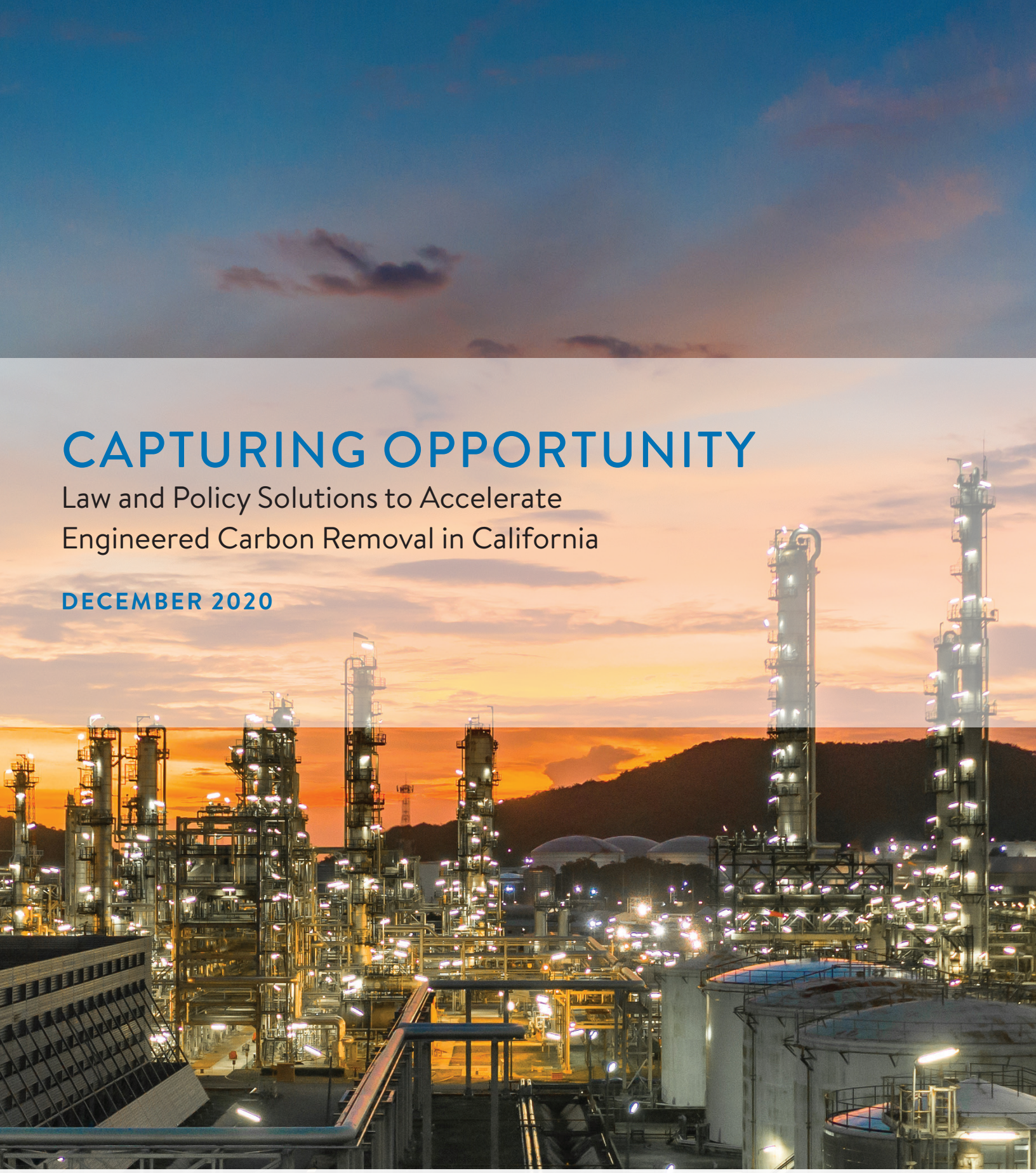

CAPTURING OPPORTUNITY

Law and Policy Solutions to Accelerate Engineered Carbon Removal in California

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BANK OF AMERICA

Berkeley Law
Center for Law, Energy, & the Environment

UCLA School of Law
Emmett Institute on Climate Change & the Environment

About this Report

This policy report is part of a series on how specific sectors of the business community can drive key climate change solutions and how policymakers can facilitate those solutions. Each report results from workshop convenings that include expert representatives from the business, academic, policy, and environmental sectors. The convenings and resulting policy reports are sponsored by Bank of America and produced by a partnership of UC Berkeley School of Law's Center for Law, Energy & the Environment (CLEE) and UCLA School of Law's Emmett Institute on Climate Change and the Environment.

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I. INTRODUCTION & EXECUTIVE SUMMARY

Senate Bill 32 and Executive Order B-55-18 require California to reduce emissions 40 percent below 1990 levels by 2030 and to achieve carbon neutrality as soon as possible and no later than 2045, then achieve and maintain net negative emissions thereafter.[1] The state continues to make progress toward carbon neutrality through programs that boost clean and low-carbon technologies, such as the Renewables Portfolio Standard, cap-and-trade program, low carbon fuel standard (LCFS), and zero-emission vehicle mandate, among other ambitious initiatives.

However, California must also deploy new methods of removing carbon and storing it permanently on or under the ground to meet the carbon neutrality and net negative emissions goals spurred by the urgency of global climate change. A 2020 analysis led by Lawrence Livermore National Laboratory estimated that the state must remove roughly 125 million tons of atmospheric carbon dioxide per year by 2045, with negative emissions beginning in 2025 and increasing annually through 2045, to reach statewide carbon neutrality targets.[2] The report concludes that these removals can be achieved "at modest cost using resources and jobs within the State, and with technology that is already demonstrated or mature."[3] Furthermore, the Intergovernmental Panel on Climate Change projected that limiting warming to 1.5°C by 2100 will require reducing net global emissions and pursuing net negative emissions.[4]

The severity and scale of climate change demand creative solutions, and engineered carbon removal technologies will play a crucial role in meeting this challenge, to complement natural carbon removal opportunities presented by our lands and oceans. These emerging approaches can include direct air capture of carbon dioxide from the atmosphere, utilization of bioenergy with carbon capture and underground storage, deploying carbon capture and storage of emissions from industrial facilities or power plants, and injecting captured carbon into various products, such as plastics and concrete. Carbon dioxide removal techniques can also include bioengineered approaches or enhancement of natural carbon sinks (e.g., forests, soils, wetlands, and agricultural lands, among others), though this report focuses solely on engineered options. It covers two distinct technological pathways for engineered carbon dioxide removal: negative emissions and avoided emissions. As Lawrence Livermore National Laboratory generally defines them: negative emissions involve the long-term, physical removal of carbon from the atmosphere, while avoided emissions refer to an emission that would have occurred but is prevented by a negative emissions technology or practice (for example, capturing and geologically storing fossil fuel emissions).[5]

Engineered technologies, and the permanent storage options that go alongside them, are still generally uneconomic at a commercial scale and would benefit from additional research, development, demonstration, and deployment. Demonstration projects face several urgent regulatory challenges, from siting and permitting to incentives and industry standards. California has a window of opportunity now to influence future deployment of engineered carbon removal technologies by building supportive policies and a broad coalition to address these uncertainties, particularly through near-term deployment of demonstration projects.

To address these challenges, UC Berkeley School of Law's Center for Law, Energy and the Environment (CLEE) and UCLA School of Law's Emmett Institute on Climate Change and the Environment convened state energy, fossil fuel, and natural resources management leaders; carbon removal experts; and climate and air quality advocates in November 2020 to identify top-priority policy solutions. This policy brief outlines the vision these stakeholders described for deploying engineered carbon removal technologies, the key barriers limiting progress toward that vision, and actionable solutions to overcome those barriers.

