and compatibility with artificial photosynthesis.[46]

Chemolithotrophs are microbes that derive their energy from the oxidation of reduced inorganic compounds and their carbon from CO_2. This allows chemolithotrophs to perform light-independent CO_2 fixation, eliminating photosynthetic production issues like cell shading. However, cultivating chemolithotrophs is more complex, as two inputs are required instead of one.

Acetogens are an efficient class of anaerobic chemolithotrophs that have been the focus of several nonphotosynthetic carbon utilization efforts. They have been used in laboratory-scale testing to convert both CO_2 and CO into a variety of chemical products. One promising approach has been to use a two-stage process in which acetogens are used to produce acetic acid that is then fed into a second bioreactor where it is aerobically converted to lipids for ultimate production of fuels.

Another nonphotosynthetic approach that is actively being researched is the use of bioelectrochemical systems to support artificial photosynthesis. These systems provide microorganisms with electrons that the cells use to reduce CO_2 into small organic compounds. In a basic bioelectrochemical system, electrons are generated at the anode from water, and microbes carry out the reduction of CO_2 into organic products at the cathode. This typically occurs in an anaerobic environment to prevent oxygen reduction from depleting available electrons and generating toxic by-products. Bioelectrochemical systems have the potential to be more productive than photosynthesis-based systems.

3.4 Mineral Carbonation to Produce Construction Materials

CO_2 can be incorporated into the production of cement and aggregate (and thus concrete) through the formation of carbonates. As noted above, carbonates are even lower-energy than CO_2, minimizing energy needs to form them. This is important because the need to add energy in the process of making large volumes of material could be extremely expensive and make the materials non-cost-competitive. Moreover, the production of cement accounts for approximately 6-7% of global CO_2 emissions;[47] there may be opportunities to couple CCUS with cement production to reduce overall emissions from the sector while producing low-carbon aggregates.

3.4.1 Mineral Carbonation Pathways

One way that CO_2 can be incorporated into building materials involves formation of carbonate or carbonate coatings on small solid materials. To form carbonate-based solids, the negatively charged carbonate ions must be balanced by positively charged ions. This is most commonly done with either calcium or magnesium. Possible sources of calcium and magnesium include seawater, volcanic rocks, slags, and other alkaline industrial wastes. Each of these options requires proximity to a CO_2 source to be economic. Development of methods to produce reliable, sustainable, low-cost calcium and magnesium is an area of active research. Some promising approaches use coal combustion residues as the alkalinity source to combine with CO_2 in flue gas to form carbonates.

Another form of CO_2 utilization in construction materials is direct utilization, which involves adding CO_2 to concrete during curing, as illustrated in Figure 6.[48] This reduces the amount of cement required to produce equivalent-strength concrete, leading to reduced emissions from cement production, in addition to the CO_2 incorporated into the concrete.

Another approach uses a cement that contains more silica-rich materials than conventional Portland cement. This unconventional cement binds with more CO_2 during curing and can be used to make low-carbon, high-strength, pre-cast materials. The technology has been demonstrated at pilot scale and is

anticipated to be ready for commercialization soon. Research associated with direct utilization focuses on increasing the amount of CO_2 absorbed, while still maintaining concrete product standards.

The reliance on existing prescriptive standards for construction materials represents one of the challenges in advancing the use of CO_2-based construction materials. For example, ASTM International (formerly known as the American Society for Testing and Materials) has narrow standards for a variety of parameters/characteristics, including setting times and compressive strength for Portland Cement-sand mixtures, and the specific amounts of ground limestone and inert extender that can be blended with cement, among many others. If CO_2-based construction materials do not match those specific requirements, they may not be accepted for use. Successful entrants to the market have focused on making incremental changes to traditional concrete formulations to minimize the acceptance challenges. Meanwhile, a pivot towards a performance-based approach instead of prescriptive standards may be highly beneficial for CO_2-based construction materials. There is a possibility that a mixture design for a particular application could be out of specification according to prescribed requirements, but it still may perform at acceptable levels.

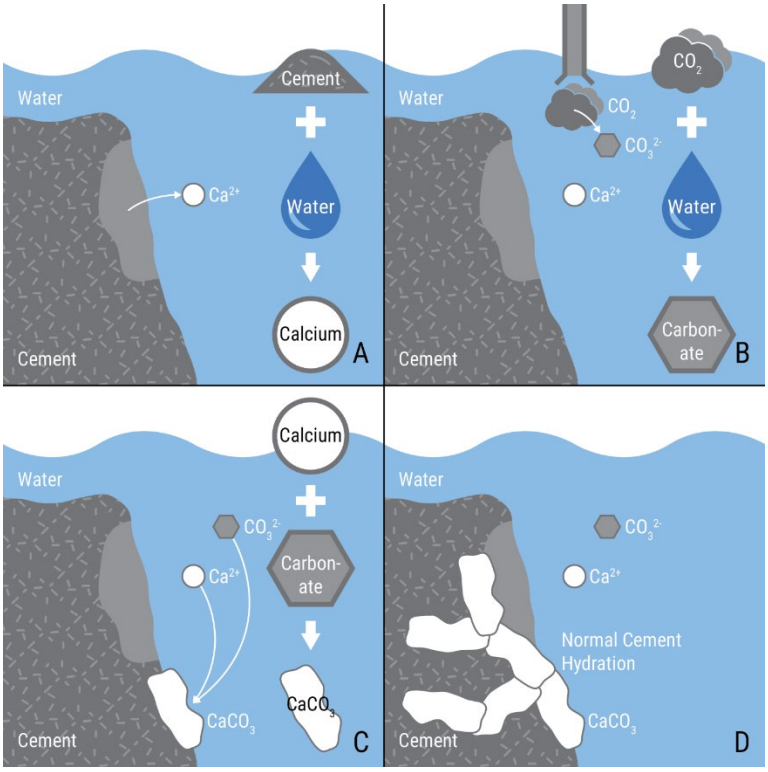


Figure 6. Example of a direct CO_2 utilization process: a) water is added to cement leading to dissolution; b) CO_2 is introduced and enters solution; c) solid phase calcium carbonate ($CaCO_3$) is formed; d) normal cement hydration occurs with $CaCO_3$ acting as a nucleating agent[49]

3.5 Enabling Tools

CO_2 utilization is enabled through an active RDD&D program managed by DOE and other incentives described in Section 7, such as the Section 45Q tax credit. These Federally supported incentives require and rely on an accurate TEA and robust LCA for which guidance, templates, and training have been developed, as referenced in Section 5.3.[50] These tools could be expanded upon and improved with experience in applying them to various CCU projects.

TEA and LCA are critical elements in the development and commercialization of carbon utilization technologies. TEA combines process modelling and engineering design with economic evaluation in order to assess the economic viability of a process, and provides direction to research, development, investment, and policy making.

Similarly, LCA assesses environmental and sustainability impacts (e.g., water, criteria pollutants, and greenhouse gases like CO_2) associated with all stages of a product's life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal. Many previous assessments of carbon utilization technologies in the literature have focused solely on the carbon content of CO_2 conversion products as an indicator of emissions reduction potential. However, only looking at the carbon sequestered within a product ignores emissions associated with making the product. A full accounting of a product's potential impact on climate change should consider all stages of the product's life cycle and include all greenhouse gases emitted.

4 Carbon Dioxide Pipelines

This section of the report is being developed to respond to the Congressional mandate to inventory:

> *"existing initiatives and recent publications that analyze or identify priority carbon dioxide pipelines needed to enable efficient, orderly, and responsible development of carbon capture, utilization, and sequestration projects at increased scale."*

4.1 Inventory of Existing CO_2 Pipelines in the United States & Regulatory Framework

There is currently no network of CO_2 pipelines at a scale large enough for the specific purpose of permanent carbon sequestration in the United States across all industrial sectors. Nearly all existing CO_2 pipeline mileage is used to transfer CO_2 to oil fields for EOR,[51] however, these existing CO_2 pipelines can also be used for CCUS.

Achieving climate goals will likely require a significant increase in the need for liquid CO_2 transport infrastructure. This demand will be heavily reliant on the increased development and deployment of CO_2 pipelines. There are currently approximately 5,200 miles of dedicated pipelines that could be used for geologic sequestration, however the scale of the existing pipeline network is insufficient in the context of a CCUS industry designed to contribute meaningfully to net-zero emissions goals across all industrial sectors.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) at the U.S. Department of Transportation (USDOT) is responsible for the safety regulation and oversight of over 2.8 million miles of gas and hazardous liquids pipeline systems, 400 Underground Natural Gas Storage Facilities, and 163 Liquefied Natural Gas Plants. PHMSA does not, however, have statutory authority for the siting or permitting of pipelines. The Federal Energy Regulatory Commission (FERC) is responsible for approving siting of interstate natural gas pipelines, and the Departments of the Interior and Agriculture oversee siting on Outer Continental Shelf and Federal lands within their jurisdictions. However, no Federal entity is responsible for siting interstate CO_2 pipelines across Federal and non-Federal lands. States establish the regulatory frameworks within their state boundaries, which include responsibility for siting and permitting intrastate pipelines as well as segments of interstate hazardous liquids pipelines within the state boundary.

As of 2019, when PHMSA last published annual report data, there were approximately 32 liquid CO_2 pipeline operators under USDOT regulatory authority in the United States, totaling approximately 5,200 miles of pipe, transporting supercritical fluid CO_2.[52] A significantly smaller amount (~60 miles) of gas CO_2 pipelines existed in 2019.

4.2 Identification of Priority CO_2 Pipelines for CCUS Deployment

Research & Analysis

There is extensive research on CO_2 pipeline prioritization for CCUS which shows that the expansion of CO_2 pipeline infrastructure in the near term is critical to CCUS project development, and that it must be carefully planned in a way that engages communities. The Princeton Net-Zero America study provides an in-depth analysis of the CO_2 pipeline needs to reach net-zero CO_2 emissions.[53] The study modeled "CO_2 pipelines required for lowest-cost net-zero energy systems in the United States in a variety of

scenarios."[54] Among the identified priorities stemming from this study is a 21,000 to 25,000 km interstate CO_2 pipeline network and 85,000 km of spur pipelines delivering CO_2 to trunk lines, with an estimated capital cost of $170 to $230 billion.[55] Costs were considered and analyzed using the DOE/NETL CO_2 Transport Cost Model. The analysis goes further to identify specific steps for CO_2 pipeline development, and identifies existing rights-of-way (ROW) to use for pipeline deployment. Proposed routes are mapped along with existing pipelines to illustrate potential priority CCUS pipeline corridors. The Great Plains Institute, through the Regional Deployment Initiative, completed an analysis using the Los Alamos National Laboratory's SimCCS model to identify an optimal regional-scale CO_2 transportation network capable of meeting mid-century decarbonization goals, which is illustrated in Figure 7.[56] The Decarb America analysis team has also identified CO_2 pipeline buildout compatible with reaching net zero by 2050.[57]

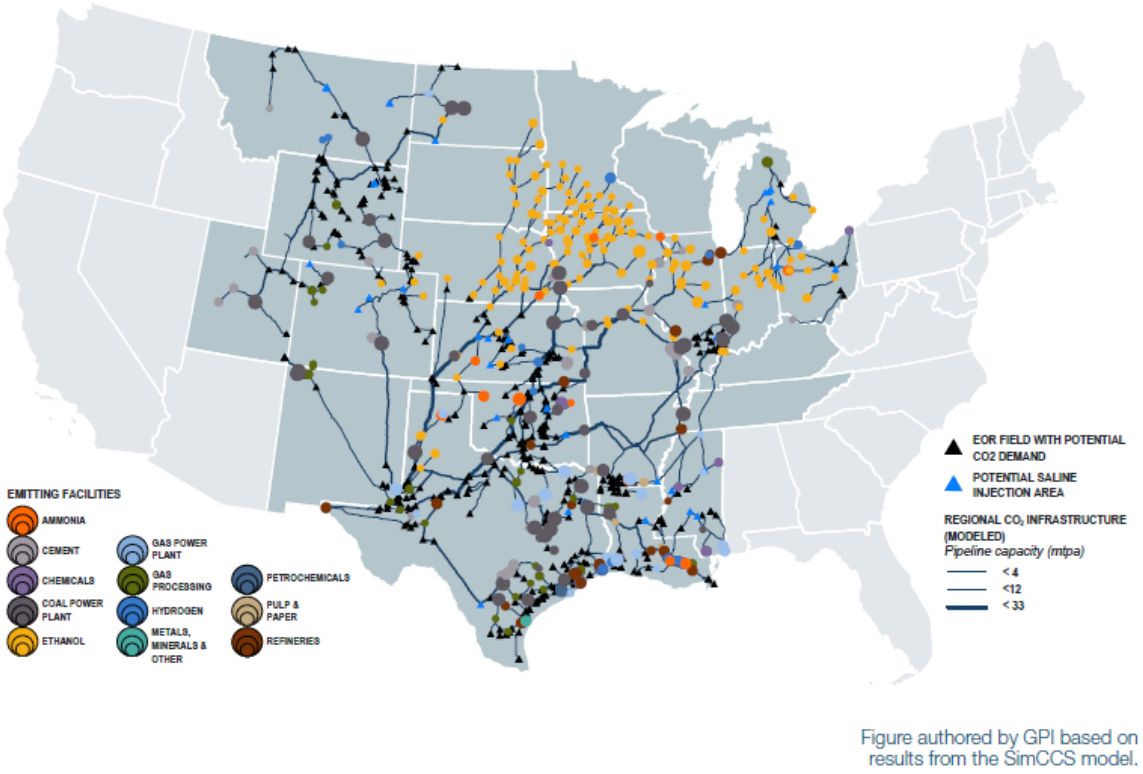


Figure 7. Optimized transportation network for economy-wide carbon capture and storage in the mid-continent of the United States

Other analyses have emphasized the value of a phased approach to CO_2 pipeline deployment. This research has identified near-term pipeline expansions with the objective of making immediate progress towards net-zero GHG targets. In a report produced by the Proceedings of the National Academies of Sciences, Engineering and Medicine, it is proposed that targeting the lowest-cost capture opportunities by deploying only commercially proven technologies is a viable solution for near-term results. [58] The overall objective of the proposal was to assess the viability of a pipeline network to transport CO_2 from Midwest ethanol biorefineries to the Permian Basin in Texas. The proposed network would serve near-

term EOR demand while also connecting multiple prospective, long-term, dedicated geological storage resources.[59]

Several studies have prioritized efficiency and cost-effectiveness in identifying and analyzing CO_2 pipeline expansion options. A DOE/NETL report proposes a model that can be used to determine "which combination of pumps and pipeline diameter gives the lowest overall cost in dollars per ton ($/ton) of CO_2 transported."[60] While this report does not identify specific pipelines to be built or expanded, it provides a roadmap to efficiently expand CCUS efforts through pipeline development and deployment. Corridors for existing pipeline infrastructure may have potential for repurposing, but in most cases, the pipelines themselves, which currently carry other materials, would need to be replaced due to CO_2 pipeline specification requirements. Analysis has made clear that the push to net-zero has the potential to employ "orphaned" pipeline networks formerly used for oil and gas that pose significant environmental risks without proper remediation.[61] Efforts to repurpose and utilize these pipelines safely for CCUS is a focus of current research.

