California Legislature
JOINT LEGISLATIVE COMMITTEE ON
CLIMATE CHANGE POLICIES
ASSEMBLYMEMBER AL MURATSUCHI, CHAIR

Informational Hearing: "Carbon Capture and Storage"

May 31, 2022, 10:30AM
1021 O St., Room 1100

BACKGROUND

Carbon Capture and Storage. Carbon Capture and Storage (CCS, also sometimes referred to as carbon capture and sequestration) is the process of capturing carbon dioxide (CO2) that is formed during combustion or industrial processes and putting it into long-term storage so that it is not emitted into the atmosphere. Once the CO2 is captured, it may be compressed and chilled (depending on the storage situation), and transported to an appropriate storage site, usually by pipelines and/or ships and occasionally by trains or other vehicles. To store the CO2, it is injected into deep, underground geological formations, such as former oil and gas reservoirs, deep saline formations, and coal beds.

Carbon Capture and Utilization. Captured CO2 can be used to produce manufactured goods and in industrial and other processes, rather than being stored underground. Such utilization leads to the acronym CCUS (carbon capture, utilization, and storage). Different CO2 uses lead to different levels of emissions reductions, depending on the specific use, and what fuels or other materials, if any, the CO2 is displacing. Most captured carbon is used for enhanced oil recovery, discussed further below.

Carbon Dioxide Removal. Carbon Dioxide Removal (CDR) is an umbrella term used to describe a range of strategies used to remove CO2 from the atmosphere (without relationship to where or when the CO2 was emitted). CCS is distinct from CDR in that CCS is an abatement strategy and functions by preventing CO2 from entering the atmosphere by capturing the CO2 from the emitting source, or point source, such as the flue of a gas-fired power plant or a cement plant.

In contrast, CDR is a negative emissions strategy and involves capturing legacy CO2 directly from the atmosphere. CDR strategies include technological processes such as Direct Air Capture (DAC) or enhancing the natural carbon sequestration of Natural and Working Lands (NWL). DAC typically involves using large fans to pull untreated air through a separation system, in which the CO2 is selectively removed. Restoration and management of NWL, including forests, wetlands, and agricultural lands, removes CO2 from the atmosphere by sequestering it in its vegetation and soils.

Biomass Energy with Carbon Capture and Storage. It should be noted that CCS coupled with the generation of energy (such as biofuels) using biomass, a process known as Biomass Energy with Carbon Capture and Storage (BECCS), is considered a

CDR strategy[1]. This is because biomass is a carbon sink, when it is combusted it can theoretically become carbon neutral, so capturing associated emissions from the process of combustion would be considered CO2 removal.

Existing CCS projects. According to the Global CCS Institute, there are currently twenty-seven operating commercial CCS facilities worldwide, and twelve of those are in the United States.[2] Of the facilities in the United States, four are deployed in natural gas processing, three in ethanol production, three in fertilizer production, one in syngas production, and one in hydrogen production. Altogether, CCS facilities in the United States currently capture around 20 Mt of CO2 per year.[3] As a point of reference, a study by Princeton University estimates that up to 1.8 Gt of CO2 per year is needed by 2045 for some net-zero scenarios.[4]

Cost of Implementation. A facility with CCS requires additional equipment, increased upfront construction costs, and has additional operations and maintenance expenses. Since a considerable amount of energy is required to extract, pump, and compress CO2, a facility with CCS require 15 – 30 percent more energy to operate depending on the particular type of carbon capture technology used. The percentage of CO2 captured also affects the cost. The higher percentage captured, the higher the costs. There are also additional costs associated with building pipelines to transport the CO2, injecting it underground, monitoring the injection site, and liability.

Enhanced Oil Recovery. One of the primary uses of captured CO2 is for enhanced oil recovery (EOR). EOR is a method of oil extraction that uses CO2 and water to drive oil up the well, improving oil recovery and theoretically sequestering part of the CO2 underground in the process. All but one of the existing CCS facilities in the US use the captured CO2 for EOR.[5]

EOR can provide a revenue source for CCUS sufficient to make a project economical in the absence of enough revenue from a carbon price or CCUS tax credit. Though, low oil prices can undermine the commercial viability of projects that couple CCUS with EOR. This was the case with the Petra Nova coal power plant equipped with CCUS in Texas, which used captured CO2 for EOR but nevertheless closed in 2020.[6]

The Legislature is currently debating whether to prohibit the use of CCS for purposes of EOR. The primary rationale behind this effort is that CCS used for EOR emits four times more carbon than it captures[7] and subsidizes the extraction of oil and gas.