The top barriers and solutions include:

Barrier: Lack of a clear statewide strategy for engineered carbon removal creates uncertainty

Solutions:

- The Governor or the state legislature could establish a single point of contact for engineered carbon removal policies and projects, by designating a lead agency, appointing a new role in an existing agency or the Administration, or creating a new entity.
- The Governor could issue an executive order establishing the state's commitment to engineered carbon removal technologies and establishing clear targets for engineered carbon removal, based on estimates of what is necessary to meet statewide carbon neutrality goals.
- State energy, air quality, and environmental planning agencies, with supportive legislation or executive direction, could develop a clear strategy regarding the role of engineered carbon removal in California's broader climate change strategy, in light of the necessary role of negative emissions to meet carbon neutrality goals.

Barrier: Lack of coordinated, clear, and centralized permitting adds complexity and cost to project development

Solutions:

- The Governor and the state legislature could direct state agencies to coordinate and develop a centralized, master permitting process for engineered carbon removal projects, taking into account environmental justice and other community concerns.
- State and federal government agencies could explore opportunities for memoranda of understanding/agreement to coordinate permitting and enforcement procedures.
- California agencies could identify corridors and sites in advance that would be prime areas for engineered carbon removal facilities and associated infrastructure, in order to conduct advance, pre-permitting review, while incorporating and analyzing land use impacts on disadvantaged communities and critical ecosystems.
- The state legislature could clarify ownership of underground pore space for carbon storage, particularly when different parties own the surface land and underground mineral rights.
- The state legislature could direct the Governor's Office of Planning and Research to develop guidelines under the California Environmental Quality Act for permitting and lead agency guidance.
- California could seek primacy status from the U.S. EPA for granting Underground Injection Control (UIC) Class VI permits, which are required for wells for carbon injection into deep rock formations.[6]

Barrier: Lack of public awareness of engineered carbon removal needs and benefits impedes public confidence and slows project development

Solutions:

- The California Geologic Energy Management Division, Air Resources Board, Energy Commission, State Water Resources Control Board, Natural Resources Agency, Environmental Protection Agency, and Governor's Office of Planning and Research (possibly in partnership with a third-party nonprofit or university) could host a series of community dialogues on engineered carbon removal.
- The state legislature could direct the California Energy Commission, Geologic Energy Management Division, and/or State Lands Commission to sponsor one or more demonstration projects using new appropriations or cap-and-trade proceeds.
- The California Energy Commission, in consultation with the California Air Resources Board, could develop and publish a state engineered carbon removal project opportunity map, including an analysis of potential local and regional benefits and risks.

Barrier: Financial uncertainty clouds the engineered carbon removal investment path

Solutions:

- The California Air Resources Board could extend annually-decreasing carbon intensity limits under the Low-Carbon Fuel Standard beyond 2030 and consider future program adjustments that could support carbon removal project financing.
- The California Energy Commission and Public Utilities Commission could collaborate with the Geologic Energy Management Division, Air Resources Board, and other agencies to develop a coordinated approach to transitioning natural gas infrastructure to carbon transportation infrastructure.
- Congress could modify the 45Q tax credit to extend beyond the current 12-year duration and/or extend the construction deadline of Jan. 1, 2024.

II. OVERVIEW: ENGINEERED CARBON REMOVAL IN CALIFORNIA

Potential engineered carbon removal projects and technologies in California

California could host a range of engineered carbon removal project types in the coming decade as developers move technologies to deployment and scale. This report distinguishes between negative emissions and avoided emissions, as defined previously. Key distinctions among engineered carbon removal processes include how they remove or capture carbon, how they store it, and on what timescale. Negative emissions technologies, such as large fans used for direct air capture or biomass taking up carbon through photosynthesis, capture carbon dioxide from the ambient air and therefore are location independent. They can be deployed in any location and capture emissions that may have occurred long ago and outside of California. By contrast, avoided emissions pathways capture carbon associated with a specific source, such as an industrial facility or power plant, to avoid letting the gas reach the atmosphere.[7] For the purposes of this report, engineered carbon dioxide removal includes:

Negative emissions technologies (NETs)

Negative emissions technologies directly remove carbon already in the atmosphere, not carbon associated with a specific industrial process or facility. Engineered negative emissions technologies include bioenergy with carbon capture and storage (BECCs) and direct air capture with carbon capture and storage (DACCS), among other technologies.[8] Negative emissions technologies are important for offsetting past and current emissions and can be used to remove carbon on a geologic timescale when paired with permanent storage.

Avoided emissions technologies

Avoided emissions technologies prevent carbon emissions that would have otherwise occurred by directly capturing carbon at the source, such as a fossil fuel power plant or industrial facility. They are especially important for sectors with emissions that are difficult to reduce. According to the Center for Climate and Energy Solutions, "[c]arbon capture can achieve 14 percent of the global greenhouse gas emissions reductions needed by 2050 and is viewed as the only practical way to achieve deep decarbonization in the industrial sector."[9]

Avoided emissions are a necessary but not sufficient component of climate change mitigation, as carbon already in the atmosphere will continue to cause climate change for centuries to come, even if all anthropogenic emissions ceased.[10] Therefore, policy makers should support technologies and practices that take previously emitted carbon dioxide out of the atmosphere via negative emissions technologies, in conjunction with approaches that reduce current emissions.[11] Both avoided and negative emissions will be critical to statewide and global climate change goals.

Storage and utilization

Permanent sequestration technologies must be paired with both negative and avoided emissions technologies to have a lasting impact on the carbon cycle. Examples of sequestration mechanisms include geological sequestration via injection into underground rock formations or saline aquifers, or use in materials with long lifespans, such as concrete.[12]

Some methods capture carbon after or alongside utilization and sequester it permanently in underground storage, or sequester carbon directly without utilization. Other approaches repurpose the captured carbon for use in manufacturing, fuels or enhanced oil recovery (EOR).[13] (Some participants at the convening acknowledged potential controversy associated with EOR: while it can promote development of engineered carbon removal technologies, it can also facilitate further production of carbon-emitting oil and gas from existing wells. Ultimately, the merits of its inclusion as an area of focus for additional state policy support is beyond the scope of this report.) For example, carbon might be sequestered directly in a product that has a long lifespan, such as concrete. However, utilization technologies generally are less mature than underground storage technologies. Carbon capture, utilization, and storage could expedite emission reductions across many sectors, especially those in which mitigation is challenging.

The following section describes technology pathways under potential consideration in California.

Biomass Conversion

Biomass conversion, such as bioenergy with carbon capture and storage (BECCS), is a type of negative emissions technology. It pairs energy production with technology that traps and stores carbon released from biomass, counteracting the carbon emissions that otherwise result from natural decomposition of plant matter and/or its use in traditional bioenergy production. Examples of waste biomass include agricultural residue, municipal solid waste, biomass from forest management, gaseous waste, and sawmill residue.[14] Waste biomass can be converted to liquid or gaseous fuel, renewable natural gas, biochar, or electricity through gasification, combustion, fast pyrolysis, hydrothermal liquefaction, or biogas utilization.[15] The carbon dioxide produced can be sequestered to achieve net-negative emissions if it is stored permanently, given that the biomass absorbed the carbon from the atmosphere. Additional carbon dioxide reductions are possible if bioenergy offsets fossil fuel use, although this practice would represent mitigation, not negative emissions.