To reach net-zero emissions targets, CCUS is essential; however, the current CO_2 transport infrastructure for large-scale CCUS build-out is not sufficient. Estimates vary on what is required to meet the demand of large scale CCUS efforts in the United States, but there is a clear consensus that CO_2 pipelines are critical to the future deployment of CCUS nationwide. The current 5,200 miles of liquid CO_2 pipelines are mostly used for EOR, and there is currently no pipeline network that supports significantly expanded CCUS and large-scale carbon sequestration across all industrial sectors. There has been extensive research identifying the priority pathways and necessary pipeline infrastructure required to meet the demands of CCUS, but significant investments will be required.

Federal Government

Congress is considering support for CO_2 pipelines as part of the bipartisan Storing CO_2 and Lowering Emissions (SCALE) Act, designed to build out the national infrastructure for CCUS through a new CO_2 Infrastructure Finance and Innovation Act program that would provide flexible loans for building pipelines with excess capacity, as well as support for permanent sequestration. In line with the SCALE Act, the President's American Jobs Plan supports large-scale sequestration efforts that leverage the best science and prioritize community engagement.

Recent regulatory changes to enhance and encourage CCUS, such as specific reference to CCUS under FAST-41, may further help facilitate the buildout of pipeline networks. A CO_2 pipeline in Wyoming completed the Federal environmental review and permitting process using FAST-41 in 2019.[62] Preliminary analysis has been done within USDOT to identify CCUS opportunities on Federal highway right-of-way, but these efforts have not analyzed pipelines or other forms of CO_2 transport for CCUS operations. USDOT and PHMSA are, however, engaging in discussions with colleagues from other agencies, such as DOE and EPA, on CCUS, including on the feasibility, policy, safety, technical, and operational aspects of increased CCUS deployment.

While USDOT is responsible for the regulation and oversight of safety for liquid CO_2 pipelines, and PHMSA has conducted research and analysis regarding the applicability of existing regulations to gaseous CO_2 pipelines, the agency has not conducted an analysis on the identification or prioritization of existing pipelines for expanded CCUS, which is related to several general underlying circumstances. First, because PHMSA does not have siting or permitting authority for pipelines, and may not apply new

design standards to existing pipelines, it lacks the authority to require operators to modify existing pipelines for the purpose of transporting CO_2. Second, although there are conversion-to-service provisions in the pipeline safety regulations, there are a number of design and operational challenges associated with converting existing gas or other hazardous liquids pipelines to safely transport CO_2, given certain unique characteristics of the product, as evidenced by the design incompatibilities for existing pipelines. Specifically, supercritical CO_2 pipeline maximum operating pressures generally exceed 1500psi (>2000psi is typical), which may limit the pipelines that can be considered for CO_2 service. Compatibility of pipeline and associated compressor materials is also a consideration when converting existing pipelines to move CO_2. Metal fatigue can be a larger integrity concern for liquids pipelines than for gas pipelines, and could be of concern when converting a 49 CFR Part 192 gas pipeline to a 49 CFR Part 195 hazardous liquids pipeline for CO_2 service. Additionally, it is unlikely that CO_2 can be comingled or batched with other hazardous liquids products for transportation. Furthermore, existing pipelines, with or without excess capacity, may or may not be located in geographic areas where hubs and clusters for CCUS may emerge.

Additionally, because PHMSA is not authorized to permit or site pipelines, including those that transport CO_2, it can only follow trends and communicate with stakeholders to best anticipate changes to market demands that may spur construction and conversions of pipelines to meet market needs.

States

Several states are moving forward to identify priority CO_2 pipeline needs. Kansas, Louisiana, Maryland, Montana, Pennsylvania, Oklahoma, and Wyoming have committed to the establishment and implementation of a Regional CO_2 Transport Infrastructure Action Plan through the State Carbon Capture Working Group.[63] The Wyoming Pipeline Corridor Initiative (WPCI) identified future corridors on Federal lands to accommodate expanded pipeline infrastructure. The identified pipeline corridors included areas that crossed states, local, and Federal lands.[64] State-specific analyses of enabling CCUS hubs and clusters connected by CO_2 pipelines have been conducted, including a 2009 Pennsylvania-specific study that highlighted the value of shared infrastructure where several carbon capture projects use the same CO_2 pipeline.[65] Such shared infrastructure is driving development in Canada through a government-funded CO_2 trunk line.[66]

5 Review of Existing Federal Permitting Information & Resources

This section of the report is being developed in response to the Congressional mandate to compile:

> *"existing relevant Federal permitting and review information and resources for project applicants, agencies, and other stakeholders interested in the deployment and impact of carbon capture, utilization, and sequestration projects and carbon dioxide pipelines, including—*
>
> *(aa) the appropriate points of interaction with Federal agencies;*
>
> *(bb) clarification of the permitting responsibilities and authorities among Federal agencies; and*
>
> *(cc) best practices and templates for permitting in an efficient, orderly, and responsible manner, including through improved staff capacity and training at Federal permitting agencies."*

Because CCUS and CDR projects are diverse and complex, generalizing about permitting and regulatory interactions is difficult. Nevertheless, in many cases, a number of private, local, state, Tribal, and/or Federal agencies will be involved in responding to authorizing requests for CCUS projects. The domestic CCUS industry is somewhat nascent, so a more granular discussion of permitting opportunities and challenges may be ripe after a larger set of commercial-scale projects have been built. Broadly speaking, existing permitting requirements for a CCUS effort mirror the permitting requirements for other industrial activities.

The applicable permits and reviews will depend on the characteristics of the particular project. Table 1 was adapted from a report written by researchers at Lawrence Livermore National Laboratory, and provides an overview of the types of permits and permissions that may be needed for CCUS.[67] Private parties may need to be consulted on a variety of issues, including access to land for site characterization or monitoring, pore space ownership or mineral rights, and local land use. Because states and localities have distinct regulatory regimes, it may be more complex to move CCUS efforts forward in some jurisdictions than others.[68] States have taken, and will likely continue to take, action to clarify the regulatory requirements for CCUS efforts, including:

- Inclusion of geologic sequestration and CO_2-EOR as applicable for greenhouse gas reduction credits (e.g. California[69])
- Approved pipeline corridors for carbon storage (e.g. Wyoming[70])
- State primacy for Class VI geologic sequestration wells (e.g. North Dakota[71])
- Legislation clarifying who owns the geologic sequestration capacity (e.g. Montana[72])
- Acceptance of long-term liability for CCUS projects (e.g. Louisiana[73])

Table 1. Overview of types of permits and permissions needed for CCUS projects

Portion of the CCUS effort *	Authorization	Authorities that may require permits/permissions	Type of Agency**
	Land use	Local government, Federal Government (public lands)	City Council, Federal Land Manager (USFS, BLM, etc.)
 	Discharges to surface water	State and/or Federal Government	State Department of Environmental Quality, U.S. Environmental Protection Agency
	Discharge of dredge or fill materials to waters of the U.S.	State and/or Federal Government	U.S. Army Corps of Engineers and or relevant State office (Florida, Michigan and New Jersey)
	Endangered species	State and/or Federal Government	State Environmental or Natural Resources Department, U.S. Fish and Wildlife Service, NOAA Fisheries
	Greenhouse gas reporting	State and/or Federal Government	State Environmental Department, U.S. Environmental Protection Agency
 	Air permits	State and/or Federal Government	State Environmental Department, U.S. Environmental Protection Agency
	CO_2 pipeline safety	State and/or Federal Government	State and Federal Departments of Transportation
	Siting CO_2 pipelines	Local, State, and Federal Government	State Transportation Department or Utility Commission; Federal land management agencies
	Pore space ownership and mineral rights	Local, State, and Federal Government (if Federal lands)	Determined by State-specific law, Federal agency managing Federal Lands to be used
	CO_2 injection (and sequestration) permitting	State and/or Federal Government (some states have primacy for Class VI permitting)	State Environmental Department, U.S. Environmental Protection Agency

 denotes utilization,  denotes capture,  denotes transportation, and  denotes geologic sequestration

**Federal responsibility is listed together with exemplary state and local governments (which vary depending on local context). For Tribal lands/sovereign nations, the Tribal government will have oversight.

Permitting a CCUS project is similar to the process for permitting any industrial activity. The pathway for regulating CCUS projects is established, and the precise mix of permits and reviews needed for a particular project will be determined by the specific details of the project. For example, a project on Federal lands will need to comply with the National Environmental Policy Act (NEPA), the Endangered Species Act, Federal land management statutes, and other safety, environmental, and ecological regulations. An inventory of existing Federal statutes and regulations that could potentially apply to a CCUS project (including CO_2 pipelines) is attached to this report. It is important to note that not all of these statutes and regulations will apply to every project; as stated elsewhere, permit and environmental reviews are fact-dependent.

Enacted on December 27, 2020, the Consolidated Appropriations Act, 2021 allowed CCUS projects to be identified as covered projects under Title 41 of the FAST Act, a statutory program designed to improve the timeliness, predictability and transparency of the Federal environmental review and authorization process for significant infrastructure projects. Construction of infrastructure for carbon capture is now a specific sector eligible for FAST-41 coverage, and CCUS projects now can be covered under FAST-41 even if they are worth less than $200 million in economic investment. In this context, carbon capture infrastructure includes construction of any facility, technology, or system that captures, utilizes, or sequesters carbon dioxide emissions, including DAC projects. FAST-41 covered projects are subject to coordinated Federal agency review and permitting supervised by the Federal Permitting Improvement Steering Council (Permitting Council), which requires the establishment and execution of a coordinated project plan and project permitting timetable that is transparent and accountable to the project sponsor and the public through the Federal Permitting Dashboard.

Specific timelines associated with FAST-41 are designed to provide clarity, transparency, and coordination for covered projects:

- The Permitting Council Executive Director must add a project to the Permitting Dashboard as a covered project within 14 days after receipt of a FAST-41 application,
- Within 45 days after the project is added to the Permitting Dashboard, the lead or facilitating agency must identify and invite other responsible Federal agencies to participate in the environmental review and authorization process for the project,
- Within 60 days after the project is added to the Permitting Dashboard, the lead agency must establish a comprehensive permitting timetable for the project, which may be modified pursuant to the timetable and milestone modification procedures contained in the FAST-41 statute.

For the purposes of this report, relevant Federal permits and review programs that *may* apply to CCUS projects were analyzed for salient issues, including the permitting and/or authorizing agency, the relevant agency point of interaction (or where within the agency the review process or permitting is facilitated), a summary of the required permitting/review process, and published best practices for permitting in an efficient, orderly manner. The compiled information does not include permits required for utilization of CO_2 in industrial, manufacturing, and agriculture processes (e.g., FDA regulations for the manufacture of carbonated beverages). Also excluded are Federal permits or reviews that are related to industry-specific characteristics or otherwise not generally related to CCUS projects or CO_2 pipelines. Nothing in this review is intended to impair or otherwise affect the authority granted by law to an executive department or agency.

5.1 Inventory of Existing Federal Permits & Review Requirements

An inventory of Federal permits and reviews that may apply to a CCUS effort is in Appendix A and summarized in this section. Some of these permits may be required for a facility independent of the CCUS project, due to its emissions or discharges of pollutants.

The following permits could be required from the Federal Government or, if applicable, the designated state/territorial/Tribal agency for a CCUS project, depending on project-specific facts:

- Clean Air Act New Source Review preconstruction permit, required for any new or modified air emissions source (EPA)
- Clean Air Act Title V operating permit, required for any major air emissions source (EPA)
- Underground injection Control (UIC) Permit, Class II for CO_2-EOR and Class VI for geologic sequestration (EPA)
- National Pollutant Discharge Elimination System (NPDES) permit for discharges to water (EPA[74])

The following Federal permits may also be required for offshore environments:

- Marine Protection, Research and Sanctuaries Act (MPRSA) permit for transport, including by pipelines, and geologic sequestration in marine environments
- Outer Continental Shelf Lands Act (OCSLA) permit for rights-of-way for offshore pipelines, lease for offshore energy and mineral resources, and/or permit for offshore injection wells. The statute has never been used to authorize permanent CO_2 storage.

CCUS efforts on Federal lands, as well as those which are directly supported with Federal funds (such as public RDD&D projects), may need to comply with the following, depending on the nature of the project:

- NEPA applies to major Federal actions that may significantly affect the quality of the human environment. Unless a proposed Federal action is subject to a categorical exclusion, NEPA requires that an environmental assessment (EA) or environmental impact statement (EIS) be conducted to consider environmental impacts of the proposed action, including consideration of reasonable alternatives.
- Rights-of-way through Federal lands require a permit from the Secretary of the appropriate agency (Interior, Agriculture, etc.).
- The Federal Land Policy and Management Act and National Forest Management Act are applicable to activities on Bureau of Land Management and United States Forest Service lands.
- The Mineral Leasing Act (MLA) authorizes the leasing of certain resources, including oil, gas, and coal, on hundreds of millions of acres of Federal lands. Additional guidance and regulations may be necessary to clarify the role that the MLA may play, if any, in geologic sequestration of CO_2.

- Compliance with the Endangered Species Act requires consultation with the Department of Interior's Fish and Wildlife Service and Department of Commerce's NOAA Fisheries to avoid impacts to any threatened or endangered species and their habitats. The Endangered Species Act prohibits the "take" of listed species except pursuant to a Federal permit, and prohibits Federal actions that are likely to jeopardize the continued existence of listed species or adversely modify designated critical habitats.

- National Historic Preservation Act compliance may be required to ensure the CCUS project does not impact sites listed on or eligible for the National Register of Historic Places.

CO_2 pipelines will need to comply with Federal safety requirements promulgated by the PHMSA.

5.2 Appropriate Points of Interaction with Federal Agencies

This section provides a summary of appropriate points of interaction with Federal agencies, based on the information summarized throughout the report.