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[1] National Research Council, Division on Earth and Life Studies, Ocean Studies Board, Board on Atmospheric Sciences and Climate, Committee on Geoengineering Climate: Technical Evaluation and Discussion of Impacts. (2015). Climate intervention: carbon dioxide removal and reliable sequestration. London, UK: National Academies Press, 1–140.
[2] "Facilities," Global CCS Institute. Retrieved September 21, 2021, from https://co2re.co/FacilityData.
[3] Ibid.
[4] Larson, E., C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, et al., *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*, interim report, Princeton University, Princeton, NJ, December 15, 2020, https://netzeroamerica.princeton.edu/the-report.
[5] Ibid.
[6] Groom, Nichola, "Problems Plagued U.S. CO2 Capture Project Before Shutdown: Document," *Reuters*, August 6, 2020, https://www.reuters.com/article/us-usa-energy-carbon-capture-idUSKCN2523K8.
[7] https://pubs.acs.org/doi/10.1021/es902006hhttps://pubs.acs.org/doi/10.1021/es902006h

Permitting requirements for CCS. There isn't an official permitting scheme for CCS in California. However, due to the myriad of existing requirements a CCS project would trigger, there would be a number of permits a prospective CCS operator would need to get prior to launching a CCS project. The figure below[8] depicts the various permits needed.

	Authorization related to:	Entity: Local Government	State Agency	Federal Agency	Tribal Government	Private Party
Capture, Transportation, Storage	Local land use	✓				
Transportation	Siting CO_2 pipelines	✓	✓	✓	✓	✓
Storage	Pore-space ownership & mineral rights	✓	✓	✓	✓	✓
Capture	Air permits		✓	✓		
Transportation	CO_2 pipeline safety		✓	✓		
Capture, Transportation, Storage	CO_2 injection permitting		✓	✓		
Transportation, Storage	Discharges to water (including those of the State)		✓			
Transportation, Storage	Discharge of dredge or fill materials into waters of U.S.			✓		
Capture, Transportation, Storage	Endangered species		✓	✓		
Transportation, Storage	Stream/river/lake alterations		✓			
Capture, Transportation, Storage	Greenhouse gas reporting		✓	✓		
Capture, Transportation, Storage	CO_2 crediting: the revenue stream		✓	✓		

Capture Transportation Storage

Figure ES-1. *Summary of main authorizations needed for a typical CCS project.*

Transportation and safety. After the CO2 is captured, it needs to be pressurized before it can be transported to where it will be permanently stored or used. Significant energy is required to compress and chill CO2 and maintain high pressure and low temperatures throughout transportation. Transportation options include pipeline and rail.

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[8] Source: George Peridas, Permitting Carbon Capture & Storage Projects in California, February, 2021, Lawrence Livermore National Laboratory, LLNL-TR-817425.

Although the most common and usually the most economical method to transport large amounts of CO_2 is through pipelines.[9]

Existing oil and gas pipeline are not suitable for transporting CO_2. Dangerous leaks and eruptions can occur if there are impurities in the pipeline. For example, if water is present in the CO_2 stream, carbonic acid can form. Carbonic acid is corrosive to carbon steel pipes, which are the most economically viable material for pipeline construction and what is most typically used. In order to avoid carbonic acid from forming, CO_2 can be dried to very low levels before transportation, which adds cost to the overall CCS project. There are also other preventative measures such as corrosion monitoring, but those also add cost.

In 2020, a pipeline transporting carbon dioxide in Mississippi leaked. The engines of the cars of emergency responders stalled as carbon dioxide concentrations increased. Forty-nine people were ultimately hospitalized.[10]

Federal regulation of carbon dioxide pipelines. There are currently about 5,000 miles of carbon dioxide transmission pipelines in the United States, and these are mostly used for EOR. A recent report prepared for the independent Pipeline Safety Trust[11] highlighted a number of potential concerns in existing federal regulation that should be addressed in order to reduce public health and safety risk prior to increasing the length of the proposed national CO_2 network by a factor of 10. It appears that the effort to facilitate the use of CO_2 for EOR and for geologic sequestration, particularly with the federal tax credit subsidies, has moved much faster than the promulgation of federal pipeline regulations. The report recommends that federal regulators (specifically the Pipeline and Hazardous Materials Safety Administration (PHMSA)) do all the following:

- Broaden the definition of carbon dioxide in pipeline regulation to include CO_2 at less than 90% purity and other than in a supercritical state;
- Identify the potential impact areas for CO_2 pipeline leaks in regulation;
- Require safety and response criteria to be promulgated;
- Specifically address risks of pipeline fracture promulgation in regulation;
- Require the addition of odorants (CO_2 is odorless);
- Update emergency response requirements in coordination with responders;
- Establish maximum impurity levels for pipeline transportation; and
- Strengthen the regulations for the conversion of existing pipelines to CO_2 service.