Biomass conversion offers California key benefits by reducing reliance on traditional fossil fuels while generating net negative emissions. However, bioenergy production can have environmental impacts (e.g., air quality degradation) that can affect local communities—raising significant environmental justice questions—and some participants noted that although the low carbon fuel standard credits bioenergy projects and accounts for full lifecycle carbon emissions of fuels, it does not reflect project air quality impacts. Ultimately, biomass counts towards California's Renewables Portfolio Standard (RPS), and capturing the associated carbon can help the state reach zero-carbon energy targets.[16]

Biomass conversion could capture roughly 84 million tons of carbon dioxide per year in California as soon as 2025.[17] The California Forest Carbon Plan identifies biomass utilization from forest management as an activity important to managing greenhouse gas emissions.[18] Additionally, waste biomass can aid in forest management to mitigate wildfires.[19] Lawrence Livermore National Laboratory estimated that the largest amounts of forest management biomass will need to be collected from the counties of Humboldt, Mendocino, Siskiyou, Trinity, Shasta, and Plumas.[20]

Only a few bioenergy with carbon capture and storage facilities were in operation worldwide as of 2019, most of which were in the Midwest United States.[21] The National Academy of Sciences identified bioenergy with carbon capture and storage as one of four negative emissions technologies ready for large-scale deployment.[22] Illinois is already home to the first large-scale bioenergy with carbon capture and sequestration project in the world, which is the first project to operate deep carbon dioxide injection into geologic formations under a Class VI injection well permit.[23] While California has no bioenergy with carbon capture and sequestration facilities to date, the technology offers the potential to reduce the state's emissions while promoting wildfire resilience and jobs in rural areas of the state.

Direct Air Capture with Carbon Capture and Storage (DACCS)

Direct air capture, a negative emissions technology, removes carbon dioxide that is already in the atmosphere, filtering air through large fans and capturing carbon by chemical adsorption or absorption. As a result, direct air capture is not associated with a specific point source or sector and therefore can be deployed anywhere. Once captured, the carbon can be stored permanently (in solid materials or in geologic formations, for example) to achieve negative emissions or utilized in other applications. Barriers to direct air capture in its current form include its high energy intensity, high cost, and large land-area footprint.[24]

Direct air capture could remove tens of millions of tons of carbon dioxide per year, but it represents the most expensive option available currently. Direct air capture projects are eligible for Low Carbon Fuel Standard (LCFS, described later in this report) credits under the Carbon Capture and Sequestration Protocol (CCS Protocol).[25] In 2010, Global Thermostat unveiled a direct air capture pilot plant in Menlo Park, California. The project was expanded to a commercial demonstration in 2013.[26]

Carbon Capture from Industrial Facilities or Power Plants

Implementing carbon capture at emitting facilities reduces the amount of carbon entering the atmosphere, making this avoided emissions technology helpful in reducing emissions across several industrial and energy-related processes. Sectors in California that are candidates for carbon capture, utilization, and storage include cement, petroleum refining, and natural gas power generation, among others.[27] However, several participants urged that carbon capture at polluting facilities must facilitate, rather than delay, the state's transition away from fossil fuels. Certain industrial carbon capture projects are eligible for credits under California's Low Carbon Fuel Standard. Project developers may sequester the carbon via enhanced oil recovery (EOR) or deep saline reservoir, so long as they store the carbon permanently.[28] Overall, carbon capture technologies have been proven at scale, with more than 21 large-scale facilities in operation globally as of September 2020;[29] however, research and pilot projects still can improve efficiency and reduce costs, and targeted policy is still needed to incentivize project development through mechanisms like tax credits.[30] In Summer 2020, researchers at UC Berkeley published findings on a new approach that captured over 90 percent of carbon from experimental emissions.[31]

Carbon Sequestration

Where carbon should be stored, how it might be utilized, and how to transport it are key considerations for both negative emissions technologies and point source capture applications. Permanent sequestration locations include depleted oil and natural gas fields, coal beds, or saline reservoirs.[32] The Central Valley alone has more than 17 billion tons of potential underground storage capacity.[33] However, transporting carbon from the point of capture to point of injection will require additional infrastructure investments (e.g., pipelines to transport carbon dioxide). Given the high concentration of disadvantaged communities in areas that may host underground storage or transportation infrastructure, policy makers and industry will need to address environmental justice concerns—particularly those associated with new industrial development and with potentially prolonging operation of existing polluting facilities—in any additional infrastructure deployment.

Carbon Utilization

Several industrial and manufacturing processes can utilize captured carbon before—or instead of—permanent storage. If carbon is not ultimately stored in a permanent location (e.g., geologic formations or long-lived building materials), the utilization method may avoid or delay emissions but is not a permanent method of carbon removal.[34] The National Academy of Sciences identifies three pathways of carbon utilization: chemical

conversion to fuels and chemicals; mineralization into inorganic construction materials; and biological conversion by photosynthetic organisms (e.g., algae).[35]

California policy landscape for engineered carbon removal

While the California market for engineered carbon removal technologies—and thus the full scope of regulatory needs—is still developing, a group of state agencies and policies responsible for emission reduction targets, energy planning, oil and gas permitting, and natural resource management populates the regulatory landscape. These include:

- **Senate Bill 100** (De León, Chapter 312, Statutes 2018), which sets a state policy of achieving 100 percent zero-carbon electricity by 2045, for which the California Air Resources Board is developing engineered carbon removal compliance plans.[36]
- **The state cap-and-trade program,** which sets state carbon emissions credit requirements under Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) and Senate Bill 32 (Pavley, Chapter 249, Statutes 2016), for which the Air Resources Board is also developing engineered carbon removal compliance plans.[37]
- **The California Environmental Quality Act**, which requires analysis and mitigation of environmental impacts of projects approved or funded by state and/or local lead agencies (with implementation guidelines prepared by the Governor's Office of Planning and Research), and which can prove particularly complex for large industrial-scale projects.[38]
- **Underground injection control regulations** at the federal level (including Class II oil and gas wells and Class VI geologic sequestration wells, overseen by the US Environmental Protection Agency under the Safe Drinking Water Act); state level (overseen by the California Geologic Energy Management Division); and local level (overseen by regional water quality control boards).[39]

Financial incentives and programs driving the engineered carbon removal market

The Federal 45Q Tax Credit

Federal and state financial incentives are available for certain engineered carbon removal projects. At the federal level, Section 45Q of the Internal Revenue Code establishes a tax credit for carbon capture and storage at industrial facilities or direct air capture facilities.[40] Congress extended and modified the 45Q tax credit to include carbon capture and sequestration through the *Furthering carbon capture, Utilization, Technology, Underground storage, and Reduced Emissions Act* (FUTURE Act), which was passed with bipartisan support as part of the 2018 omnibus budget bill.[41] The federal 45Q tax credit provides credits of $10-$35 per ton of carbon stored for enhanced oil recovery projects and $20-$50 per ton for saline and other geologic storage projects. The value of the credit per ton of carbon captured varies depending on the operational date of the capture equipment, as well as whether the carbon is utilized. Credit amounts are higher for carbon secured in geologic storage and not used for enhanced oil recovery or other secondary uses. Eligible projects must begin construction before 2024, which presents a barrier for certain projects that require longer time horizons to plan and execute (discussed in more detail below). Advocates and developers are calling for an extension of the deadline so that more projects may take advantage of the 45Q tax credit and continue strengthening the industry.[42]

The California Low Carbon Fuel Standard

California's Low Carbon Fuel Standard, administered by the California Air Resources Board, is intended to reduce transportation-related greenhouse gas emissions and local air pollutants by

incentivizing the use of lower carbon intensity fuels and transport options. Regulated entities, such as fuel producers or refiners, must achieve a carbon intensity below an established benchmark to earn credits, which they then trade in private transactions to meet their regulatory obligation (meaning the credit price is set by the market based on the amount of fossil fuel sold in the state, subject only to the Air Resources Board's price ceiling). Fuels with a carbon intensity above the benchmark incur a deficit. The program also includes standalone credit-generating activities not associated directly with transportation fuel carbon intensity; these features of the Low Carbon Fuel Standard help to ensure a well-functioning credit market while providing incentives for selected other greenhouse gas reduction mechanisms, including carbon capture and sequestration. In 2018, the Air Resources Board added a Carbon Capture and Sequestration Protocol to the Low Carbon Fuel Standard, which allows for credit generation by carbon capture and sequestration projects associated with fuel consumed in California, as well as direct air capture projects not associated with any fuel production.[43] Credits are issued only to projects that sequester carbon dioxide for at least 100 years, and all projects must contribute a portion of their credits towards a buffer account.[44]

In combination, the federal 45Q tax credit and California's Carbon Capture and Sequestration Protocol attribute a monetary value to carbon captured, stored, and utilized, thus incorporating some of the positive externalities associated with avoiding or removing carbon dioxide emissions. These two incentives help to drive market demand for engineered carbon removal technologies and create conditions conducive to deployment of the technologies. However, additional opportunity remains to encourage the development and deployment of engineered carbon removal technologies, including outside of the Low Carbon Fuel Standard and transportation sector.