Federal Permitting Improvement Steering Council (Permitting Council)

- Information on how eligibility for the FAST-41 Covered Project process is available at https://www.permits.performance.gov/fpisc-content/become-fast-41-covered-project
- An interested project developer can contact the Office of the Executive Director (FAST.fortyone@fpisc.gov) at any stage of a project to discuss becoming covered under FAST-41

United States Department of Energy (DOE)

- For information about RD&D on CCUS at DOE, contact DOE via https://www.energy.gov/fe/contact-us
- For information about DOE loan guarantees, mentioned in Section 7.2, potential applicants are encouraged to contact the Loan Program Office (LPO) for no-fee, no-commitment, pre-application consultations prior to submitting a formal application. Pre-application consultations allow potential applicants to begin a dialogue directly with LPO staff to help LPO learn more about the project and to ensure that applicants fully understand DOE's requirements and processes. Contact can be made by emailing lpo@hq.doe.gov
- For information about CO_2 utilization LCA, subject matter expertise support is available by emailing lca@netl.doe.gov

Environmental Protection Agency (EPA)

- For Title V Operating Permits and New Source Review Pre-Construction Permits, points of contact are listed at the EPA region level at https://www.epa.gov/caa-permitting. Click on the appropriate region for state-specific points of contact, including telephone numbers and email addresses
- Underground Injection Control Program permitting information and regional points of contact are available at https://www.epa.gov/uic
- For National Pollution Discharge Elimination System Permits, see https://www.epa.gov/npdes/forms/contact-us-about-npdes

- For information about Marine Protection, Research and Sanctuaries Act (MPRSA) permits and site designations, see https://www.epa.gov/ocean-dumping/forms/regional-contacts-ocean-dumping-management-program
- For information about the Greenhouse Gas Reporting Program, contact EPA via https://www.epa.gov/ghgreporting/forms/contact-us-about-ghg-reporting

Department of the Interior

- For information about activities on Federal lands, contact the Federal Lands Division of the Appraisal and Valuation Services Office, via https://www.doi.gov/valuationservices/contact-us or by email at AVSO_Info@ios.doi.gov
- For information about offshore leasing, contact the Bureau of Ocean and Energy Management (BOEM), see https://www.boem.gov/contact-us
- For information about offshore safety and regulation, contact the Bureau of Safety and Environmental Enforcement, at https://www.bsee.gov/newsroom/connect-with-us
- For information about the United States Geological Survey work on CCUS, see https://answers.usgs.gov/

National Institute of Standards and Technology (NIST)

- For information about measurement science, reference data and materials, and standards for direct air capture, carbonate materials development, CO_2 pipeline materials reliability, and greenhouse gas measurements, email dac.ccus@nist.gov

United States Department of Agriculture

- For information about the rural development loan program mentioned in Section 7.3, see https://www.rd.usda.gov/contact-us

United States Department of Transportation

- For information on pipeline safety, contact the PHMSA, see https://www.phmsa.dot.gov/about-phmsa/phmsas-mission

Surface Transportation Board

- For information regarding rates and access to pipelines, contact the Surface Transportation Board, via https://prod.stb.gov/resources/need-assistance/ or by email at rcpa@stp.gov

Department of Treasury

- For information including instructions on filling out the form for claiming the Section 45Q Carbon Oxide Sequestration credit, see https://www.irs.gov/instructions/i8933

5.3 Guidance Documents & Best Practice Resources

In addition to the information for each permit or review included in the inventory and identified in Appendix A, there are a number of key guidance documents and best practices that have been developed by the Federal Government to assist CCUS project developers in moving CCUS efforts forward

responsibly and efficiently. Additionally, there are externally developed best practices manuals and international standards for CCUS projects. These guidance documents and best practices resources are listed below.

Environmental Protection Agency (EPA)

The EPA has published a series of guidance documents to support regulators and project developers in complying with the UIC program Class VI geologic sequestration regulations, including:

- Class VI Implementation Manual for UIC Program Directors[75]
- Class VI Well Plugging, Post Injection Site Care and Site Closure Guidance[76]
- Class VI Record-keeping, Reporting, and Data Management Guidance for Owners and Operators[77]
- Class VI Primacy Manual for State Directors[78]
- Class VI Well Site Characterization Guidance[79]
- Class VI Well Area of Review Evaluation and Corrective Action Guidance[80]
- Class VI Well Testing and Monitoring Guidance[81]
- Class VI Well Project Plan Development Guidance[82]
- Class VI Well Construction Guidance[83]
- Research and Analysis in Support of UIC Class VI Program Financial Responsibility Requirements and Guidance[84]
- Key Principles in EPA's UIC Program Class VI Rule Related to the Transition of Class II Enhanced Oil or Gas Recovery Wells to Class VI[85]

Federal Permitting Improvement Steering Council

The Federal Permitting Improvement Steering Council (Permitting Council) has collected tools and resources for potential applicants. Resources available from the Permitting Council website that could be useful for CCUS projects include:

- Federal Environmental Review and Authorization Inventory[86]
- Regulatory and Permitting Information Desktop (RAPID) Toolkit[87]

Each year, the Permitting Council publishes a Recommended Best Practices Report[88] providing guidance in eight categories:

1. Enhancing early stakeholder engagement
2. Ensuring timely decisions regarding environmental reviews and authorizations
3. Improving coordination between Federal and non-Federal governmental entities
4. Increasing transparency;
5. Reducing information collection requirements and other administrative burdens on agencies, project sponsors, and other interested parties;
6. Developing and making available to applicants' appropriate geographic information systems and other tools;
7. Creating and distributing training materials useful to Federal, state, Tribal, and local permitting officials; and
8. Addressing other aspects of infrastructure permitting, as determined by the Council.

Department of Energy

The Department of Energy (DOE) has published a series of best practice manuals designed to share lessons learned through its regional carbon sequestration partnership activities as well as its research and development activities. The best practices were first published in 2011 and were updated in 2017 to incorporate lessons learned from the large-scale field projects conducted by the regional carbon sequestration partnerships.

The DOE Best Practice Manuals are:

- Monitoring, Verification, and Accounting (MVA) for Geologic Storage Projects[89]
- Public Outreach and Education for Geologic Storage Projects[90]
- Site Screening, Site Selection and Site Characterization for Geologic Storage Projects[91]
- Risk Management and Simulation for Geologic Storage Projects[92]
- Operations for Geologic Storage Projects[93]
- Geologic Formation Storage Classification[94]

The DOE has also established guidance, documentation templates, training resources, and a toolkit for CO_2 utilization LCA.[95]

Department of Treasury, Internal Revenue Service

The Treasury Department has issued two notices for CCUS projects, as well as a regulation designed to provide guidance for taxpayers regarding the process and procedures for claiming the Section 45Q tax credit.

- Notice 2020-12: Beginning of Construction for the Credit for Carbon Oxide Sequestration under Section 45Q[96]
- Rev. Proc. 2020-12: Revenue procedure to establish a safe harbor to simplify the application of Section 45 to partnerships that are eligible to claim the Section 45Q Credit[97]
- Final Regulations, Credit for Carbon Oxide Sequestration: Final regulations providing guidance regarding the credit for carbon oxide sequestration[98]

Department of the Interior, Bureaus of Land Management (BLM) and Ocean Energy Management (BOEM)

In December 2011, BLM issued Interim Guidance on Exploration and Site Characterization for Potential Carbon Dioxide Geologic Sequestration.[99]

BOEM has issued a manual examining potential best management practices for offshore CO_2 transport and storage:

- Outer Continental Shelf Carbon Dioxide Transportation and Sub-Seabed Geologic Storage Best Management Practices[100]

Non-Governmental and International Standards

Best practices manuals have also been published by the World Resources Institute (WRI) for technical aspects of CCS projects[101] and for community engagement.[102] The WRI best practices, the DOE best practices, and experience with the earliest CCUS efforts led to interest in developing more formal

standards for CCS. As a result, the process for development of international standards for CCS began in 2010 as EPA regulations for Class VI wells under UIC were finalized. A US-Canada binational technical committee developed standards for geologic storage that were published by the Canadian Standards Association and later used as a seed document for the International Standards Organization (ISO) technical committee in drafting international standards. The ISO technical committee has since published international standards for carbon capture, transportation, and CO_2-EOR, and a technical specification for risk management for integrated CCS projects, which are available for project owners' and operators' use.[103]

Sequestration of CO_2 under the seabed is regulated internationally under the London Protocol, which is designed to clarify and strengthen the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972. The London Convention is implemented domestically by EPA under the MPRSA. The United States is not yet a Party to the 1996 London Protocol, but has signed it. As a signatory, the United States has an obligation to refrain, in good faith, from acts that would defeat the object and purpose of the Protocol, though the United States does not yet consent to be bound by the terms of the Protocol itself. The United States has been working toward ratification of the London Protocol. The Contracting Parties of the Convention and Protocol have developed guidance to address the risks posed by CO_2 sequestration in sub-seabed geological formations and the potential effects on the marine environment, including:

- Specific guidelines for the assessment of by CO_2 sequestration in sub-seabed geological formations and
- Risk Assessment and management framework for CO_2 sequestration in sub-seabed geological formations.[104]

6 Opportunities to Accelerate Efficient, Orderly, & Responsible CCUS Deployment under Existing Regimes

This section of the report is being developed to respond to the Congressional mandate to identify:

"gaps in the current Federal regulatory framework for the deployment of carbon capture, utilization, and sequestration projects and carbon dioxide pipelines."

The discussion below focuses on areas where improvements could be made or where new or revised regulations may be required to ensure the efficient, orderly, and responsible development and deployment of CCUS. The analysis was informed by the inventories of information that were compiled in other sections of the report.

As described in the inventory in Section 5 of this report, there is a robust CCUS regulatory framework in the United States to protect the environment and public health across multiple statutes. This framework is in place today, and there is a pathway for CCUS projects to receive permits and begin operations in compliance with environmental laws, evidenced by 45 facilities operating or under development in the United States. There are also a number of guidance documents that are available for owners and operators, as well as regulators, to use in implementation of CCUS projects, as outlined in Section 5.3.

This section of the report is designed to address opportunities for clarifications and improvements to ensure that CCUS is responsibly scaled in a timely manner, while maintaining the integrity of public health, the environment, and the economy. The issues raised build on a series of actions that have been taken over the past decade. For example:

- EPA finalized a regulatory framework to ensure the long-term, secure and safe storage of large volumes of CO_2 underground. EPA developed these UIC Class VI geologic sequestration well regulations under the authority of the Safe Drinking Water Act to facilitate injection of CO_2 for geologic sequestration, while protecting human health by ensuring the protection of underground sources of drinking water. The Class VI regulations are built upon decades of Federal experience regulating underground injection wells, and many additional years of state UIC program expertise. EPA and states also have UIC experience with the Class II program, which provides a regulatory framework for the protection of underground sources of drinking water for CO_2 injected for purposes of EOR. In addition, to complement both the Class VI and Class II regulations, EPA used Clean Air Act authority to develop an accounting framework through the Greenhouse Gas Reporting Program for facilities to report to EPA amounts of CO_2 sequestered annually. Information collected under the Greenhouse Gas Reporting Program provides a transparent means for EPA and the public to continue to evaluate the effectiveness of geologic sequestration. These requirements help ensure that sequestered CO_2 will remain securely underground.
- To address stakeholders' concerns that regulatory requirements for hazardous wastes might apply to captured CO_2 and these requirements might be inconsistent with geologic sequestration of captured CO_2, EPA acted to remove uncertainty. The Resource Conservation and Recovery Act (RCRA) authorizes EPA to regulate the management of hazardous wastes. In particular, RCRA Subtitle C authorizes a cradle-to-grave regulatory program for wastes identified as hazardous, whether the waste is specifically listed as hazardous or the waste fails certain

tests of hazardous characteristics. To reduce potential uncertainty regarding the regulatory status of CO_2 streams under RCRA Subtitle C, and to facilitate the deployment of geologic sequestration, EPA finalized a rulemaking to exclude certain CO_2 streams from the RCRA definition of hazardous waste. In that rulemaking, EPA determined that even if any such CO_2 streams would otherwise be hazardous wastes, further RCRA regulation is unnecessary to protect human health and the environment provided certain conditions are met. Specifically, the rule conditionally excludes CO_2 streams from Subtitle C regulations if (1) they are transported in compliance with U.S. Department of Transportation or state requirements, (2) they are injected in compliance with UIC Class VI requirements, (3) no other hazardous wastes are mixed or co-injected with the CO_2 stream, and (4) generators (e.g., emission sources) and Class VI well owners or operators sign certification statements.

- In response to questions from stakeholders regarding the pathway for CO_2-EOR projects to transitioning to geologic sequestration projects, EPA provided principles to the regional offices regarding that transition, as outlined in a 2015 EPA memo.[105]
- IRS issued regulations to provide clarity for taxpayers on the process for implementation for the "Credit for Carbon Oxide Sequestration," or Section 45Q tax credit, in 2021. The regulations communicate the requirements for secure geologic sequestration. The regulations also require taxpayers to provide IRS with the identification number assigned to the facility by the EPA's electronic Greenhouse Gas Reporting Tool (e-GGRT ID number) so that IRS can reconcile information with data reported to the EPA's Greenhouse Gas Reporting Program. The regulations also allow application of the Standard CSA/ANSI ISO 27916:2019 for monitoring and verification of CO_2-EOR projects, and outline the process for LCA for CCU projects.[106] Stakeholders have, however, requested greater public transparency in demonstrating geologic storage to receive the tax credit.[107]

Possible areas for improvement to the existing regime are listed below:

Improved staff capacity and training: There may be opportunities to invest in staff training and capacity-building to improve responsible CCUS deployment outcomes. This will be especially important as the volume of CCUS projects increases due to new and improved incentives, and because robust community engagement on these issues is necessary. These ongoing efforts could be supported by the increased support for staff capacity at agencies, particularly EPA and state agencies, as outlined in the SCALE Act. Several ongoing efforts in this regard are listed below:

Implementation Training – EPA's UIC national program office presented an eight-part webinar series that covered various aspects of Class VI program implementation for EPA regional staff in 2020. The trainings were recorded and are now available in a learning management system where states and EPA staff can access the asynchronous training (released in 2021).

Workflow Planning for Class VI Permit Application Reviews – EPA developed a planning document to support EPA regional permit writers as they evaluate Class VI permit applications and attachments. It provides an overview of the permit application review process during the pre-construction phase of a Class VI project, with a focus on the relationships among various aspects of the evaluation, and a recommended "sequencing" of the steps of the review.