Storage considerations. The California Department of Conservation, California Geological Survey (CGS) conducted a preliminary screening and inventorying of potential sites for geologic CO_2 sequestration in California. CGS found that California has numerous sedimentary basins containing saline aquifers and/or oil or gas fields. An initial evaluation identified 104 sedimentary basins making up approximately 33 percent

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[9] https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter8-1.pdf
[10] https://www.huffpost.com/entry/gassing-satartia-mississippi-co2-pipeline_n_60ddea9fe4b0ddef8b0ddc8f
[11] https://pstrust.org/carbon-dioxide-pipelines

of the state's area.[12] These basins contain 465 oil and gas fields, for which varying amounts of subsurface geological and petro physical information are available to aid in the evaluation of sequestration potential. Of the104 sedimentary basins, 27 were screened out for further study as potentially appropriate for sequestration.

While the limitation on the availability of geologic storage is generally not considered a barrier to widespread CCS deployment, some researchers have expressed concerns about the long-term ability of storage sites to sequester carbon without significant leakage. Injections of CO2 underground can also trigger seismic activity[13]. There are also concerns with soil and aquifer acidification. Researchers continue to look at ways to minimize these risk, including considering the potential for above-ground carbon dioxide mineralization as an alternative to underground storage.

Federal Funding for CCS. The Department of Energy has funded research and development in aspects of CCS since at least 1997 within its Fossil Energy and Carbon Management Research, Development, Demonstration, and Deployment program (FECM) portfolio.[14] Since 2010, Congress has provided $7.3 billion in appropriations for DOE CCS-related activities, including annual increases in recent years. In 2021, Congress provided $750 million to FECM, of which $228.3 million was directed to CCS.

The Bipartisan Infrastructure Bill, which passed in 2021, allocated billions of dollars to support and expand the existing Carbon Capture Technology program at the DOE.[15]

The Bill allocates:

- $3.5 billion for carbon capture demonstration projects and carbon capture large-scale pilot projects over the next five years.
- $100 million for carbon capture front-end engineering and design projects.
- $2.1 billion in low-interest loans to large CO2 pipeline projects. The loan would finance up to 80% of the costs of approved projects, including planning, permitting, design work, construction, real property acquisition, capitalized interested, legal, and technical consultant costs.
- $2.5 billion for the carbon storage program.
- $5 million annually until 2026 to improve the permitting of Class VI Underground Injection Control wells for geologic sequestration by the US Environmental Protection Agency.
- $50 million in grants for States to establish and operate their own Class VI permitting program.
- $3.5 billion for the Carbon Removal Program to create four regional direct air capture hubs.
- $15 million to fund a pre-commercial direct air capture technology prize competition

[12] https://www.conservation.ca.gov/cgs/Documents/Publications/Special-Reports/SR_183-Carbon-Report.pdf
[13] https://nap.nationalacademies.org/catalog/13355/induced-seismicity-potential-in-energy-technologies
[14] https://sgp.fas.org/crs/misc/R44902.pdf
[15] https://www.jdsupra.com/legalnews/bipartisan-infrastructure-bill-invests-9111801/

- $100 million for a commercial direct air capture technology prize competition.

Additionally, Internal Revenue Code Section 45Q (45Q) provides tax credits for carbon oxide sequestration in order to incentivize investments in carbon capture and sequestration. The tax credit is computed per metric ton of qualified carbon oxide (prior to 2018, credits were only available for CO2) captured and sequestered.[16] Congress is currently considering expanding incentives in the Reconciliation Proposal (also known as the Build Back Better Bill). The proposal would increase the subsidy rate from $50/ton of captured CO2 to roughly $85/ton. The proposal would also create a minimum capture requirement for plants; any plant that captures less than 75 percent of its emissions would not be eligible for the credits.

CCS cost overruns and failures. According to a report[17] by the US Government Accountability Office, most of the CCS projects funded by the DOE have failed. This includes Hydrogen Energy California in Kern County, which received over $153 million from the DOE.