III. VISION FOR ENGINEERED CARBON REMOVAL IN CALIFORNIA'S CLIMATE PROGRAM

Participants at the November 2020 convening described a vision for how California's climate program, particularly the statewide carbon neutrality goal by 2045, could incorporate engineered carbon removal projects. These projects should:

- **Enhance, not interfere with, efforts to transition energy** from fossil fuels and other polluting fuels to non-greenhouse gas emitting technologies.
- Achieve **as much carbon removal as feasible**, annually and cumulatively, using the 2045 carbon neutrality goal as a floor rather than a ceiling, given the urgency of climate change.
- **Advance a just transition** for workers and host communities, reflecting an understanding of economic impacts and the need for sustaining job opportunities.
- **Avoid any carbon leakage** from underground storage sites.
- Be sited and managed with the goal of **preserving and enhancing important ecosystems and working lands** that can function as natural carbon sinks.
- **Achieve emission reductions across multiple sectors**, including the power and industrial sectors.
- **Address environmental impacts** on disproportionally burdened communities, while ensuring that projects do not perpetuate existing harms or create new ones.

To support this vision, policy makers could bolster investments in research and development, coordinate and clarify regulatory processes, address environmental and environmental justice concerns, and support demonstration and pilot projects to improve scalability and affordability. Early project deployment could help surface crucial obstacles and barriers that policy makers and stakeholders can address in the short term, which could pave the way for more innovative technology development in the long run. The goal would be to achieve scale that begins statewide in California, then becomes regional in appropriate states around the country, and then national and beyond, much as California has helped pioneer other clean technologies like solar PV and electric vehicles.

IV. BARRIERS AND PRIORITY POLICY SOLUTIONS

Participants at the November 2020 convening identified a range of barriers to achieving this vision for deployment of engineered carbon sequestration technologies. These barriers focused on four central themes:

- **A lack of clear statewide strategy** on engineered carbon removal creates uncertainty for project developers and government actors
- **A lack of coordinated, clear, and centralized permitting** for engineered carbon removal adds complexity and cost to project development
- **A lack of public awareness of engineered carbon removal needs and benefits** impedes public confidence and slows project development
- **Financial uncertainty** clouds the engineered carbon removal investment path

This section describes those barriers in detail and highlights the top-priority policy solutions participants identified to overcome them.

Barrier: Lack of a clear statewide strategy creates uncertainty

The lack of a statewide strategy for engineered carbon removal creates uncertainty for developers, communities, financial institutions, and other parties interested in deployment of projects. Participants underscored that the state of technology may be less of an impediment than the regulatory landscape in terms of project development. While several state agencies are taking important action on engineered carbon removal, including the California Air Resources Board and Geologic Energy Management Division, convening participants expressed concern that the patchwork nature of these efforts hinders progress. Expanding and aligning California's existing engineered carbon removal efforts and establishing a cohesive statewide strategy would provide certainty to developers and investors, facilitating project deployment and enabling progress towards carbon neutrality targets.

Engineered carbon removal technologies are in various stages of development and feasibility, with mitigation-focused solutions like carbon capture, utilization, and storage closer to commercial-scale operation than most negative emissions technologies, like direct air capture. Because the technologies under consideration are new to California, and indeed new to most of the world, California's regulatory landscape has yet to incorporate engineered carbon removal technologies. The adoption of emerging technologies faces inherent delays in regulatory and governance structures. However, participants identified aspects of the state's current response that could be improved or changed, including:

- **Disconnected regulatory landscape.** Existing barriers include an incomplete or inconsistent integration into existing programs and policies, a lack of alignment between state agencies' efforts, a burdensome permitting process requiring communication with several different agencies, and a lack of public awareness about ongoing work at the state level.
- **Discrepancy between climate goals and urgency for technology deployment.** Engineered carbon removal must be adopted if California is to meet its long-term climate goals, but the state does not place sufficient emphasis on these technologies to enable timely, widespread deployment.
- **Lack of unified vision and strategy.** Demand exists for a central strategy pertaining to engineered carbon removal technologies, as well as clear direction regarding the state's vision for these technologies.

- **Lack of clear support or momentum.** A lack of a robust statement of support from the Governor's Office leads to uncertainty about investments, weak interest in pursuing projects, and a gap in the market for technologies.

Solution: The Governor or the state legislature could establish a single point of contact for engineered carbon removal policies and projects.

Many convening participants identified the creation of a single government entity responsible for overseeing engineered carbon sequestration as their top priority action. Participants sought clarity regarding which agencies were responsible for different components of the development process, from supporting research and development to siting pipeline transportation, among several other critical regulatory needs. The Governor's Office could address this concern by entrusting a single point of contact (which could take one of several forms, as described below) with responsibility over projects, programs, and policies related to engineered carbon removal. This point of contact could coordinate with other state agencies, as well as federal and local government entities (e.g., U.S. EPA) to ensure permitting and oversight is done in a thorough yet timely fashion. The selected or created entity could ensure that state policies consider engineered carbon removal appropriately and could oversee analysis and data collection to inform future regulatory efforts. The entity would ensure incorporation of environmental justice concerns into projects, policies, and overall regulatory frameworks, while improving public communication about the state's ongoing engineered carbon removal work. A sole point of contact could increase efficiency and improve certainty for project developers. Some participants expressed preference for an interagency group, rather than a single agency with sole jurisdiction, to minimize risk of internally conflicting mandates and incentives. The point of contact could take the form of an:

- **Agency**: designating a lead state agency (or perhaps two) with engineered carbon removal jurisdiction (either an existing state agency or newly created agency)
- **Interagency Group**: establishing an interagency commission or working group tasked with aligning efforts across multiple agencies
- **Individual**: appointing a "carbon removal czar"—an individual charged with integrating and guiding state efforts

Solution: The Governor could issue an executive order establishing the state's commitment to engineered carbon removal technologies and establishing clear targets.

Participants noted that a clear commitment from the Governor's Office could bolster engineered carbon removal market development and technology uptake across several industries in California. Uncertainty about the state's long-term vision for engineered carbon removal can create lackluster project investment, especially for projects with long planning horizons that need certainty for years, if not decades, into the future. Clear acknowledgement of carbon capture and sequestration and negative emissions technologies as critical components of California's climate change goals could signal that these projects are top priorities for the state. Through an executive order, Governor Newsom could address the role of engineered carbon removal technologies in achieving California's carbon neutrality goals and could increase ambition to reach net-negative emissions, not just net-zero emissions. An executive order establishing a specific goal for engineered carbon removal could help motivate efforts throughout the state. For example, Executive Order B-48-18's goal of putting five million or more zero-emission vehicles on roads by 2030 has helped catalyze regulatory and policy efforts statewide, helping California extend its leadership position in the electric vehicle market.[45]

The Governor's Office also could consider supporting a demonstration project that captures emissions from a difficult-to-mitigate sector while maximizing benefits for a host community through local air quality improvement and creation of employment and training opportunities for local residents. Participants suggested cement manufacturing as a primary candidate for a pilot project because it generates a significant amount of emissions and also results in a product that can store carbon dioxide for decades, if not centuries.[46] Several cement facilities that meet eligibility criteria for capture, some of which are located near suitable permanent geologic storage, could be candidates for pilot project funding, potentially with cap-and-trade proceeds (provided the funds benefit disadvantaged communities, concurrent with the requirements of Senate Bill 535 and Assembly Bill 1550).[47]

Solution: State energy, air quality, and environmental planning agencies, with supportive legislation or executive direction, could develop a clear strategy regarding the role of engineered carbon removal in California's broader climate change strategy.