STOMP Training – EPA's UIC national program office organized a virtual short course for EPA staff on Subsurface Transport Over Multiple Phases (STOMP) modeling, hosted by DOE's Pacific Northwest National Laboratory. The course trained about 30 EPA UIC Class VI national program and regional staff in the application of the STOMP simulator for modeling geologic sequestration projects. Course participants attended live virtual lectures and completed computer laboratory exercises using the STOMP software.

Compliance with NEPA: Federal agency reviews and authorizations for CCUS projects are subject to compliance with NEPA. Under NEPA, agencies must evaluate whether their proposed actions will have significant environmental effects and consider the reasonably foreseeable environmental effects of their proposed actions. NEPA promotes better decisions by ensuring that agencies consider the environmental effects of their proposed actions and obtain public input before making decisions.

A 2010 Interagency CCUS Report recommended that Federal agencies develop NEPA analyses related to CCUS to help ensure timely and sound environmental reviews. Where appropriate to Federal decision-making, agencies may find that preparing a programmatic EIS covering environmental issues that are common to CCUS projects could facilitate the preparation of shorter environmental assessments (via "tiering") for individual CCUS projects or components of such projects. The report also suggested that CEQ should consider development of CCUS-specific NEPA guidance.[108] And it encouraged agencies to tailor the scope of their analyses by deploying whatever NEPA tools might be appropriate, including project-specific EISs, EAs, or categorical exclusions.

As larger and more complex CCUS projects are proposed or developed, CEQ could potentially assist Federal agencies in more efficiently and soundly planning for and permitting these projects by convening agencies to identify areas where development of programmatic EISs or EAs could be helpful and share lessons learned. CEQ could also develop and provide resources that are designed to assist agencies in implementing emerging NEPA guidance, given agencies' obligations to provide a full accounting of the climate effects (beneficial and adverse) in NEPA documents and CCUS projects' purpose in limiting carbon emissions. CEQ guidance on how to address climate impacts has not specifically addressed CCUS projects.[109]

FAST-41 permitting: CCUS projects are eligible to become "covered projects" under Title 41 of the Fixing America's Surface Transportation (FAST-41), 42 U.S.C § 4370m *et seq.,* which aims to improve the timeliness, predictability, and transparency of the Federal environmental review and authorization process for significant infrastructure projects. As referenced in Section 4.2, a FAST-41 covered CO_2 pipeline project completed the Federal environmental review and authorization process in 2019.[110]

Capture: Overall, the effects of CCUS deployment are expected to be positive on air quality;[111] however, increases of ammonia emissions are possible with the use of some conventional amine-based solvents, and researchers have raised concerns about potential watershed impacts from associated acidification and eutrophication associated with these potential air emissions impacts.[112] There is a need to further assess and quantify potential impacts on local criteria air pollutants, and other pollutant emissions resulting from carbon capture retrofits at industrial facilities. This should be done in the context of potential effects of retrofit projects on air quality non-attainment, and while engaging with communities with potential environmental justice concerns. Further research should be done, including air pollution data collection associated with Federally funded demonstration projects, to enable more robust

environmental impact analyses and decision-making regarding future projects. This is critical to address potential cumulative effects and other environmental justice concerns.

Transportation: Orders by both the FERC pursuant to the Natural Gas Act, and the Surface Transportation Board (STB) pursuant to the Interstate Commerce Act, indicate that they generally have no jurisdiction over rates and siting of inter- or intra-state CO_2 pipelines. While a report by the Government Accountability Office indicated that the STB does have jurisdiction over CO_2 pipelines, the STB has not weighed in on the matter as part of, or following, the report. A 2008 Congressional Research Service analysis of Federal jurisdiction clarified that while neither FERC nor the STB has indicated they have jurisdiction, it is possible for agencies to change their interpretation of existing law. Although the STB may have jurisdiction to hear complaints related to the economic regulation of interstate CO_2 pipelines, no cases have been brought forward to-date.[113]

Pipeline safety is established at the Federal level under PHMSA, and although states can be authorized as safety inspectors for intra-state pipelines, the responsibility for enforcement of pipeline safety for inter-state pipelines remains at the Federal level. States may adopt the federal minimum pipeline safety regulations and be authorized to inspect and enforce such regulations for intrastate pipelines by submitting a certification to PHMSA. The federal pipeline safety regulations do not include standards for CO_2 composition or purity. However, the Federal Government, USDOT as well as other Federal agencies, could issue additional rulemakings or guidance related to the construction and safe operation of pipelines for use in expanded CCUS in order to facilitate the buildout of a more extensive network.

There are several opportunities for the Federal Government to facilitate the buildout of a more extensive pipeline network in the United States. For example, the following actions were among the recommendations in a 2017 DOE report on the topic:[114]

- States can advance the permitting process by working with the Federal Government to avoid potential impacts to Federal lands or otherwise associated with siting and development.[115]
- The Federal Government could encourage collaboration among Federal agencies, private industry, states, and other stakeholders to identify priority pathways and support efficient and equitable siting and construction of multi-user regional CO_2 pipeline networks.
- State and Federal tax policies and incentives could be implemented at various points of the planning, building, and operating timeline to maximize the industry's ability to capture and store CO_2. The technical design and planning of pipelines could benefit from incentives. An individual pipeline's capacity is generally designed for the needs of a particular project. This could lead to pipelines with insufficient capacity to support expansion or changes in project scope, or allow for additional, nearby projects to benefit from the transportation provided. Canada has taken supported a pipeline with extra capacity in the context of the Alberta Trunk Line effort.[116]

Utilization: Although there are no Federal regulations that specifically govern CO_2 utilization, there is an opportunity for the Federal Government to use its procurement power to support early markets for CO_2 utilization. There is also a need for continued improvement of LCA methods, as well as a need to make LCA of different types of utilization options publicly available. Guidance on LCA for utilization has been developed for DOE-supported projects. There are also LCA provisions under the Federal Renewable Fuels Standard (RFS) program. The RFS program currently has approved pathways for fuels produced

from oil from algae grown photosynthetically. These LCA guidelines and provisions could be expanded and improved to address a broader range of technologies

In addition to inclusion of fuels produced from CO_2 utilization, there are provisions under renewable fuels programs for facilities capturing CO_2 to potentially get credits under the program. In California, captured CO_2 associated with a refinery or ethanol facility is eligible to generate credits under the LCFS. This is not true at the Federal level. Under the Federal RFS program, fuel pathways (combinations of feedstocks, production processes, and fuel types) that meet the applicable greenhouse gas reduction thresholds are qualified and assigned codes representing the kind of renewable fuel they can be used to produce. Obligated parties under the RFS program are refiners or importers of gasoline or diesel fuel. Compliance is achieved by blending renewable fuels into transportation fuel, or by obtaining credits (called "Renewable Identification Numbers", or RINs) to meet an EPA-specified Renewable Volume Obligation (RVO). EPA calculates and establishes RVOs every year through rulemaking. The standards are converted into a percentage and obligated parties must demonstrate compliance annually. The RFS program does not currently have fuel pathways that include CCUS as part of the renewable fuel production process. Companies interested in such pathways may submit petitions to EPA to add new pathways pursuant to the process in 40 CFR 80.1416.

Sequestration: The United States regulatory framework for geologic sequestration is extensive, and regulations were designed for the specific purpose of CCUS. As mentioned previously, the Class VI permitting program is the subject of a separate report to Congress required under Division G. There are, however, a few issues beyond Underground Injection Control (UIC) Program Class VI regulation that are worth mentioning.

Some stakeholders have expressed concern about property rights and the permitting processes for CCUS activities on Federal lands. There is a need to clarify ownership, as well as the process for leasing pore space for geological sequestration (terrestrial) on Federal lands for CCUS-related activities, including geological site characterization and monitoring. To address these concerns, new regulations would likely be required for the Departments of Interior and Agriculture (for lands managed by the Forest Service). Royalty rate reduction credits for CO_2 capture and non-EOR permanent storage could potentially create worthwhile financial incentives, but a number of legal, procedural, and long-term monitoring guidance questions still need to be clarified. The 2010 Interagency CCUS Task Force recommended that EPA, U.S. Department of Agriculture (USDA), and DOI formalize coordination and prepare a strategy to develop regulatory frameworks for Federal lands (including offshore).[117] The strategy remains under development.

While the Federal government does have statutory authority for authorization and deployment of CCUS offshore, further clarity or regulatory detail would ensure that it can provide comprehensive management of CCUS activities offshore while protecting the coastal, marine, and human environment. Until that time, EPA and DOI could continue to work together to design requirements for CCUS using existing authorities in complementary ways, and finalize a strategy to develop regulatory frameworks for CCUS for offshore Federal lands. In some ways, offshore authority is simpler than onshore, since the entire Outer Continental Shelf (OCS) is owned by the Federal government, eliminating concerns about mixed ownership of mineral rights, or "split estate" situations where mineral rights and surface rights are owned by two different entities. However, the OCSLA has never been used for permanent geologic

storage of CO_2. Although these issues were flagged in 2010 by the Interagency Task Force for CCUS, the opportunity to provide clarity regarding how to move forward with offshore CCUS remains.

Long-term liability, or liability for potential damages that may occur after the post-injection site care period and after a CO_2 storage site has closed, is a topic that has been raised by some stakeholders. There is substantial evidence that sequestered CO_2 will remain in place for extended periods of time (centuries, millennia, or longer). The risks associated with geologic sequestration of CO_2 are expected to be highest during the operational phase of the project and then decrease over time through post-closure. This expectation is based on a technical understanding of the variety of subsurface trapping mechanisms that work to reduce CO_2 mobility over time, ultimately arresting subsurface CO_2 buoyancy. In addition, site characterization, site operations, and monitoring strategies can work to promote storage security.

Some state governments have acted to assume the long-term liability for CCS projects (liability during operation is usually assumed by the project operator). Specifically, some states have established processes for transferring long-term liability to the state. For example, in Indiana, a CO_2 storage project operator can transfer ownership and liability for a CO_2 storage facility to the state's Finance and Administration Cabinet, following project completion and plugging the well.[118] Texas has also enacted legislation where the state's School Land Board assumes ownership and liability for offshore CO_2 injections.[119] Other states, such as Louisiana,[120] have established trust funds for long term liability. Enacted in 2009, Louisiana House Bill 661 enables CO_2 storage operators to transfer liability for stored CO_2 to the state. Ten years after CO_2 injection has ceased, the Commissioner of Conservation will issue a certificate of completion of injection operations, provided that the CO_2 storage operator can demonstrate that the storage reservoir "is reasonably expected to retain mechanical integrity and the carbon dioxide will reasonably remain in place." After a certificate has been issued, the CO_2 storage operator can transfer liability for the storage facility and stored CO_2 to the state.

7 Incentives

This section of the report is being developed to respond to the Congressional mandate to identify:

"Federal financing mechanisms available to project developers"

There are several existing programs available across the Federal government that could support CCUS projects across the country, helping communities and regions achieve economic revitalization while avoiding or minimizing other potential impacts, including cumulative pollution.

7.1 Federal RD&D Efforts & Resource Assessments

Resource Assessments and Large-Scale Sequestration Efforts

Assessments of geologic storage potential can play a critical role in accelerating responsible innovation in CCUS, providing important information to industry and other stakeholders. The United States Geological Survey (USGS) has assessed the potential CO_2 storage resources in conventional geology.[121] Through its Regional Carbon Sequestration Partnership (RCSP) Initiative, DOE has similarly conducted resource assessments as documented in the DOE's Carbon Storage Atlas.[122] These detailed assessments can be especially useful for industry as they contemplate projects. With additional resources, this work could be expanded to provide more detailed and granular assessments of carbon mineralization opportunities, and assess storage resources offshore.

R&D

DOE's Carbon Capture and Storage Program partners with industry and others to conduct research and development activities on advanced carbon capture and storage technologies.

DOE's Carbon Storage Program[123] has supported the RCSPs Initiative [124] since 2003, which conducted small- and large-scale injection tests that cumulatively stored more than 11 million metric tons of captured CO_2 in a variety of depositional settings. With the RCSP initiative largely complete, DOE is now supporting the successors of the original seven RCSPs, which were recompeted in FY19. These new "Regional Initiative" projects – now consolidated into four regions that cover the continental U.S. including Alaska – are providing technical assistance to their established regional stakeholder base to accelerate CCUS deployment.

DOE is leveraging the lessons learned from the RCSP projects to address commercial-scale (>1 million metric tons per year injection) geologic storage of captured CO_2 through its Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative.[125] The CarbonSAFE Initiative is a multi-year, multi-phase effort to characterize, permit, and construct commercial-scale CO_2 storage complexes with capacity to safely and securely store greater than 50 million metric tons of CO_2. At present, DOE is supporting five CarbonSAFE projects that are in the characterization and EPA UIC Class VI permitting phase.

As shown in Figure 8, the five CarbonSAFE projects are integrated with five (of nine) Front End Engineering Design (FEED) studies for commercial-scale advanced solvent and membrane capture systems supported by DOE's Carbon Capture Program.[126] These capture systems have the potential to provide step-change reductions in both cost and energy requirements as compared to currently available technologies.

The Carbon Capture program is comprised of Post-Combustion Capture and Pre-Combustion Capture R&D projects ranging from conceptual engineering and materials design to 10 MW-electrical (MWe) equivalent pilot testing. The Carbon Capture Program research will facilitate cost-effective implementation of CCUS technologies that can be applied to fossil-based power plants, hard-to-decarbonize industrial facilities, and the removal of CO_2 from the atmosphere.