According to the DOE's National Energy Technology Laboratory, 147 CCS projects have been proposed or built worldwide.[18] Of those, 58 have been terminated and 36 have been placed on indefinite hold. The DOE spent nearly $1.3 billion on nine CCS demonstration projects since 2010.[19] Only three remain active as of 2017.

Southern Company's Kemper plant, often cited as the poster child of cost overruns, was originally forecast to cost $2.2 billion,[20] but ultimately ballooned to $7.5 billion.[21] The Illinois FutureGen project, despite receiving $200 million in subsidies, was ultimately scrapped due to cost and technology concerns. Petra Nova, a coal fired CCS project in Texas, was plagued with cost overruns, prolonged outages, and failed to meet its CO2 capture goals.[22] Petra Nova was ultimately shutdown in 2020.

Carbon Capture Rate. The capture rate refers to how much CO2 is being captured relative to how much is being emitted. As such, a number of factors can affect the capture rate. This includes the purity of the CO2 stream, the duration which the CCS device is operational, how many emission points contain CCS devices, and how the CCS is powered (since burning fossil fuels to power CCS equipment reduces effective capture rates).

Most research available indicates a capture rate of 90 percent. Yet, data gathered from CCS projects indicate a much lower capture rate. For example, The Petra Nova CCS project in Texas, one of the largest CCS plants in the world, reported a 33 percent

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[16] https://sgp.fas.org/crs/misc/IF11455.pdf
[17] https://www.gao.gov/assets/gao-22-105111.pdf
[18] National Energy Technology Laboratory 2018 *Carbon Capture and Storage Database* (Washington, DC: U.S. Department of Energy). https://netl.doe.gov/coal/carbon-storage/worldwide-ccs-database
[19] https://www.gao.gov/assets/700/694656.pdf
[20] https://sequestration.mit.edu/tools/projects/kemper.html
[21] https://ieefa.org/ieefa-u-s-southern-company-demolishes-part-of-the-7-5-billion-dollar-kemper-power-plant-in-mississippi/
[22] https://www.osti.gov/servlets/purl/1608572

capture rate[23] while the Shell Quest CCS project in Canada reportedly only captured 48 percent.[24]

Part of this discrepancy between the theoretical and actual capture rates is likely due to reporting methodology. Facilities such as refineries have multiple emission points. Sources indicating a 90 percent capture rate might be looking at the emissions captured relative to the emissions from the emission point to which the CCS device is attached as opposed to the total emissions from that facility.

A study from Stanford,[25] which looked at the health impacts of CCS and DAC, found that the low net capture rates are due to uncaptured combustion emissions from natural gas used to power the equipment, uncaptured upstream emissions, and, in the case of coal with carbon capture and use, uncaptured coal combustion emissions.

CCS impacts on local air quality. Due to the increased energy needs of CCS technologies, this leads to increased 'direct emissions' from facilities where CCS is installed, and increased 'indirect emissions' caused by the extraction and transport of the additional fuel. A report from the European Environment Agency in 2020 describes the effects that CCS may have on localized emissions of some key air pollutants.[26]

CCS and water impacts. Depending on the specific type of CCS technology used, it can involve large water consumption during the energy-intensive capture process. Given the scarcity of water in California, the water footprint assessment of CCS is a crucial factor in evaluating these technologies.

Low Carbon Fuel Standard CCS Protocol. The Low Carbon Fuel Standard Program (LCFS) is a market-based program operated by CARB and designed to reduce carbon intensity of transportation fuels. The program functions by setting declining benchmarks over time on transportation fuels sold, supplied, or offered for sale in California. Fuels with a carbon intensity that is lower than the relevant annual benchmark generate credits and fuels with a carbon intensity that is higher than the relevant benchmark generate deficits. Regulated parties under LCFS must ensure they have sufficient credits in a year.

The LCFS regulation was approved in 2009 and implementation began in 2011. In 2018, the LCFS Program was amended to enable CCS projects that reduce emissions associated with the production of transport fuels sold in California, and projects that directly capture CO2 from the air, to generate LCFS credits. These changes came into effect in January 2019. To qualify, projects need to meet the requirements of the CCS Protocol. To-date, no projects have qualified under the LCFS CCS protocol.