Participants encouraged the state energy, air quality, and natural resources agencies to align priorities and issue a clear strategy detailing the role of engineered carbon removal in California's climate goals and its transition away from fossil fuels. The California Air Resources Board, along with the Energy Commission, Public Utilities Commission, Governor's Office of Planning and Research, and other agencies hold substantial statutory authority to promote engineered carbon removal deployment. In some cases they are considering ways to integrate the technology into plans and programs; the Air Resources Board is already beginning to consider how carbon removal will fit into California's carbon neutrality strategy and, as previously noted, issued a Low Carbon Fuel Standard credit protocol in 2018.[48] But legislative direction to develop an integrated approach identifying the role of engineered carbon removal across multiple policies and industries could signal a clear sense of urgency and help mobilize resources towards a shared vision. Several participants underscored the possibility that California could achieve carbon neutrality before 2045 if adequate emphasis is placed on engineered carbon removal technologies in the near term. Specifically, the participants stated that carbon removal action must begin now if California is to achieve its 2045 targets and that increased ambition could expedite the achievement of those targets. Carbon capture and sequestration deployment in the immediate near term can reduce emissions while paving the way for negative emissions technologies that need more time to reach commercial-scale deployment. The governor or legislature could increase the ambition of near-term goals (e.g., 2025 or 2030) on the pathway to 2045 carbon neutrality goals by addressing engineered carbon removal directly. Potential actions include:

Develop a statewide engineered carbon removal strategy.

Participants encouraged California to develop an overarching engineered carbon removal strategy detailing the state's vision for these technologies in the context of broader climate change and environmental goals, including economic development and environmental justice goals in disadvantaged areas and host communities, potentially through an executive order clearly outlining the responsibilities and targets of each relevant agency. A shared vision could motivate investment, research, and action. The strategy could provide a comprehensive picture of engineered carbon removal technologies across multiple sectors and applications, from industrial sources and power plants to transportation fuels and stand-alone negative emissions technology facilities. The strategy could also integrate with state planning for fossil fuel operations and transition, including oil and gas extraction and natural gas-fired electricity, which will have significant implications both for physical storage and transportation infrastructure and for the viability of making long-term investments in carbon capture for legacy power generation facilities. In addition, participants described a need for new policies and guidance specific to engineered carbon removal. The state could develop policies

that accelerate uptake of engineered carbon removal technologies, establish specific numeric targets and timelines, and reduce startup barriers while addressing the concerns of affected and host communities regarding local impacts.

Update existing regulations, programs, and processes.

Several existing policies and programs could be updated to include engineered carbon removal technologies and align these technologies with the state's goals. In some cases, legislative action would be required to initiate the relevant updates. Authorities overseeing updates include the California Air Resources Board, the California Energy Commission, the California Public Utilities Commission, and the Governor's Office of Planning and Research. Participants identified the potential need for new legislation to update the California Environmental Quality Act (CEQA) guidelines and suggested that the Air Resources Board update the cap-and-trade program under Assembly Bill 32, Senate Bill 32 and Assembly Bill 398 (E. Garcia, Chapter 135, Statutes of 2017), and electricity decarbonization by 2045 under Senate Bill 100. Participants also urged inclusion of engineered carbon removal technologies in the California Energy Commission's Integrated Energy Policy Report, a biennial report that describes the state's energy landscape and offers policy recommendations. The Air Resources Board intends to include carbon capture and sequestration in its 2022 Scoping Plan. The Air Resources Board also issued the Carbon Capture and Sequestration Protocol under the Low Carbon Fuel Standard, an important step towards integrating engineered carbon removal technologies with existing emission reduction mechanisms; however, some participants stated that project developers are experiencing challenges using the protocol and suggested that some modifications (discussed later in this report) could help to strengthen the its effectiveness. Others encouraged the state to focus on deployment in the power sector broadly by requiring a certain percentage of fossil fuel power portfolios to incorporate carbon capture and storage. Several participants envisioned the creation of a market that enabled power purchase agreements for carbon capture and sequestration, similar to how the Renewables Portfolio Standard created market support for renewable energy.

Improve communication about existing and forthcoming state efforts.

Several state agencies are engaged in engineered carbon removal efforts, but communication could be improved between agencies and the public, especially stakeholders like researchers, policy advocates, communities that will host or potentially be impacted by new projects, or others with interest in these technologies. Agencies could also strengthen communication and coordination among themselves to improve efficiency. One barrier highlighted during the convening was that some state and private sector leaders may not be aware of the Air Resources Board's progress, including the carbon capture and sequestration protocol for the Low Carbon Fuel Standard; eligibility as a zero-carbon resource under Senate Bill 100; modeling demonstrating that engineered carbon removal is required to achieve carbon neutrality goals; and plans to include carbon capture and sequestration across multiple sectors in the 2022 Scoping Plan. Additional communication about these actions, especially accessible materials for non-technical audiences and affected communities, could help advance conversation among stakeholders in the state.

Barrier: Lack of coordinated, clear, and centralized permitting adds complexity and cost to project development

Because so many engineered carbon sequestration technologies are new, government agencies at multiple levels have not yet developed clear, consistent, and efficient policies for permitting them. In addition, the technologies can straddle multiple jurisdictions with varied

environmental impacts, including from pipelines, surface facilities, and underground injection sites. Permitting therefore requires project developers to navigate various state and federal agencies that are not always coordinated in their timelines or requirements. In some cases, developers are unclear on these various agencies' roles and overlapping authorities, while transparency can be lacking for the public. As described above, at the state level, no single agency is responsible for permitting and regulatory enforcement, leading to uncertainty and costs.

Solution: The Governor and the state legislature could direct state agencies to coordinate and develop a centralized, master permitting process for engineered carbon removal projects, taking into account environmental justice and other community concerns.

The governor could direct the single point of contact entity described above to create a master permitting process for engineered carbon removal projects, with legislative support as needed to consolidate existing legal authority over permitting for air quality, water quality, underground injection, land use, and other issues implicated by the projects. The goal would be the development of a unified permitting process with a reliable timeline for completion, such as 24 months. The process could identify all the necessary permits and agencies involved in engineered carbon removal projects, in order to develop a single point of contact for project developers on permitting information. It could include a checklist and workflow process for a more efficient permitting process, integrated with federal and state financial incentives and their respective timelines. The point of contact could also identify applicable federal agencies involved and develop a unified vision and coordination plan. The resulting regulations could first apply during an interim "test period" for pilot projects, in order to ensure that the processes are functional before applying to all projects statewide. In addition, the point of contact could identify the necessary training and capacity building required at agencies for staff to learn more about these new technologies and the various modeling required to assess their impacts. Through this centralization and bolstered staffing, California could also potentially participate in multi-state discussion groups or carbon capture coalitions to share and learn best practices on permitting.

Solution: State and federal government agencies could explore opportunities for memoranda of understanding/agreement to coordinate permitting and enforcement procedures.

In place of or in concert with a centralized permitting process, state leaders could consider memoranda of understanding (MOU) or agreement (MOA) to develop concrete procedures for permitting coordination. MOUs and MOAs can assist agencies with planning and information-sharing to coordinate permits issued to the same projects while exercising their existing authority under state law. An example is an existing memoranda of agreement between the State Water Resources Control Board and the California Geologic Energy Management Division (CalGEM) that facilitates information sharing, reporting requirements, and enforcement activities, among others, for underground injection control (UIC) Class II wells.[49] Another example could be the California Marine Renewable Energy Working Group under the California Ocean Protection Council, which in part seeks to address uncertainties in regulatory processes for marine renewable energy projects in California.[50] Once in place, these memoranda can allow for permits to be issued more quickly and with less cost to agencies and developers alike, while offering more transparency to the public. However, some participants noted these memoranda can take time to develop, given the complexities and review processes. As a result, the state could explore such opportunities in the near term to begin the process.