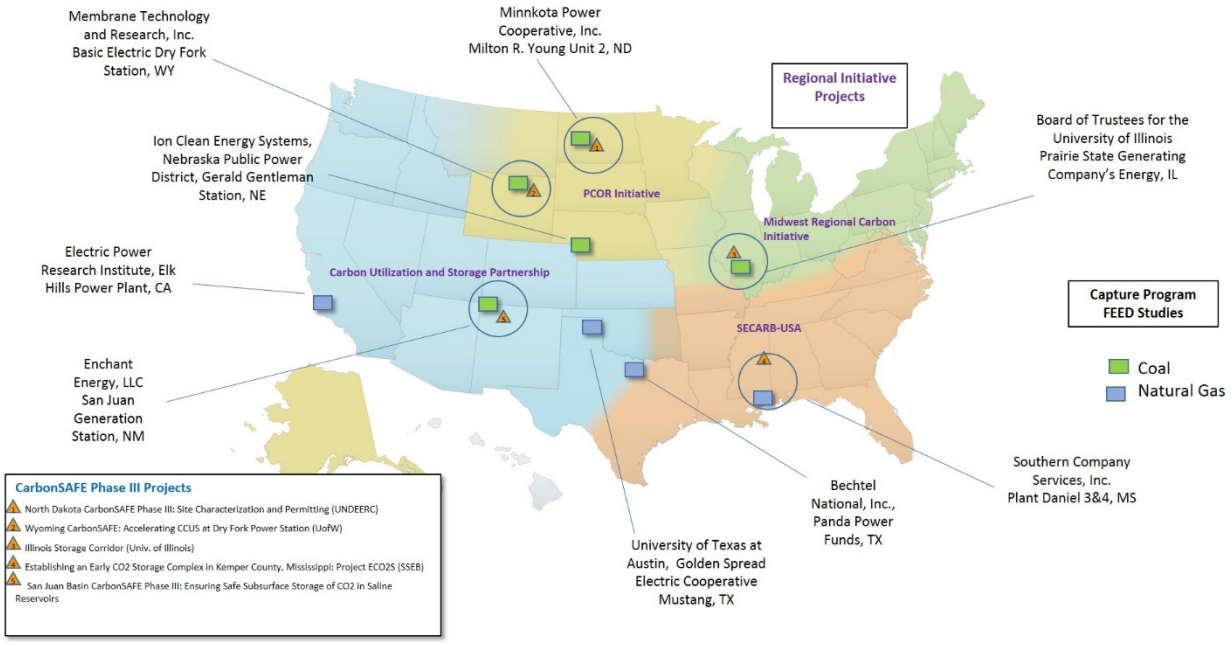


Figure 8. DOE Front-End Engineering Design Studies for commercial-scale carbon capture align with regional deployment projects and CarbonSAFE Initiative sites for commercial-scale storage design (DOE, 2021)

Demonstrations

DOE's CCUS R&D program builds on decades of work on carbon capture at DOE. For over 25 years, DOE has been co-funding major demonstrations of carbon capture technologies to hasten their adoption into the commercial marketplace. The Federal government's financial support is needed to help reduce the risks inherent in first-of-a-kind projects. Since 1985, DOE has shared in the funding of commercial-scale demonstration projects under four distinct programs:

- Clean Coal Power Initiative (CCPI) began in 2002 to address an array of domestic and global energy issues through a series of demonstrations that are ongoing.
- Industrial Carbon Capture and Storage (ICCS) demonstration's objective was to expedite and carry out large-scale CO_2 storage systems testing in a range of geologic formations, while providing information on the cost and feasibility of deployment of carbon storage technologies.
- Power Plant Improvement Initiative demonstration projects specifically addressed electric power reliability concerns for new and existing power plants.

- Clean Coal Technology Demonstration Program produced 33 completed projects in four focus areas: environmental control devices, advanced power generation, fuel processing, and industrial applications.

As Congressional interest in CCUS deployment grew, accelerating the growth in commercial-scale CCUS projects became integral to later rounds of the CCPI and ICCS programs as part of the enactment of the American Reinvestment and Recovery Act of 2009. These project funding opportunities involved cost-sharing grants from the DOE to project participants who applied new CCUS technology as part of a commercial-scale power generation or industrial project. Moving forward, DOE demonstrations will focus on CCUS applications across both the power and industrial sectors to speed commercial uptake and deployment consistent with Administration priorities. New projects will follow the successful completion of two earlier DOE industrial Major Demonstration projects: the Archer Daniels Midland and the Air Products projects. The Archer Daniels Midland project involves CO_2 capture and sequestration at a biofuels production plant in Decatur, Illinois. This project started commercial operations in April 2017, received an EPA Class VI UIC injection well permit for CO_2 storage, and, as of March 2021, successfully captured and stored over 2 million metric tons of CO_2. The Air Products project was another successful industrial CCUS Major Demonstration project that started commercial operations in a Port Arthur, Texas, hydrogen production facility in March 2013. As of March 2021, the Air Products project has successfully captured nearly 7 million metric tons of CO_2 that is used for EOR.

The recent FY 2021 Omnibus Appropriations Bill authorizes the development of programs and initiatives related to CCUS technology, including FEED studies and CCUS technology demonstration programs. As future Federal budgets are developed and funding is appropriated, it may be possible for new initiatives to be established that may provide additional Federal funding for CCUS projects.

The President's FY 2022 budget request[127] supports increased funding for a revitalized Office of Fossil Energy and Carbon Management (FECM). This request would advance carbon reduction and removal for sectors and applications that are difficult to decarbonize, including the industrial sector, with technologies and methods such as carbon capture and storage, hydrogen, and direct air capture, all while addressing pollution in overburdened communities.

7.2 DOE Loan Program Office Financing

The Department of Energy's Loan Program Office (LPO) manages several credit programs authorized to support power generation and industrial projects. These programs have various statutory requirements, which may include incorporation of innovative technologies and tribal involvement, among other attributes.

Section 1703 of Title XVII of the Energy Policy Act of 2005 authorizes the DOE to support innovative technologies that are typically unable to obtain conventional private financing due to perceived high technology risk. By statute, projects must avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases. LPO can finance CCUS projects at commercial scale with $8.5 billion of available loan guarantee authority currently available through its Advanced Fossil Energy Projects Solicitation, which can support CCUS projects.[128]

LPO works with interested parties through pre-application engagements to encourage eligible projects and reviews applications to make an eligibility determination. Project partners/developers need to

independently contact the LPO to confirm the applicability of their proposed project to DOE Loan Guarantee Program conditions and requirements.

The Tribal Energy Loan Guarantee Program (TELGP) is broadly authorized to provide loan guarantees for tribal energy development, which includes CCUS projects. The TELGP helps increase the capacity of the commercial lending market for Tribal energy development activities through the issuance of partial loan guarantees. The LPO has been consulting closely with the DOE Office of Indian Energy Policy and Programs and engaging in conversations with American Indian and Alaska Native tribes and corporations to increase awareness of the up to $2 billion in loans guarantee authority currently available to Indian Tribes for energy development. The goal of TELGP is to provide economic opportunities to Tribes through energy development projects and activities by increasing the availability of commercial debt financing, rather than replacing existing debt markets. In the longer term, it is hoped that TELGP will catalyze sustained investment in Tribal communities by the private sector.

7.3 USDA Rural Development Program Financing

The USDA utilizes various loan programs to support rural development. One USDA program is the Electric Infrastructure Loan Program under the Rural Utilities Service (RUS) Electric Program. Under the authority of the Rural Electrification Act of 1936 and 7 CFR 1710, the Electric Program makes direct loans, loan guarantees, and offers other energy project financing tools to electric utilities (wholesale and retail providers of electricity) that serve customers in rural areas. The Electric Program provides investment capital to maintain, expand, upgrade, and modernize America's vast rural electric infrastructure. The loans and loan guarantees finance the construction or improvement of electric distribution, transmission, and generation facilities in rural areas. Project financing loans can be made to developers who have power purchase agreements (PPAs) with rural electric cooperatives. These loans help diversify the power supply portfolio of rural utilities and enable more sustainable electricity to be provided to rural communities.

These types of investments can increase economic opportunity and quality of life in rural communities nationwide by maintaining a seamless electric network for all Americans, regardless of where they live. Loans are made to cooperatives, corporations, states, territories, subdivisions, municipalities, utility districts, and non-profit organizations that provide retail electric service needs to rural areas or supply the power needs of distribution borrowers in rural areas. The Electric Program is authorized in the Consolidated Appropriations Act of 2021 to loan for the construction, acquisition, design, and engineering or improvement of fossil-fueled electric generating plants (whether new or existing) that utilize carbon subsurface utilization and storage systems. Utilities serving rural areas and project developers/partners would need to independently contact the USDA Electric Program to officially confirm the applicability of the proposed CCUS project to USDA financing program conditions and requirements. As mentioned earlier, Rural Development can also make Government-backed loan guarantees to borrowers for CCUS projects using Business and Industry and Rural Energy for America Program authorities. Similar investments may be made for qualified facilities producing solar power and other eligible generating merchant facilities essential for the national electric infrastructure.

7.4 Available Federal Tax Credits

Various tax credits benefiting CCUS technology applications are available. The recent expansion of Section 45Q tax credits (for carbon dioxide, as well as other carbon oxides, as amended by the Bipartisan

Budget Act of 2018 in February 2018) provide tax credits for capturing and sequestering carbon oxides that would otherwise escape to the atmosphere and contribute to climate change. Starting in 2008, for carbon capture equipment placed in service before February 9, 2018, an incentive of $20 per metric ton for CO_2 sequestered in secure geological storage and $10 per metric ton for CO_2 used for qualified EOR or enhanced gas recovery (EGR) was available. This original Section 45Q tax credit was capped at 75 million metric tons of CO_2 and the credit amount per ton was adjusted annually for inflation. In February 2018, the tax credit was updated and increased for carbon capture equipment placed in service after the passage of the Bipartisan Budget Act of 2018. The tax credit is also available for direct air capture projects. Tax policies adopted by numerous state governments complement these Federal tax incentives.

The tax credit is available for a 12-year period, beginning when carbon capture equipment is placed in service. There is no cap on the total amount of Section 45Q tax credit that can be claimed by a taxpayer. The revised Section 45Q tax credit allows credits for qualified carbon oxides, not only carbon dioxide, and for qualified forms of utilization, in addition to sequestration, EOR, and EGR. The applicable dollar amount is as follows: a yearly applicable dollar amount that rises to $50 per metric ton of qualified carbon oxide in 2026 (and is adjusted for inflation in later years) for disposal of qualified carbon oxide in secure geological storage, and a yearly applicable dollar amount that rises to $35 per metric ton of qualified carbon oxide in 2026 (and is adjusted for inflation in later years) for EOR, EGR, or qualified utilization. Qualified facilities are defined as those for which construction begins before January 1, 2026, and which captures not less than particular amounts of qualified carbon oxide stated in Section 45Q(d) of the Internal Revenue Code, depending on the type of facility. The Section 45Q tax credit may be claimed by the owner of the carbon capture equipment. However, Section 45Q provides an election for the taxpayer that owns the carbon capture equipment to allow the person that disposes of the qualified carbon oxide, uses it in an EOR or EGR project, or utilizes it, to claim the credit. In January 2021, the IRS issued final regulations that provide detailed implementation guidelines for the Section 45Q tax credit. The President's American Jobs Plan includes proposals to boost and extend the Section 45Q tax credit to make it easier to use for hard-to-abate sectors, direct air capture, and retrofits of existing power plants.[129]

There are a number of other tax credits available that involve carbon capture. The Section 48A Qualifying Advanced Coal Project Credit was enacted in 2005 to provide: $800 million of tax credits for investments in integrated gasification combined cycle (IGCC) projects (with a credit rate of 20% of eligible project costs) and $500 million in tax credits for investments in other advanced coal-based electricity generation technologies (with a credit rate of 15% of eligible project costs). In 2008, the Energy Improvement and Extension Act of 2008 authorized an additional $1.25 billion in Section 48A tax credits (with a credit rate of 30%). Beginning in 2009, qualifying advanced coal and IGCC projects were defined to encompass projects that include equipment that separates and sequesters at least 65% of the project's total CO_2 emissions. Various allocation and re-allocation rounds for Section 48A credits have been established. Most recently, on December 28, 2020, the IRS published Notice 2020-88 to announce a new round under Phase III of the Section 48A Qualifying Advanced Coal Project Program for $2,041,500,000 of Section 48A credits available for reallocation due to forfeitures. Credits allocated in Phase III of the Section 48A program are required to separate and sequester 70% of such project's total CO_2 emissions. Phase III of the Section 48A program includes both IGCC and advanced coal-based generation technologies.

The American Recovery and Reinvestment Act of 2009 also provided the Section 48C tax credit for investments in facilities that manufacture clean energy technologies, including CO_2 capture and sequestration equipment.[130] This credit originally provided a 30% investment tax credit to 183 domestic clean energy manufacturing facilities valued at $2.3 billion. The President's American Jobs Plan supports the extension of the 48C tax credit program.

7.5 Other Incentives Under Consideration

The President's American Jobs Plan includes several provisions to incentivize responsible CCUS deployment, while ensuring that overburdened communities are protected from increases in cumulative pollution. Several bills focused on incentivizing CCUS have also been introduced on a bipartisan basis in Congress. For example, the bipartisan SCALE Act (introduced in March 2021) creates a new financial incentive modeled after the Transportation Infrastructure Finance and Innovation Act designed to support transportation projects of regional and national significance. The carbon dioxide transportation infrastructure finance and innovation program would provide Federal loans and credits for government entities and public utilities undertaking CCUS projects. This would include common carrier pipelines.

President Biden's American Jobs Plan reforms and expands the Section 45Q tax credit, making it direct pay and easier to use for hard-to-decarbonize industrial applications, direct air capture, and power plant retrofits. Several bipartisan bills, including the Coordinated Action to Capture Harmful Emissions Act, the Carbon Capture, Utilization, and Storage Tax Credit Amendments Act of 2021, and the Accelerating Carbon Capture and Extending Secure Storage through 45Q Act, also include provisions to reform and enhance Section 45Q to make it more effective, particularly for hard-to-decarbonize sectors. Aspects under consideration include increased credit values for power generation and hard-to-abate industry, making the credits fully refundable, extending the timeline for beginning construction, and modifying or eliminating the annual CO_2 capture thresholds for projects.

The American Jobs Plan also includes a technology-inclusive Energy Efficiency and Clean Electricity Standard, which could benefit CCUS projects, as well as support ten CCUS demonstration projects. The President's FY2022 discretionary budget request includes several provisions critical for the rapid scaling of responsible CCUS, including increased RD&D funding, a new office of demonstration projects, and a re-balancing in FECM's portfolio to focus on carbon management. All of these actions must be situated in the context of efforts to ensure that overburdened communities have a meaningful voice in technological development and are aided by reductions in pollution.

Congress also routinely considers policies to offset the upfront financing costs associated with CCUS investments such as Investment Tax Credits, Master Limited Partnerships, and Private Activity Bonds. Market-based policies that incentivize clean energy, such as clean energy standards or economy-wide carbon pricing, can also be inclusive of CCUS.