CCS Liability. CARB's LCFS Protocol contain safeguards for the deployment of CCS in California. They include ongoing monitoring requirements, indemnity bonding to ensure

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[23] https://www.smh.com.au/national/millions-of-tonnes-of-carbon-added-to-pollution-as-gorgon-project-fails-capture-deal-20210215-p572na.html

[24] https://www.cnbc.com/2022/01/24/shell-ccs-facility-in-canada-emits-more-than-it-captures-study-says.html

[25] https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-CCS-DAC.pdf

[26] https://www.eea.europa.eu/publications/carbon-capture-and-storage

costs associated with various elements of the project are available, and extensive site characterization and planning requirements, among other things.

As the Legislature debates the broader use of CCS, it is also debating whether to adopt safeguards to limit the liability associated with CCS.

Pore space ownership. Split estates are common in California. A split estate exists when the surface and the mineral rights are owned by different entities. To avoid conflict associated with geologic storage, it would be important to clarify the ownership of pore space.

Under the Low Carbon Fuel Standard, CCS operators are required to show the exclusive right to use the pore space and proof of a binding agreement that drilling and extraction that penetrate the “storage complex” are prohibited to ensure public safety and the permanence of stored carbon dioxide.

CCS-related legislation. There are a number of bills pending before the legislature containing one or more provisions related to CCS. Each bill is listed below.

- SB 905 (Skinner, 2022) would require CARB to administer a Geologic Carbon Sequestration Demonstration Initiative to fund up to three geologic carbon sequestration demonstration projects in the cement sector and would require CARB to adopt guidelines for carbon sequestration projects under the Initiative. It would also streamline permitting and clarify pore-space ownership.

- SB 1101 (Caballero, 2022) would require CARB to establish a carbon capture, utilization, and storage program to deploy carbon capture technologies to reduce the carbon dioxide emissions from new and existing facilities. This bill also clarifies pore-space ownership.

- SB 1297 (Cortese, 2022) requires the California Natural Resources Agency to, among other things and in consultation with specified state agencies, develop a plan to advance low-carbon materials and methods in building and construction projects that details a strategy and recommendations to minimize embodied carbon and maximize carbon sequestration in building materials, as provided.

- SB 1314 (Limón, 2022) prohibits an operator from injecting CO2 produced from a CCS project into a Class II injection well for the purposes of EOR.

- SB 1399 (Wieckowski, 2022) requires the California Energy Commission to establish a grant program to fund carbon capture and storage demonstration projects at industrial facilities in the state.

- AB 1395 (Muratsuchi, 2021) would set state policy to achieve net-zero greenhouse gas emissions by 2045 and net-negative emissions thereafter and establishes criteria for CCS.

- AB 1531 (O’Donnell, 2021) among other provisions, would establish the CEC as the lead agency for CEQA environmental reviews of proposed carbon capture and storage projects. The bill would also require the CPUC to authorize gas corporations to file applications for investments in carbon capture, sequestration, or utilization projects.

- AB 1676 (Grayson, 2022) adds CO2, compressed to a supercritical state, to the substances included in the Elder California Pipeline Safety Act of 1981, giving the Office of the State Fire Marshall exclusive jurisdiction to regulate intrastate pipeline transportation of CO2 under the existing provisions of the Elder Act, which currently applies to petroleum and other hazardous liquids.

- AB 2578 (Cunningham, 2022) specifies that carbon capture, utilization, and sequestration technologies shall be included in the evaluation of the environmental performance of California's electric generation facilities in the biennial integrated energy policy report prepared by the California Energy Commission.

- AB 2944 (Petrie-Norris, 2022) requires the Air Resources Board to include an evaluation of how carbon capture, utilization, and sequestration technologies are contributing to the state's greenhouse gas emission reduction goals in an annual report to the Legislature.

Potential Questions:

- Is CCS worthwhile to pursue given the cost of implementation, additional energy needs, and associated risks?
- What are some of the technological challenges associated with CCS?
- How does the use of CCS compare with other strategies?
- Are there alternatives to CCS?
- Does the use of CCS result in lower emissions once the extra energy needed (for capture, transport, and storage) is taken into account?
- Does CCS increase local air pollution? In what ways? If so, what options are there to mitigate that?
- Would the deployment of CCS extend the use of fossil fuels inappropriately?
- If we make investments in CCS, are we locking in the continued use of fossil fuels for another 30 years?
- Should CCS be limited to hard to-decarbonize sectors?
- If the gap between theoretical and actual capture rates is so large, is it appropriate that the scoping plan assumes a 90% capture rate?
- Should the liability provisions under LCFS be a model for all CCS projects in California regardless of whether LCFS credits are being sought?