Solution: California agencies could identify corridors and sites in advance that would be prime areas for engineered carbon removal facilities and associated infrastructure, in order to conduct advance, pre-permitting review, while incorporating and analyzing land use impacts on disadvantaged communities and critical ecosystems.

Certain geologic sites and corridors may be particularly well suited for engineered carbon removal investments. Working with industry, affected communities and other stakeholders to help map these sites, agencies could conduct pre-evaluation of these sites, such as through California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) environmental review. Evaluating the impacts of engineered carbon removal technologies and their associated infrastructure through a cross-agency, -sector, and -technology approach could help to avoid adverse impacts to biodiverse habitats, natural and working lands, and people. While energy decisions typically are made at a statewide or regional scale, the impacts of energy infrastructure occur on a local scale.[51] One potential methodology for assessing impacts is the planning framework developed by Wu, et al. to determine the land areas affected by different energy planning scenarios using environmental exclusions data, site suitability modeling, capacity expansion modeling, optimal site selection and transmission modeling, and environmental impact assessment.[52] Another potential (though time- and resource-intensive) model could be the Desert Renewable Energy Conservation Plan (DRECP), in which California energy and natural resources regulators sought to work with the federal government to map federal lands in the state suitable for renewable energy development and streamlined environmental review.[53] In 2016 CLEE and Conservation Biology Institute also led a stakeholder-based mapping project for utility-scale solar photovoltaics in California that could similarly be utilized for outreach on engineered carbon removal project siting.[54] Through a similar process, engineered carbon removal developers could be encouraged to site projects in these consensus, stakeholder-based locations if much of the environmental permitting and land use conflicts have already been addressed.

Solution: The state legislature could clarify ownership of underground pore space for carbon storage.

Pore space refers to the underground areas not occupied by solid matter, where injected carbon would be sequestered. California property rights currently create uncertainty about what entity or individual owns the rights to this underground space, particularly when different parties own the surface land and underground mineral rights. At the same time, the California Air Resources Board requires that a carbon capture project operator show proof of exclusive right to use the pore space in order to obtain Low Carbon Fuel Standard credits.[55] The state legislature could clarify which party has pore space ownership through legislation, using models from states like Wyoming, Montana, and North Dakota, which specify that surface owners own the pore space.[56]

Solution: The state legislature could direct the California Governor's Office of Planning and Research to develop guidelines under the California Environmental Quality Act (CEQA) for permitting and lead agency guidance.

The California Environmental Quality Act (CEQA) requires environmental review of projects subject to discretionary approvals, in order to determine feasible mitigation of any anticipated significant impacts. The Office of Planning and Research (OPR) drafts the implementing guidelines for the law. Participants noted that engineered carbon removal developers and state agencies currently lack clarity on which agency should be the lead for California Environmental Quality Act review purposes. Participants recommended that the state legislature direct the Office of Planning and Research to provide greater clarity on which agency should be the lead

for these projects, if not the local government with jurisdiction. The Office of Planning and Research could also provide guidance on suitable mitigation measures and how local climate action plans could incorporate guidance for these projects. The state agency coordination team discussed above could help develop such recommended guidance.

Solution: California could seek primacy status from the federal government for granting Class VI injection well permits.

CalGEM could seek primacy status for permitting Class VI deep saline reservoir storage wells from the U.S. Environmental Protection Agency (EPA), should state leaders and stakeholders feel this role would ensure improved deployment for California. Primacy would give the state primary enforcement responsibility and provide industry with more regulatory certainty, particularly as to where the carbon should be stored and timelines for completion. EPA would still retain oversight and enforcement if the state agency failed to act adequately. CalGEM secured similar status for Class II wells, used for enhanced oil recovery, in 1983.[57] Class VI wells in California otherwise remain under the permitting authority of EPA Region 9. Wyoming and North Dakota have obtained primacy from EPA, although the process took three and five years, respectively.[58] Texas may soon seek primacy, with potential legislation to consolidate approvals within the state's railroad commission.

Barrier: Lack of public awareness of engineered carbon removal needs and benefits impedes public confidence and slows project development

While the scientific community is increasingly reaching consensus that some level of engineered carbon removal will be needed to achieve California's carbon neutrality goals and limit global temperature increases, a lack of awareness and acceptance—among government leaders and the public—can slow the development of pilot projects and broader strategies. Participants identified a number of public awareness and acceptance barriers including:

- **Public misunderstanding** of the need for engineered carbon removal strategies, the function and status of key technologies, and their potential impacts and mitigation strategies, slowing statewide momentum for project deployment;
- **Community concern over safety and environmental impacts**, generating local opposition to project siting;
- **Environmental and community concerns** regarding the potential for engineered carbon removal to prolong polluting fossil fuel operations;
- Questions about **state agency capacity**, staffing, and training to effectively and efficiently conduct permitting, oversight, and regulation; and
- A **lack of non-governmental and advocacy organizations** focused on the issue, limiting the spread of accurate knowledge and pressure on state leaders to enact needed policies.

Addressing these barriers will require enhanced communications efforts, greater coordination among regulatory agencies, and high-profile demonstration projects to build public support.

Solution: The California Geologic Energy Management Division, Air Resources Board, Energy Commission, State Water Resources Control Board, Natural Resources Agency, Environmental Protection Agency, and Governor's Office of Planning and Research (possibly in partnership with a third-party nonprofit or university) could host a series of community dialogues on engineered carbon removal.

Engineered carbon removal projects will present some communities with major infrastructure investments, employment opportunities, and environmental impact considerations. Some state residents more broadly may have questions around new technology and the evolution of state energy supplies. To educate the public and local leaders about the needs, benefits, and potential or perceived risks of engineered carbon removal, the key state agencies leading the planning and permitting process (or potentially the single point of contact entity described in the previous section) could organize a "road show" for dialogue with and presentation of key information to relevant communities. Topics of focus could include:

- How engineered carbon removal factors into California's carbon neutrality and negative emissions goals;
- How the various technologies (such as carbon capture and sequestration, bioenergy with carbon capture and sequestration, and direct air capture) function, how they differ, and where they might be deployed throughout the state;
- Potential employment and job training opportunities;
- Potential risk mitigation and communication frameworks;
- The structure of state and local authorities responsible for project review and approval; and
- Opportunities for community participation on both the overall policy framework and individual projects through public review and comment processes, including the California Environmental Quality Act.

This program could follow a general template with local adjustments depending on the likely project mix, community demographics, environmental concerns, and employment needs in particular areas. The state agencies could work with project developers and technology providers to craft possible development scenarios; environmental and community based-organizations to build participation strategies; and community colleges and regional media outlets to assist with outreach. Leaders could look to the California Air Resources Board's AB 617 Community Air Protection Program—which implements community air monitoring and emission control programs in high-priority areas throughout the state—for examples of targeted outreach and education in priority communities, cooperation with community-based organizations, and multilingual communications as an initial and ongoing step in a broader state planning process.[59] Since engineered carbon removal projects do not address the same public health issues as the community air monitoring program and come with a range of perceived risks, state leaders and outside experts will have to be particularly clear about the projects' potential community employment and air quality benefits, particularly for oil and gas communities that are facing a looming economic transition. The Diablo Canyon nuclear power plant decommissioning plan, which was co-developed by utility, labor, environmental, and community stakeholders before the legislature codified it, could serve as a model for development of an agreed just transition pathway for workers and communities.[60] Leaders could coordinate with, or integrate findings from, the effort led by the California Environmental Protection Agency under the Budget Act of 2019 to identify fossil fuel supply and demand reduction strategies, which includes carbon removal strategies and is focused on the impacts to low-income communities of phasing out fossil fuel production.[61] The legislature could also make a similar appropriation from cap-and-trade funds to support this education and outreach effort.