7.6 State & Regional Policies

Combined with Federal incentives such as the Section 45Q tax credit, state policies can help enable responsible CCUS deployment. Various states have tax and non-tax policies that support CCUS development. The types of state tax incentives vary dramatically, both in terms of the percent reduction of a particular tax and the amount of time the incentive applies to a particular project. Tax incentives include tax credits, exemption or reduction of property tax, severance tax, gross receipt tax, and sales tax, among others. Non-tax incentives can also support CCUS deployment and include other measures

states have taken such as: low carbon fuel standards, declaring CO_2 storage to be in the public interest, clarifying CO_2 ownership laws, transfer of long-term liability to the state, various forms of financial assistance, off-take agreements (providing a guaranteed buyer for the electricity or output from a CCUS project), and eligibility of CCUS in Electricity Generation Portfolio Standards or Voluntary Goals (earning saleable compliance credits by generating electricity using CCUS). In addition to these policies, Federal and state regulatory requirements and programs play an important role in enabling CCUS deployment. As mentioned previously, some state governments have also assumed the long-term liability for CCUS projects.

8 Public Engagement

This section of the report is being developed in response to the Congressional mandate to identify:

> *"public engagement opportunities through existing laws, including under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.)"*

An analysis of public engagement opportunities was undertaken that focused on existing Federal laws that relate to CCUS projects and CO_2 pipelines. The analysis examined the types of public engagement opportunities provided, who is allowed to participate, and the timing of public engagement.

There may be public engagement opportunities within existing Federal laws that are related to industry-specific characteristics or that are not generally related to CCUS projects, or CO_2 pipelines; these were excluded from this review. Nothing in this review is intended to impair or otherwise affect the authority granted by law to an executive department or agency. There are also needs identified by social science research for public and community engagement on CCUS which fall outside this analysis, including the need for risk communication, transparency, and involvement in decision-making where possible.[131] There is a need to invest in research to support the development and evaluation of equity indicators and public engagement, and to define how CCUS plays into a broadly shared understanding among the energy industry, local, state, and Federal governments, and American families, businesses, workers, and communities to support and advance deep decarbonization goals.[132]

The analysis found four overarching categories of public engagement opportunities: (1) rulemakings, (2) permitting, (3) environmental reviews, and (4) environmental information. Each category of public engagement is described below.

8.1 Rulemaking

One way in which the public may engage in activities related to CCUS projects and CO_2 pipelines is through public engagement opportunities provided during a rulemaking process. Federal law provides public engagement opportunities related to rulemaking activities through numerous statutes and regulations, but the overarching standards for the rulemaking process derive from the Administrative Procedure Act (APA). Under the APA, rulemaking is, along with adjudication and licensing, one of the processes through which a Federal agency acts with the force of law. Rulemaking involves formulating, amending, or repealing "the whole or a part of an agency statement of general or particular applicability and future effect designed to implement, interpret, or prescribe law or policy."[133]

In the CCUS context, Federal rulemakings may impact a range of issues related to a project. Participation in the rulemaking process provides the public the opportunity to influence this range of issues. Rulemakings most often follow the "informal" or "notice-and-comment" process, which requires that a notice of a proposed rule be published in the Federal Register at least thirty days before the proposal's effective date and that interested persons be afforded an opportunity to submit written comments.[134] Final rulemakings must address the major issues of policy raised in comments and why the agency reacted to them as it did.[135] Interested persons also have the right to petition for the issuance, amendment, or repeal of a rule.[136] In addition to the APA requirements generally applicable to rulemakings, several statutes also provide opportunities for public engagement related to rulemakings.

The opportunity for public engagement in rulemakings related to CCUS is meaningful. For example, the "Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide

Geologic Sequestration Wells" rulemaking docket received hundreds of public submittals and the final rule provided a substantial discussion of those comments.[137] Likewise, the promulgation of Greenhouse Gas Reporting Program (GHGRP) regulations in 2009 and 2010 was accompanied by public hearings, received thousands of comments, and included a discussion of, and response to, CCUS-related issues raised by commenters.[138]

8.2 Permitting

Public engagement plays an integral role in permitting and is generally required during the permit application phase. Access to information and strong communication among stakeholders, participating agencies, and the public are an integral part of the permitting process. A good public engagement program will create an inclusive dialogue, allowing agency staff, facility personnel, and community members to talk openly about related issues and search for mutually agreeable solutions. The public engagement process for permitting may include access to reports and other non-confidential data, newspaper advertisements, postings, mailings, public meetings, and public hearings made available by the permit applicant. Permitting programs include provisions for notifying and involving the public if a permit is applied for, issued, or revised. Below is an example of a program relevant to CCUS projects that provides public engagement opportunities within Federal permitting processes.

Injection wells are regulated by the Underground Injection Control (UIC) program under the Safe Drinking Water Act in order to protect underground sources of drinking water (USDW). EPA has the authority to implement the UIC program unless EPA has authorized primacy enforcement responsibility for a state, territory, or Tribe. EPA may approve primacy for all or part of the UIC program. This means that in some jurisdictions, permitting responsibility for certain well classes may be shared with EPA or divided between two different state, territory, or Tribal authorities. Permitting authorities provide public notice of draft permits and major permit modifications through means such as newspaper advertisements, postings, mailings, or e-mails to interested parties; hold public hearings if requested; solicit and respond to public comment; and involve a broad range of stakeholders.

8.3 Environmental Reviews

The National Environmental Policy Act (NEPA) applies to any project with a Federal nexus, including receipt of Federal funding. For those CCUS projects that occur on Federal lands or require a Federal permit, the lead Federal agency would determine if NEPA applies and would conduct an environmental review, including appropriate public involvement, prior to commencement of the project. For other CCUS projects, state, Tribal, or local environmental reviews may apply. The NEPA environmental review process is described in the statute and further outlined in the CEQ NEPA regulations at 40 CFR 1500-1508.[139] CEQ's NEPA regulations establish requirements for environmental reviews of Federal actions, including requirements for preparation of EAs or EISs for major Federal actions. A NEPA review could involve a Categorical Exclusion for proposed projects that fall within a category determined to have no significant effects on the human environment, an EA for proposed projects that are not likely to have a significant effect on the human environment or where the effects are unknown or uncertain, or an EIS for proposed projects that will have a significant effect on the human environment.

Public involvement in the NEPA process is also described in CEQ's NEPA regulations. Pursuant to 40 C.F.R. § 1506.6(b),[140] an agency is required to provide "public notice of NEPA-related hearings, public meetings and the availability of environmental documents so as to inform those persons and agencies who may be interested or affected."

Federal agencies establish agency-specific implementing procedures under CEQ's NEPA regulations. Agency-specific NEPA implementing procedures may reflect agency-specific statutory requirements, regulations, timelines, and guidance, as well as the agency's use of NEPA analysis to satisfy other review requirements.

Pursuant to NEPA and in conjunction with public engagement, environmental reviews ensure that significant environmental impacts or consequences of the proposed action are thoroughly reviewed, assessed, and considered in decision making. NEPA's requirements allow for active public involvement and engagement in the review process and decision making while considering a reasonable range of alternatives. Public engagement and involvement can occur in the form of public meetings, hearings, workshops, calls, and media communication. Comments on a proposed action from Federal, state, Tribal, and local agencies and governments, organizations, and individuals are all considered in developing NEPA documents. For EISs, the public is notified about how to get involved from the publication of a Notice of Intent (NOI) at the beginning of the NEPA process through to publication of a final EIS. These opportunities for engagement through the NEPA process for EISs are described in more detail below.

- Notice of Intent: As soon as practicable after determining that a proposal is sufficiently developed to allow for meaningful public comment and require an EIS, a lead Federal agency prepares and publishes an NOI. Federal agencies are encouraged to engage key stakeholders and members of the public, especially potentially affected communities, well before this point to help inform the purpose and need for the proposal and identify key information or information gaps to support the NOI. The NOI starts the official process in which the public is notified of the agency's proposed action and engages the public in the discussion and evaluation of potential issues and alternatives that may be identified in the environmental review.
- Scoping Process/Scoping Meetings: Pursuant to the NEPA regulations, the public scoping process determines the scope of issues to be analyzed in the EIS by conducting scoping outreach. The agency invites Federal, State, Tribal, and local agencies and governments, and organizations to participate. The scoping period typically lasts a minimum of 30 days from the date of publication of the NOI. Agencies conduct public scoping meetings during the scoping period to solicit public comment on the proposed action. Agencies are encouraged to tailor the scoping process to the needs of relevant communities and stakeholders, such as by ensuring that low-income or marginalized communities have access to scoping meeting notices and means to participate effectively. Agencies then prepare a scoping report that summarizes the public scoping comments received and agency responses, which are included in the draft EIS. Henceforth, the scoping comments inform preparation of the draft EIS.
- Draft EIS: The agency prepares a draft EIS, files the draft EIS with the Federal agency, and the agency publishes a Notice of Availability (NOA) that initiates the public comment process for the draft EIS. Agencies shall prepare draft environmental impact statements in accordance with the scope decided upon in the scoping process. Under 40 CFR § 1502.9(b), "[t]he lead agency shall work with the cooperating agencies and shall obtain comments as required in part 1503 of this chapter. To the fullest extent practicable, the draft statement must meet the requirements established for final statements in section 102(2)(C)" of NEPA.
- Public Comment/Public Hearings: The public comment period on a draft EIS is open for a minimum of 45 days from the date of publication. In addition to inviting comments, an agency

may hold public meetings or public hearings. An agency may conduct public hearings or public meetings by means of electronic communication except where another format is required by law. As noted above with respect to scoping, the public comment process should be tailored to ensure that all relevant stakeholders and affected community members have an opportunity to participate in the process. This means that steps should be taken to ensure broad stakeholder and community engagement, including with potentially marginalized communities and communities with potential environmental justice concerns.

- Final EIS and Record of Decision: Public comments are used to inform and prepare the final EIS. The final EIS must address the public comments received on the draft EIS and shall discuss any opposing view that was not adequately discussed in the draft. A notice of availability of a final EIS is issued with a minimum 30-day public review period. Upon completion of the final EIS, the agency publishes a Record of Decision (ROD). The ROD presents the agency's decision on the proposed action to the public. The ROD should also state whether the agency has adopted all practicable means to avoid or minimize environmental harm from the alternative selected, and if not, why the agency did not.[141] The agency shall also adopt and summarize, where applicable, a monitoring and enforcement program for any enforceable mitigation requirements or commitments.[142] The issuance of the ROD concludes the NEPA process.

8.4 Environmental Information

Opportunities for public engagement in CCUS projects may also exist throughout the life of projects in the form of public access to related environmental information. For example, through Federal regulation, various EPA programs create reporting requirements or information collection requests under which either information becomes readily accessible to the public or a framework is established under which the public can request information on specified topics. This information could include reports, permits, or other non-confidential data. The following are examples of programs relevant to CCUS projects that include public access to environmental information within the program requirements.

EPA's Greenhouse Gas Reporting Program collects key information regarding the supply, underground injection, and geological sequestration of CO_2 in the United States. GHG data from these activities are reported under 40 CFR Part 98, Subpart PP, Subpart UU, and Subpart RR. Every year, EPA publishes the reported, non-confidential data on the its website. Through its Facility Level Information on Greenhouse Gases Tool, the EPA provides facility-level information via an interactive website with mapping features.[143] The EPA also provides publicly available data collected by the Greenhouse Gas Reporting Program in a searchable, downloadable format for facilities.[144]

Under the Marine Protection, Research, and Sanctuaries Act (MPRSA), which would be relevant to offshore transport and storage of CO_2, the EPA may issue permits for the transportation and ocean disposal of material like CO_2 in the ocean. For MPRSA permitting and site designation, a permit applicant would need to provide environmental information to EPA for review. Information received by the EPA as a part of any application or in connection with any permit issued under the MPRSA, including information related to any stakeholder engagement on offshore permits, is required under the MPRSA to be available to the public as a matter of public record.[145]

8.5 Inventory of Public Engagement Opportunities

An inventory of public engagement opportunities under existing laws through Federal permits and reviews is found at the end of this report, Appendix B.

9 Conclusion & Next Steps

This report responds to Section 102 of Division S of the Consolidated Appropriations Act, 2021. It compiles information regarding Federal permits and reviews that a CCUS or CO_2 pipeline project operator or owner should consider (depending on the specific features of the project), and includes a summary of the guidance documents and information currently available to ensure the permitting and review process is efficient, orderly, and effective. This report makes clear that the Federal Government has an existing regulatory framework that is capable of safeguarding the environment, public health, and safety as CCUS projects move forward. Because CCUS projects are often complex, involving capture, transportation, and storage, identifying relevant permitting requirements that are broadly applicable to all projects is difficult. The report includes points of contact for interaction at relevant agencies. The Appendices provide a compilation of material related to the permitting and review processes, not all of which applies to every project, and are intended to be useful to those planning future CCUS projects. It is important to note that the vast majority of these regulations are not unique to CCUS and apply to any industrial activity in the United States. The report also includes a technical summary of CO_2 utilization technologies and a summary of available financial incentives for CCUS activities. These incentives are already driving CCUS investments, which are being regulated according to the existing regulatory framework outlined in this report.

The report identifies a number of areas where CEQ may potentially work with Federal agencies to continue to facilitate efficient, orderly, and responsible deployment of CCUS, such as:

1. Coordination of permitting processes among agencies:
    - FAST-41 implementation
    - NEPA guidance
    - Evaluating programmatic EIS opportunities
2. CO_2 Capture:
    - RDD&D of carbon capture, especially for difficult-to-abate sectors (steel, cement, etc.) and CDR
    - Convening agencies to further evaluate cumulative impacts and other potential consequences of carbon capture specifically, and CCUS broadly, in the context of environmental justice
    - Collecting air emissions data associated with future R&D and demonstration projects, including dispersion modeling to further inform analysis of potential health impacts
    - Convening agencies to consider actions that can be taken to further promote transparency and engagement regarding CCUS activities in the United States
3. Transportation and Siting:
    - Clarifying jurisdiction for establishing rates and access for common carrier pipelines
    - Federal Government convening to facilitate further development of CO_2 pipeline networks
    - Federal lands permitting and consideration of approved corridors on Federal lands
4. CO_2 Utilization and CDR:
    - Identifying opportunities for Federal procurement of products that utilize and remove CO_2
    - Expanding, improving, and making publicly available any LCA methods and analyses regarding different types of utilization options

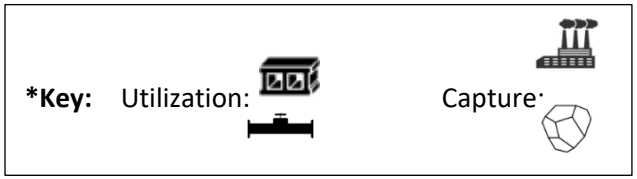
5. Storage:
    - Clarifying the process for offshore storage leasing and project implementation
    - Clarifying pore space leasing and the permitting process on Federal lands
    - Increasing staff capacity and training at agencies with geological sequestration permitting authorities

Moving forward, CEQ will establish an interagency working group to develop guidance based on this report and establish not fewer than two regional task forces required by statute. Any new guidance based on this report will be issued to agencies by the end of the year.

10 Appendix A: Inventory of Federal Permits & Reviews that Are Potentially Relevant to a CCUS Project

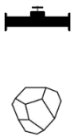
Appendix A provides an inventory of Federal permits and reviews potentially relevant to CCUS. The specific Federal permits and reviews applicable to a particular project will depend upon the type of project, the location of the project, applicable utilization processes, and whether the project occurs on Federal lands, among other factors. Therefore, the Federal permits and reviews listed in Appendix A may not all apply to a particular project. For example, separate sets of Federal statutes and regulations (implemented by different Federal agencies) would apply, depending on whether a sequestration project site is located onshore (green shading) or located offshore in Federal lands and waters (blue shading). Some statutes and regulations are only applicable to projects that are located on Federal lands. Appendix A therefore provides a list of certain *potentially* applicable statutes and regulations related to permitting and environmental reviews of CCUS projects and to CO_2 pipelines, but not all of these will apply to any given project.

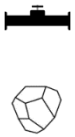
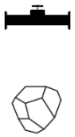
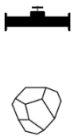
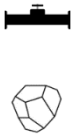
Note that statutes and regulations listed in Appendix A only cover project permitting and environmental reviews. Other environmental statutes and regulations that may apply to CCUS projects and to CO_2 pipelines but that do not directly affect permitting and environmental reviews are not included in Appendix A.

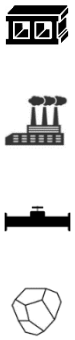
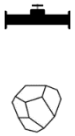


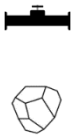
Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
Clean Air Act Title V Operating Permit	Environmental Protection Agency for states, territories, or tribes that do not have EPA-approved programs or delegated authority	EPA Regional Office for states, territories, or tribes that do not have EPA-approved programs or delegated authority		A Title V Operating Permit is required for any "major source" and certain other sources. A major source has actual or potential emissions at or above the major source threshold for certain air pollutants. In air quality attainment areas, the major source threshold is 100 tons/year, while lower thresholds may apply in non-attainment areas (for the pollutant that is in non-attainment). Major source thresholds for hazardous air pollutants (HAP) are 10 tons/year for a single HAP or 25 tons/year for any combination of HAP. Also, sources with a Major Source permit under the New Source Review (NSR) permitting program are required to obtain a Title V permit. The Title V operating permit generally does not add new requirements for the facility; rather, it contains emission limitations and other conditions as necessary to assure compliance with all air quality control requirements or "applicable requirements" required under the Clean Air Act (e.g., New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants (NESHAP), State Implementation Plans (SIP), and NSR), and it requires that certain procedural requirements be followed.	42 U.S.C. § 7661 et seq; 40 CFR Parts 70, 71
Prevention of Significant Deterioration (PSD) / New Source Review (NSR)	Environmental Protection Agency for states, territories, or tribes that do not have EPA-approved programs or delegated authority	EPA Regional Office for states, territories, or tribes that do not have EPA-approved programs or delegated authority		Prevention of Significant Deterioration (PSD) permits are required for new major stationary sources or major modifications for pollutants where the area the source is located is in attainment or unclassifiable with the National Ambient Air Quality Standards (NAAQS). Nonattainment NSR (NNSR) permits are required for new major stationary sources or major modifications in areas that do not meet one or more of the NAAQS. A minor NSR permit is required for any new or modified source of air pollutant that emits lower than the major NSR emission thresholds and, thus, is not subject to PSD or NNSR permitting.	42 U.S.C. §§ 7470-7479, 42 U.S.C. §§ 7501-7503; 40 CFR parts 49, 51, and 52

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
Underground Injection Control Program	Environmental Protection Agency for states, territories, or tribes that do not have primary enforcement authority (often called primacy)	EPA Regional Office for states, territories or tribes that do not have primacy for the well class. EPA may grant primacy for all or part of the UIC program. This means that in some jurisdictions, primacy for certain well classes may be shared with EPA or divided between two different state, territory or Tribal authorities.		Storage or disposal of water and fluids may be managed by injecting them underground using injection wells. Injection wells are regulated by the Underground Injection Control (UIC) program in order to protect underground sources of drinking water. Activities performed by the UIC program include maintaining well inventory, permitting injection wells, performing inspections, and ensuring compliance with permit requirements. When operators manage wells in a way that does not meet the applicable UIC requirements, the program alerts operators to issues and may assist operators in returning the wells to compliance or take enforcement action. The UIC program classifies injection wells based on the type of fluids the well receives, the purpose of the injection, and where the fluid is injected relative to underground sources of drinking water. Class II wells are used to inject fluids related to oil and gas production. Class VI wells are used to inject carbon dioxide deep underground for long-term storage.	42 U.S.C. §300f et seq.; 40 CFR Parts 144-148
Resource Conservation and Recovery Act (RCRA)	Environmental Protection Agency for states, territories, or tribes that do not have delegated authority	EPA Regional Office for states, territories, or tribes that do not have delegated authority		The Resource Conservation and Recovery Act (RCRA) conditionally excludes carbon dioxide (CO_2) streams from the definition of hazardous waste, provided these hazardous CO_2 streams are captured from emission sources, transported in compliance with U.S. Department of Transportation requirements, are injected into Underground Injection Control (UIC) Class VI wells for purposes of geologic sequestration (GS), and are not mixed with, or otherwise co-injected with, any other hazardous waste. The RCRA conditional exemption exclusion does not apply to the disposition of CO2 other than injection into a Class VI injection well.	42 U.S.C. §6901 et seq.; 40 CFR 261.4(h)

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
National Pollutant Discharge Elimination System	Environmental Protection Agency for states, territories, or tribes that do not have delegated authority	EPA Regional Office for states, territories, or tribes that do not have delegated authority		The Clean Water Act (CWA) is the principle law governing pollution control and water quality of the Nation's waterways. The CWA establishes conditions and permitting for discharges of pollutants into the waters of the United States under the National Pollution Discharge Elimination System (NPDES)—created in 1972 by the CWA. To the extent there are discharges of process wastewater or stormwater associated with CCS systems, these would be NPDES permitted. The NPDES program has the authority to implement pollution control measures such as setting wastewater standards for industries and regulating point sources that discharge pollutants to surface waters.	33 U.S.C. §1251 et seq.
Clean Water Act Section 404/Section 401	Department of Defense for states, territories, or tribes that do not have delegated authority; Environmental Protection Agency for states, territories, or tribes that do not have delegated authority	U.S. Army Corps of Engineers for states, territories, or tribes that do not have delegated authority; EPA Regional Office for states, territories, or tribes that do not have delegated authority		Discharge of dredge or fill materials to waters of the U.S. / Federal water quality certifications	33 U.S.C. § 1344/33 U.S.C. §1341
Hazardous Materials Transportation Act	Department of Transportation	Pipeline and Hazardous Materials Safety Administration (PHMSA)		The Hazardous Materials Transportation Act protects against the risks to life, property, and the environment that are inherent in the transportation of hazardous material in intrastate, interstate, and foreign commerce.	49 U.S.C. 5101 et seq. and 49 CFR parts 100 – 185
Endangered Species Act (ESA)	Department of the Interior (generally for terrestrial and freshwater species) and Department of Commerce	Fish and Wildlife Service's Ecological Services Program and National Oceanic and Atmospheric		ESA consultation must occur to prevent Federal action that may jeopardize an endangered or threatened species or result in destruction or adverse modification to critical habitat. If a Federal action "may affect" listed species, the action agency must pursue consultation with either FWS or NMFS depending on the species involved.	16 U.S.C. § 1531 et seq.; 50 CFR part 17

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
	(generally for marine species)	Administration Fisheries Service			
Fish and Wildlife Conservation Act / Fish and Wildlife Coordination Act	Department of Interior	Fish and Wildlife Service		The Fish and Wildlife Conservation Act, 16 USC § 2901 et seq., encourages Federal agencies to conserve and promote conservation of non-game fish and wildlife species and their habitats. In addition, the Fish and Wildlife Coordination Act, 16 USC § 661 et seq., requires Federal agencies undertaking projects affecting water resources to consult with the Fish and Wildlife Service and the appropriate State wildlife agency.	16 U.S.C. § 2901–2912 ; 50 CFR part 83 16 U.S.C. § 661–667d
Rights-of-Way for Pipelines through Federal Lands – Federal Lands	Department of Interior	Bureau of Land Management (BLM)		Rights-of-way through any Federal lands may be granted by the Secretary of the Interior or appropriate agency head for pipeline purposes for the transportation of oil, natural gas, synthetic liquid or gaseous fuels, or any refined product produced therefrom	30 U.S.C. 185; 43 CFR part 2880
Federal Land Policy and Management Act (FLPMA) – Federal Lands	Department of Interior	Bureau of Land Management (BLM)		The Federal Land Policy Management Act (FLPMA) directs the BLM to adopt Resource Management Plans to provide for multiple use and sustained yields on public lands. FLPMA also directs the BLM to prevent unnecessary or undue degradation of the land.	43 U.S.C. §§1701-1785
National Forest Management Act – Federal Lands	Department of Agriculture	U.S. Forest Service		The National Forest Management Act directs the U.S. Forest Service to adopt Land and Resource Management Plans to provide for multiple use and sustained yields within National Forests.	16 U.S.C. § 1600 et seq.
Mineral Leasing Act – Federal Lands	Department of Interior	Bureau of Land Management (BLM)		Leases for Federal Minerals	30 U.S.C. §181 et seq.; 30 U.S.C. §351-359;

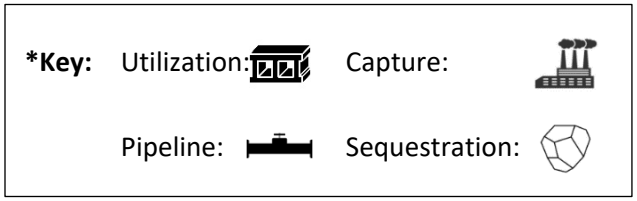
Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
					43 CFR part 2800
National Environmental Policy Act	Council on Environmental Quality	Federal Agencies conducting, funding, or permitting major Federal actions subject to NEPA		Establishes requirements for environmental reviews of Federal actions, including requirements for preparation of Environmental Assessments (EA) and Environmental Impact Statements (EIS) for major Federal actions.	42 U.S.C. § 4321 et seq.; 40 CFR parts 1500–1508
National Historic Preservation Act	Advisory Council on Historic Preservation	Advisory Council on Historic Preservation and consulting parties		The National Historic Preservation Act requires Federal agencies to evaluate the impact of Federal actions on sites listed on, or eligible for, the National Register of Historic Places. Federal agencies must consult with State Historic Preservation Offices, Tribal Historic Preservation Offices, American Indian and Alaskan Native Tribes, and Native Hawaiian Organizations before taking action that may affect resources of concern to them.	54 U.S.C. § 300101 et seq.; 36 CFR § 800.3 et seq.
Outer Continental Shelf Lands Act (OCSLA) - Offshore	Department of Interior	Bureau of Safety and Environmental Enforcement (BSEE) Bureau of Offshore Energy Management (BOEM)		Under OCSLA, DOI may permit the use of CO_2 for enhanced oil recovery (EOR) activities on existing oil and gas leases on the Outer Continental Shelf.	43 U.S.C. § 1334

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project*	Summary of Permitting/Review and Responsibility	Authority
Marine Protection, Research, and Sanctuaries Act (MPRSA) - Offshore	Environmental Protection Agency	EPA Headquarters and the seven coastal Regions share responsibilities for designating and managing ocean disposal sites and issuing MPRSA permits for material other than dredged material.		Under the MPRSA, EPA issues permits for the transportation and ocean disposal of materials other than dredged material. EPA may issue a permit if the disposition of material will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities. The statutory language is defined broadly to include "any disposition" of material but does not include the placement of a device in ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal, when such construction or such placement is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program. No MPRSA permit may be issued for industrial waste, which means any solid, semisolid, or liquid waste generated by a manufacturing or processing plant. The industrial waste prohibition was enacted by Congress in 1982, prior to the widespread understanding of carbon capture technologies to reduce carbon streams to a plasma state with some properties of a liquid and some properties of a gas. CO_2 streams prepared for storage are not solid, semi-solid, or liquid wastes.	16 U.S.C. § 1431 et seq.; 33 U.S.C. § 1401 et seq.

11 Appendix B: Public Engagement Inventory

Appendix B provides a summary of public engagement opportunities for permitting and environmental reviews of carbon capture, sequestration, and utilization projects and carbon dioxide pipelines. Similar to the permits and reviews identified in Appendix A, the specific public engagement opportunities available for a particular project will depend upon the type of project, the location of the project, and whether the project occurs on Federal lands, among other factors. Therefore, the public engagement opportunities listed in Appendix B may not all apply to a particular project. Appendix B therefore provides a list of potentially applicable public engagement opportunities as required per the statutes and regulations related to permitting and environmental reviews of carbon capture, sequestration, and utilization projects and to CO_2 pipelines. Those opportunities applicable only to Federal lands are shaded in green and those applicable to offshore CCUS are shaded in blue.

Note that as discussed above for Appendix A, statutes and regulations listed in Appendix B only cover public engagement opportunities relevant to project permitting and environmental reviews. Opportunities for public engagement as a part of environmental statutes and regulations not directly related to permitting and environmental reviews are not included in Appendix B.



Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
Clean Air Act Title V Operating Permit	Environmental Protection Agency for states, territories, or Tribes that do not have EPA-approved programs or delegated authority.	EPA Regional Office for states, territories, or Tribes that do not have EPA-approved programs or delegated authority.		The Title V Operating Permit program provides a number of public engagement opportunities including the opportunity to comment on and request a public hearing on draft Part 71 permits, appeal EPA permit decisions to the Environmental Appeals Board and Federal courts, track compliance by reviewing reports and certifications submitted by Title V permit sources, and bring citizen suit in civil court for permit noncompliance	Public notice, public hearings, petitions, citizen suits	Persons and agencies who may be interested or affected	Public may comment on and/or request a public hearing upon publication of a draft Part 71 permit during a minimum 30-day comment period (40 CFR 71.11); public may subsequently challenge facility noncompliance with provisions of the Part 71 permit. (40 CFR section 71.11(l).
Prevention of Significant Deterioration (PSD) / New Source Review (NSR)	Environmental Protection Agency for states, territories, or Tribes that do not have EPA-approved programs or	EPA Regional Office for states, territories, or Tribes that do not have EPA-approved programs or delegated authority.		The NSR program (i.e., PSD permits, Nonattainment NSR permits, and minor NSR permits) provides opportunities for public engagement to ensure that sources are complying with the requirements that apply to them. Under NSR the public may comment on and request a public hearing on draft permits that are noticed/advertised, or otherwise made available, by the permitting authority before they are issued. The public may also appeal any permit after it is issued. Appeals for permits issued by state agencies operating under their own NSR rules go	Public notice, public hearings, petitions, citizen suits	Persons and agencies who may be interested or affected; generally, a person must have commented on a draft permit in order to file an	The public may comment on and/or request a public hearing upon publication of a draft NSR permit. Permitting agencies typically publish a notice to inform the public of (1) the draft permit's

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
	delegated authority.			through state administrative process and state court. Appeals for permits issued by EPA, or on behalf of EPA, by delegated state or local agencies, go through the EPA's Environmental Appeals Board and the Federal district courts.		appeal of an issued permit	comment period (usually 30 days), and (2) the deadline for requesting a public hearing on the draft permit. The notice is usually published in a newspaper of general circulation or made available on the agency's website. After a final permit is issued, the public typically has 30 days to appeal it.
Underground Injection Control Program	Environmental Protection Agency for states, territories, or Tribes that do not have primary enforcement authority (often	EPA Regional Office for states, territories or Tribes that do not have primacy for the well class. EPA may grant primacy for all or part of the UIC program. This means that in some		Permitting authorities provide public notice of pending actions via newspaper advertisements, postings, mailings, or e-mails to interested parties; hold public hearings if requested; solicit and respond to public comment; and involve a broad range of stakeholders.	Public notifications, public comment, public hearings	The public, Indian Tribes, state and local oil and gas regulatory agencies and State agencies regulating mineral exploration and recovery, the Director of the Public Water Supply	EPA provides public notice of the draft permit. The public must be notified of all major permit modifications. All permit modifications not listed as a minor modification under 40 CFR 144.41 are considered major

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
	called primacy)	jurisdictions, primacy for certain well classes may be shared with EPA or divided between two different state, territory or Tribal authorities.				Supervision program in the State, and all agencies that oversee injection wells in the State	permit modifications.
National Pollutant Discharge Elimination System (NPDES)	Environmental Protection Agency for states, territories, or Tribes that do not have delegated authority.	EPA Regional Office for states, territories, or Tribes that do not have delegated authority.		Once the permit writer finishes drafting the NPDES permit, the permitting authority initiates a public notice period during which any interested person may submit written comments on the draft permit and accompanying fact sheet and/or request a public hearing on the draft permit.	Public notification, public comment, public hearings	The public and all interested and affected parties.	1-Public Notification: A minimum 30-day public comments period for draft NPDES permits. 2-Public Hearing: A Public Hearing is required when the permitting authority finds there is a significant degree of public interest in a proposed permit, or at the discretion of the permitting authority.

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
Hazardous Liquid Pipeline Safety Act	Department of Transportation	Pipeline and Hazardous Materials Safety Administration (PHMSA)		Pipeline operators are required to develop and implement a written continuing public education program that follows the guidance provided in the American Petroleum Institute's (API) Recommended Practice (RP) 1162. The operator's program must specifically include provisions to educate the public, appropriate government organizations, and persons engaged in excavation-related activities concerning pipeline safety.	Public awareness and communications	The public, government organizations, and persons engaged in excavation	Ongoing throughout pipeline operation
Clean Water Act Section 404	Department of Defense, U.S. Army Corps of Engineers	The Corps is responsible for all public engagement during the Section 404 permit process and is responsible for executing public engagement.		Several types of public engagement are included in the permit process. Public notice of application for an individual Section 404 permit is published. The public notice is used to solicit comments and information necessary to evaluate the activity's foreseeable beneficial and detrimental impacts on the public interest. The Corps may determine that a public hearing is necessary to make a decision on a permit application. The public may also request a public hearing to offer information relevant to the permit review. For projects involving an EIS, a scoping process is conducted to obtain the public's perspective of the scope of issues to be analyzed in the EIS. In addition, the public is engaged for comment on both the draft and final EIS. Final permit approval is summarized in the Administrative record of decision (ROD) or Statement of Findings (SOF) and made available to the public. Only permit applicants may appeal certain types of	Public notice, public hearings, and option for public hearing for projects associated with an EA; Notice of Intent, Scoping Process, Draft EIS, Final EIS, and publicati	The public and government organizations	Public engagement process commences with notification of the permit application.

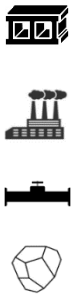
Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
				permit decisions made by the Corps, not the public. General and nationwide permits are not subject to the public engagement process once established through notice and comment rulemaking.	on of Record of Decision for projects requiring an EIS		
Endangered Species Act (ESA) – **Federal Lands**	Department of Interior (generally for terrestrial and freshwater species) and Department of Commerce (generally for marine species)	Fish and Wildlife Service's Ecological Services Program and National Oceanic and Atmospheric Administration Fisheries Service		For incidental take permits, applications are published in the Federal Register. Publication provides notice and initiates a 30-day comment period for interested parties to submit written data, views, or arguments with respect to the application. See 16 U.S.C. 1539.	Public comment	The public, interested parties	30-day comment period that commences upon publication of the permit application in the Federal Register
Rights-of-Way for Pipelines through Federal Lands – **Federal Lands**	Department of Interior	Bureau of Land Management (BLM)		43 CFR Section2884.20 What are the public notification requirements for my application? (a) When the BLM receives an application, it will publish a notice in the Federal Register and may use other notification methods, such as a newspaper of general circulation in the vicinity of the lands involved or the Internet. The notice will, at a minimum, contain:	Public notice, public hearings, public meetings	The public	The public engagement process commences upon receipt of an application for a pipeline right-of-way by BLM

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
				(1) A description of the pipeline system; and (2) A statement of where the application and related documents are available for review. (b) BLM will send copies of the published notice for review and comment to the: (1) Governor of each state within which the pipeline system would be located; (2) Head of each local or Tribal government or jurisdiction within which the pipeline system would be located; and (3) Heads of other Federal agencies whose jurisdiction includes lands within which the pipeline system would be located. (c) If r application involves a pipeline that is 24 inches or more in diameter, BLM will also send notice of the application to the appropriate committees of Congress in accordance with 30 U.S.C. 185(w). (d) BLM may hold public hearings or meetings on your application if there is sufficient interest to warrant the time and expense of such hearings or meetings. We will publish a notice in the Federal.			

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
Rights-of-Way for Pipelines through Federal Lands – **Federal Lands**	Department of Agriculture	U.S. Forest Service (USFS)		USFS revision of management plans to incorporate pipeline right-of-way grants would involve public engagement and participating of state, local, and Tribal governments and would involve preparation of NEPA documentation.	Public notice, public hearings, public meetings	The public; state, local, and Tribal governments	Public engagement and engagement with State, local, and Tribal governments initiates with USFS decision to revise the management plan and where appropriate, through the NEPA process.
Federal Land Policy and Management Act (FLPMA) – **Federal Lands**	Department of Interior	Bureau of Land Management (BLM)		The public notification requirements of 43 CFR 2920.4 apply to geologic sequestration (GS) exploration and site characterization proposals. The minimum requirement is publication of a Notice of Realty Action in the Federal Register and in a newspaper of general circulation in the vicinity of the public lands included in the CO_2 GS exploration and site characterization land use proposal once a week for three consecutive weeks thereafter. Before publishing formal public notices, BLM encourages land use proponents to conduct or participate in early informal contacts with local community leaders, existing authorized users (both surface and subsurface), adjacent landowners, Tribes, and other interested parties.	Stakeholder engagement, public notice	Local community leaders, existing authorized users (both surface and subsurface), adjacent landowners, Tribes, and other interested parties	Part of the proposal submission/approval process

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
Federal Land Policy and Management Act (FLPMA) – **Federal Lands**	Department of Agriculture	U.S. Forest Service		See above. The FLPMA, 43 U.S.C. § 1712 requires "meaningful public involvement of State and local government officials, both elected and appointed, in the development of land use programs, land use regulations, and land use decisions for public lands, including early public notice of proposed decisions which may have a significant impact on non-Federal lands."	Stakeholder engagement, public notice	Local community leaders, existing authorized users (both surface and subsurface), adjacent landowners, Tribes, and other interested parties	Part of the proposal submission/approval process
National Forest Management Act – **Federal Lands**	Department of Agriculture	U.S. Forest Service		The public will be provided opportunities for participating in the assessment process; developing a plan proposal, including the monitoring program; commenting on the proposal and the disclosure of its environmental impacts in accompanying NEPA documents; and reviewing the results of monitoring information.	Public awareness and communications	Per 36 CFR section 219.4, the responsible official shall encourage participation by: (i) Interested individuals and entities, including those interested at the local, regional, and national levels. (ii) youth, low-income	Subject to the notification requirements in 36 CFR § 219.16, the responsible official has the discretion to determine the scope, methods, forum, and timing of those opportunities.

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
						populations, and minority populations. (iii) private landowners whose lands are in, adjacent to, or otherwise affected by, or whose actions may impact, future management actions in the plan area. (iv) Federal agencies, States, counties, and local governments, including State fish and wildlife agencies, State foresters and other relevant State agencies. (v) Interested or affected Federally recognized	

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
						Indian Tribes or Alaska Native Corporations.	
Mineral Leasing Act – **Federal Lands**	Department of Interior; Department of Agriculture	Bureau of Land Management (BLM); U.S. Forest Service (USFS)		Under 43 C.F.R § 2920.4, before a geologic storage project site characterization proposal is submitted to BLM the proponent must meet with the agency and discuss the project and land use implications. After the proposal is submitted BLM will publish a Notice of Realty Action in the local paper to inform the public of the proposed sequestration and site characterization activities and land use.	Stakeholder engagement; Notice of Realty Action	Persons and agencies who may be interested or affected by the surface or subsurface land use	Public engagement process commences with notification of the permit application.
National Environmental Policy Act (NEPA)	Council on Environmental Quality	Federal Agencies conducting, funding, or permitting major Federal actions subject to NEPA		Public engagement opportunities and timelines under NEPA would depend upon the specific project and the specific Federal Agency (e.g., BLM, BOEM) that is the Federal lead agency for preparation of the NEPA analysis.	Public meetings, public hearings, public comment opportunities, organization consultations	The public	For an EIS, typically public scoping process 30 days from the date of publication of the NOI; public comment opportunity ranging in length following publication of a draft EIS or EA.
National Historic Preservation Act –	Advisory Council on Historic	Advisory Council on Historic Preservation		In consultation with the Historic Preservation Officer, an agency official shall plan for involving the public in the NHPA section 106 process (54 U.S.C. 306108). The agency	Public comment	The public; no definition given for the public	

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
Federal Lands	Preservation	and consulting parties		official shall identify the appropriate points for seeking public input and for notifying the public of proposed actions, consistent with 36 CFR Section 800.2(d). The agency official may use the agency's procedures for public involvement under NEPA or other program requirements in lieu of public involvement requirements in section 106.			
Marine Protection, Research, and Sanctuaries Act (MPRSA) - **Offshore**	Environmental Protection Agency	EPA Headquarters and the seven coastal Regions share responsibilities for designating and managing ocean disposal sites and issuing MPRSA permits for material other than dredged material.		Under the MPRSA, the EPA may issue permits, after notice and opportunity for public comment. For MPRSA permits (for material other than dredged material), EPA publishes a notice of application for public comment. Information received by the Administrator as a part of any application or in connection with any permit granted under the MPRSA, including information related to any stakeholder engagement in offshore permits, is a matter of public record. See 33 U.S.C. 1412; 40 CFR 222.	Public notification, public hearings, public meetings	The public	Public engagement process commences with EPA notice of intent to issue a permit under the MPRSA.
Outer Continental Shelf Lands Act (OCSLA) - **Offshore**	Department of Interior	Bureau of Offshore Energy Management (BOEM)		BOEM involves the public when it conducts a NEPA analysis regarding proposed permits for leases in OCS Federal waters. The public engagement begins when BOEM publishes a Notice of Intent (NOI) to prepare an EIS in the Federal Register. This action commences a 30-day public comment period, during which BOEM may hold public meetings	Public notice, public meetings, public hearings	The public	Public engagement process commences with publication of the Notice of Intent to prepare an EIS

Federal Permit or Review	Agency	Agency Point of Interaction	Type of Project	Summary of Public Engagement Opportunity	Type of Engage-ment	Who Can Participate in Engagement?	Timing of Engagement
				After the public comment period, BOEM prepares a scoping comment report and posts it to BOEM's website. BOEM uses the public comments to inform its alternatives analysis in the draft EIS (DEIS). When BOEM issues the DEIS, it publishes a Notice of Availability in Federal Register. Typically, the DEIS has a 45-day public comment period, during which BOEM holds public hearings. BOEM then prepares responses to all substantive comments and issues a Final EIS (FEIS) and ROD. The FEIS's appendix has all the comments and another appendix has responses to all the substantive comments.			

12 ENDNOTES

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[133] 5 U.S.C. § 551.

[134] *See* 5 U.S.C. § 553 (b), (d). Note, while 5 U.S.C. § 553(d) establishes the general 30-day minimum period for commenting on a proposed rule, Executive Order 12866 provided "most cases should include a comment period of not less than 60 days."

[135] *Auto. Parts & Accessories Ass'n v. Boyd*, 407 F.2d 330, 338 (D.C. Cir. 1968); *La. Forestry Ass'n v. Sec'y United States DOL*, 745 F.3d 653, 679 (3d Cir. 2014).

[136] 5 U.S.C. § 553€.

[137] 75 FR 772297723077229 (2010).

[138] 74 FR 56260 (2009); 75 FR 75060 (2010). .
[139] Projects that have no Federal nexus would not be subject to NEPA. However, some states have an equivalent NEPA-like analysis that projects may be subject to under state law.
[140] 40 CFR § 1506.6(b)
[141] 40 CFR § 1505.2.
[142] *Id*.
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