Solution: The state legislature could direct the California Energy Commission, Geologic Energy Management Division, and/or State Lands Commission to sponsor one or more demonstration projects using new appropriations or cap-and-trade proceeds.

Participants emphasized the value of high-profile demonstration projects to highlight the feasibility and potential benefits of engineered carbon removal efforts to build public acceptance. Providing state funding (either through new appropriations or cap-and-trade proceeds, if the projects support disadvantaged communities) and policy support for one or more of these early-stage projects would alleviate the significant financing barriers currently in place and allow state and local leaders to prove the viability of permitting processes. Furthermore, selecting projects with clear local air quality benefits and job opportunities would prove community value and build support.[62] A recent study identified ten California facilities with co-located energy generation and high-quality carbon dioxide storage resources (meaning no additional transportation infrastructure would be needed), able to reduce carbon emissions by over five million tons per year, that could serve as top candidates for demonstration projects based on feasibility, cost minimization, and potential templates for California Environmental Quality Act compliance.[63] State-sponsored demonstration projects in Norway, Canada, and Illinois (funded by the U.S. Department of Energy) have been successful in proving technological and permitting feasibility, as well as identifying knowledge and regulatory gaps. Within California, the success of the Energy Commission's Electric Program Investment Charge Program and Natural Gas Research Program show the value of state-supported research and development projects, and the latter could potentially offer funding for carbon capture and sequestration-related project development.[64] As demonstration projects are selected and deployed, state leaders could build them into the communications strategy described above.

Solution: The California Energy Commission, in consultation with the Air Resources Board, could develop and publish a state engineered carbon removal project opportunity map, including an analysis of potential local and regional benefits and risks.

Participants noted that engineered carbon removal technology is often closely associated with coal plants and fossil fuel production—drawing connections between climate pollution and environmental injustice in vulnerable communities, rather than emission mitigation and local benefits. To clarify promising locations where engineered carbon removal projects may be deployed and promising technologies in California, the Energy Commission and Air Resources Board could publish a project "opportunity map" that identifies potentially feasible sites, projects currently planned or in development, the technologies they could use, and their anticipated emission benefits. The map could demonstrate the extent to which engineered carbon removal projects will co-locate with existing fossil fuel production, energy generation, and industrial sites, mitigating their current emissions; and, if layered with CalEnviroScreen's display of pollution impacts and vulnerability, could inform project prioritization based on environmental justice goals. To this end, and to determine potential employment needs and benefits, collaboration among state agencies and community groups in potential host areas would be essential. It could also incorporate areas of important ecosystem services and natural carbon sequestration. (In addition, the map could accompany or integrate with the advance-review priority corridor identification process described in the previous section.) This effort could be accompanied by targeted stakeholder outreach in communities near potential capture and sequestration sites.

Barrier: Financial uncertainty clouds the engineered carbon removal investment path

In addition to (and as a result of) state strategy, public acceptance, and permitting barriers, participants emphasized that project developers currently lack the long-term financial certainty they need to invest at the speed and scale needed to achieve state goals. The long-term availability of two financial incentives in particular—the California Low Carbon Fuel Standard and the federal 45Q tax credit—raised the most significant questions for investment planning. Other financial barriers included the lack of clear state plans on two related issues: when and how the state plans to phase out the existing natural gas system, which could play a key role in facilitating carbon removal and sequestration; and where and how to locate carbon transmission pipeline infrastructure, which will be essential to develop removal projects that lack on-site storage. Legal issues around long-term liability, permanence of storage, and the small size of individual land parcels in some potential project areas also complicate the financial picture.

Solution: The California Air Resources Board could extend the Low Carbon Fuel Standard carbon intensity target beyond 2030 and consider future program adjustments that could support project financing.

In 2018, the California Air Resources Board took two actions critical to the engineered carbon removal industry: it adopted the Carbon Capture and Sequestration Protocol under the Low-Carbon Fuel Standard, which established standards for carbon removal projects to generate Low Carbon Fuel Standard credits; and it extended the program through 2030, establishing another decade of certainty for these valuable incentives.[65] Carbon removal credits are not a part of the Low Carbon Fuel Standard core credit market for transportation fuel carbon intensity (rather, they are generated extrinsically to provide liquidity and support greenhouse gas reduction efforts, functioning similarly to offsets). But since credit values can approach $200 per ton of carbon, they provide a key source of revenue and financial certainty for a developing market.[66]

Engineered carbon removal projects are developed on 10+ year financial planning horizons, meaning the long-term availability of Low Carbon Fuel Standard credits may be vital to getting the industry off the ground in California. The Low Carbon Fuel Standard currently sets a static carbon intensity benchmark for 2030 and subsequent years, which could lead to a significant credit price drop after that date as zero-emission vehicle manufacturing continues to accelerate.[67] Low Carbon Fuel Standard credits are available for carbon capture and sequestration associated with production of transportation fuel sold in California, as well as direct air capture projects regardless of fuel association.

While Air Resources Board leaders almost certainly plan to extend the Low Carbon Fuel Standard beyond 2030 by continuing to decrease the carbon intensity benchmark, particularly given the program's substantial success in driving the state's emission reductions, the lack of legal certainty on long-term credit value can limit creditor willingness to offer favorable financing for carbon removal projects. Although the purpose of the Low Carbon Fuel Standard is to reduce the carbon intensity of transportation fuels used in California, and not to support carbon removal projects, committing to extend the program would nonetheless have the beneficial effect of ensuring developers' ability to finance projects.[68] By directing the Air Resources Board simply to extend the program with declining post-2030 benchmarks, the legislature could achieve a long-standing policy goal with respect to transportation emissions while also creating much-needed certainty and affording the agency appropriate latitude to make necessary adjustments to program structure, as it did in the 2018 extension.

Doing so, however, could raise the risk that carbon removal credits could flood the market and reduce regulated entities' need to directly reduce transportation fuel carbon intensity.[69] Thus, in order to ensure California's continued progress in reducing fuel carbon intensity, some

experts have proposed limiting Low Carbon Fuel Standard eligibility to certain carbon removal projects, such as those that have a direct link to transportation fuel production—a step that the Air Resources Board may want to consider as the carbon removal market begins to develop.[70]

Some participants also emphasized that while the adoption of the Low Carbon Fuel Standard Carbon Capture and Sequestration Protocol has brought substantial financial support to the market for engineered carbon removal projects, certain other program features can inhibit optimal project financing. These features are designed to ensure permanence of sequestration, which is vital to achieving any project's carbon removal purpose and is particularly important in light of the protocol's primary purpose of reducing fuel carbon intensity (and avoiding dilution of the program's effectiveness). However, if the Air Resources Board extends the Low Carbon Fuel Standard and the protocol in the future, and if it is able to determine that reducing the protocol's stringency would neither create significant risk of leakage nor significantly dilute the credit market, it could consider adjusting the following provisions:

- The protocol's requirement that projects sequester carbon for at least 100 years in order to qualify for credits is appropriate from an emissions mitigation perspective but presents a barrier for project financing by increasing the financial uncertainty of a project (and creating potential financial liabilities) long beyond the typical period of financing, discouraging private investment.[71] As technology develops and sequestration permanence becomes more certain, the Air Resources Board could consider adjusting this requirement, perhaps to match the 50-year standard applicable to federal Class VI injection wells, to align better with financing needs.[72]
- The protocol's buffer account, which requires contribution of additional credits (between 8 and 16 percent of total credit value) based on a project's financial, social, management, site, and well integrity risk, provides valuable program assurance for long-term storage risks but also presents a limitation from the perspective of project financiers.[73] As the market grows and developers gain financial security, Air Resources Board leaders could consider allowing them to reduce their buffer account obligations by making contributions to an approved private risk-sharing pool, purchase insurance, or craft a similar lower-cost shared risk management structure to cover catastrophic leak risks.[74]
- The Low Carbon Fuel Standard also requires that developers obtain third-party verification of carbon storage to determine its permanence.[75] As a result, developers need to spend significant resources on certification even before they have assurances that they can receive permits for the project. To harmonize this requirement with permitting timelines, Air Resources Board leaders could consider a rulemaking or revised guidance to create a third-party process to certify projects simultaneously with permitting, to avoid undue risks to developers. The board could identify an entity to perform this scientific validator function in advance, such as the U.S. Geological Service or national labs or other neutral third party or broker. The California Geological Survey (CGS) or State Lands Commission could also potentially play this role by determining state mineral resources or state or federal lands that could be suitable for a comprehensive demonstration project.

Carbon removal could play a key role in helping the state develop a zero-carbon transportation system, particularly if the state's transition to electric vehicles is slower than hoped. But the support that the Low Carbon Fuel Standard crediting protocol provides to carbon removal project development is ultimately a secondary benefit of the program, and each of these protocol modifications, as well as Low Carbon Fuel Standard extension in general, would need to be undertaken in the broader context of preserving the program's effectiveness in reducing transportation fuel carbon intensity reduction.[76]

Solution: The California Energy Commission and Public Utilities Commission could collaborate with the Geologic Energy Management Division, Air Resources Board, and other agencies to develop a coordinated approach to transitioning natural gas infrastructure to carbon transportation infrastructure.

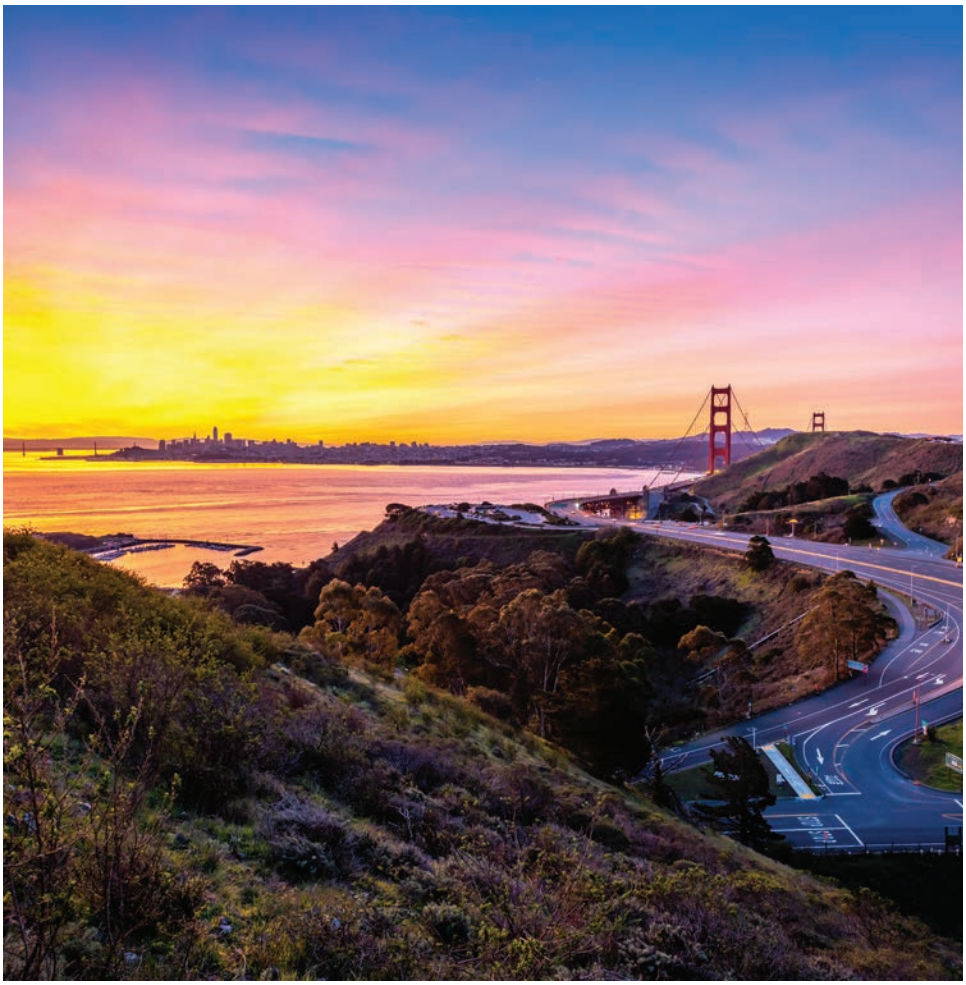
As California begins to support commercial carbon removal efforts at scale, the state will simultaneously be engaged in efforts to facilitate decarbonization by transitioning away from natural gas in power generation and building energy consumption. This transition raises a number of challenging equity, financing, and safety questions that parallel those raised by engineered carbon removal project deployment.[77] But the question of pipeline infrastructure ties the two issues together directly: a natural gas transition will likely involve the decommissioning and removal of portions of the state's gas pipeline infrastructure, while some of this infrastructure (or, at a minimum, space and rights-of-way) could be useful to transport carbon from emitting sources to storage sites and green hydrogen to end users.[78] (Almost all large-scale removal projects currently in operation in the US and around the world rely on some pipeline infrastructure.[79]) While the two processes are distinct, the agencies managing them—including, centrally, the California Energy Commission—could develop a coordinated approach to pipeline infrastructure to ensure that decommissioning decisions incorporate engineered carbon removal priorities and maximize potential opportunities for cost savings.

Solution: Congress could modify the 45Q tax credit to extend beyond the current 12-year duration and/or extend the construction deadline of Jan. 1, 2024.

The federal 45Q tax credits ($10-$35 per ton for enhanced oil recovery and $20-$50 per ton for saline and other geologic storage) create the second significant financial incentive for engineered carbon removal projects.[80] The 45Q program has been instrumental in launching commercial carbon removal efforts in the US, with over 20 projects announced following its 2018 extension.[81] However, under current law the credit is available only to projects that commence construction before January 1, 2024, a deadline that may effectively exclude any projects that have not begun initial engineering design and permitting processes by the end of 2020. This cut-off date potentially excludes millions of tons of engineered carbon removal from projects that cannot commence construction in time despite overall viability.[82] Without clarity on access to credits for projects that begin construction after 2024, developers have limited certainty on the financial viability of proposed projects and limited ability to obtain favorable financing that is premised in part on the ability to monetize the credits. Access to credits is particularly valuable for a nascent industry like engineered carbon removal; the federal investment tax credit for solar generation and production tax credit for wind generation, which have reached near-price parity with competing generation technologies, are still seen as vital by many industry members. To ensure long-term credit availability and predictability for financing purposes, Congress could extend the 45Q eligibility deadline.

V. CONCLUSION: CALIFORNIA'S OPPORTUNITY TO LEAD ON THE URGENT NEED FOR GLOBAL NEGATIVE EMISSIONS

The engineered carbon removal technologies covered in this report, as well as future innovations that may one day become viable, are increasingly urgent as the severity of climate change becomes clearer and the window for averting some of the worst impacts through greenhouse gas emission reduction closes. California is well positioned to help pioneer their deployment and help bring them to global scale, as the state has helped accomplish with so many crucial zero-emission technologies and programs over the years, from renewable energy to energy storage and electric vehicles. However, to become a global leader in engineered carbon removal, the state will need to address the permitting, financing, environmental justice, and other challenges that may hinder these projects. The recommendations included in this report can assist policy makers and stakeholders to ensure that engineered carbon solutions that advance carbon neutrality and net-negative emission goals become both achievable and widespread.



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