

December 21, 2022

Cheryl Laskowski  
Branch Chief, Transportation Fuels  
California Air Resources Board  
P.O. Box 2815  
Sacramento, CA 95812

**RE: Comments in Response to November 9, 2022 Public Workshop to Discuss Potential Changes to the Low Carbon Fuel Standard and Expanding Storage Pathways to Mineralization**

Dear Dr. Laskowski:

Thank you for your leadership at the California Air Resources Board to make California, the world's third largest economy, carbon neutral by 2045. Reducing emissions by deploying renewable energy should be the focus to achieve net neutrality, however, innovative zero- and negative-carbon technologies are also needed to abate industrial emissions and legacy CO<sub>2</sub>. **Therefore, we encourage CARB to expand the storage pathways under the Low Carbon Fuel Standard (LCFS) to include the mineralization of CO<sub>2</sub> and increase the amount of carbon dioxide safely and durably removed from the atmosphere.**

According to the 2022 Scoping Plan for Achieving Carbon Neutrality, CO<sub>2</sub> removal and carbon capture targets of 20 MMT of CO<sub>2</sub> and 100 MMT of CO<sub>2</sub> by 2030 and 2045, respectively, are necessary to meet the state's climate goals. The LCFS offers a mechanism to meet these objectives through its Carbon Capture and Sequestration Protocol (CCS Protocol). To achieve California's climate goals, CARB should expand the LCFS' CCS Protocol to include CO<sub>2</sub> that is mineralized and securely stored in geologic sites or products. CARB has an opportunity to spur investment and scale direct air capture (DAC) and storage solutions in the state by including more storage pathways under the LCFS.

**Expanding the LCFS Storage Pathways to Mineralization**

Under the LCFS, only captured CO<sub>2</sub> that is stored in depleted oil and gas reservoirs or saline formation, or that is used for enhanced oil recovery, is eligible for credits. Expanding the CCS Protocol for the LCFS to include carbon dioxide mineralization would accelerate the CO<sub>2</sub> removed by CO<sub>2</sub> capture technologies like DAC and mineralized storage approaches across the United States and help California reach net zero emissions by 2045. In this case, carbon mineralization is defined as captured CO<sub>2</sub> reacted with water and additives to form cementitious materials in natural or engineered environments. Additionally, expanding the CCS Protocol will allow for more pathways to lower the carbon intensity of transportation fuels that are produced or utilized within California by expanding storage options to mineralization.

[Capture6](#), a direct air capture company, and [CarbonCure Technologies](#), a carbon storage company, are based in, operating in, and/or plan to build in California and around the US. Including mineralization under the LCFS' CCS Protocol will enable cutting edge climate solutions to capture more CO<sub>2</sub>, deliver durable and low-risk storage solutions, which can create jobs and deliver local economic and environmental benefits. Scientific research on mineralization underscores that in-situ and concrete

storage should be included in the CCS Protocol in addition to storage of gaseous and supercritical CO<sub>2</sub>. Mineralization offers several advantages to permanently and safely sequester CO<sub>2</sub>:

### **Benefits of Mineralization**

Mineralizing CO<sub>2</sub> can adhere to the CCS Protocol requirements of durability for a minimum of 100 years. This could be achieved through CO<sub>2</sub> mineralization storage – such as in rock formations – or through utilization. The permanence of CO<sub>2</sub> storage varies between utilization and removal pathways, with storage times ranging from days to millennia. Carbon stored in rocks over millions of years can increase security of storage and decrease dependency on the efficacy of the cap rock compared to other carbon storage options.<sup>1</sup>

The mineral carbonation process (CO<sub>2</sub> dissolves into formation water and reacts with aquifer minerals and subsurface rocks to form stable carbonate minerals) aims to accelerate the natural process. Depending on the utilization pathway, CO<sub>2</sub> can be sequestered for centuries through cement curing and aggregates.<sup>2</sup> Mineralized CO<sub>2</sub>, such as in the form of solid carbonates, is stable and avoids the risk of carbon leakage that can result from storing CO<sub>2</sub> in gaseous or supercritical form.<sup>3</sup> The mineralized CO<sub>2</sub> can also be stored or utilized on site where it can be more easily monitored than the deep subsurface (i.e. reservoirs or deep saline aquifers). In addition, mineralized products including concrete allow us to quantify the amount of CO<sub>2</sub> removed from the atmosphere more easily via the measurements of the weight of generated carbonates, where established chemical reactions are available to calculate the equivalent amount of captured CO<sub>2</sub>

The California Climate Commitment has a focus on advancing technologies to remove CO<sub>2</sub>. Mineralization could be a major driver in meeting the state's negative emission targets and Governor Newsom's vision for the \$54B climate budget. By issuing LCFS credits for mineralization and storage projects, the state will be helping achieve the goals of the California Climate Commitment. Therefore, the CCS Protocol should be adapted with the best science and evidence available today to deliver California's climate goals and meet the climate crisis.

### **Recommendation**

We recommend that CARB include the mineralization of CO<sub>2</sub> under the CCS Protocol to enable secure, durable removal and storage of CO<sub>2</sub> under the LCFS, so long as the project meets the existing requirements to qualify for the LCFS. This offers a straightforward solution for CARB to enact to increase uptake of the LCFS for DAC while reviewing additional technologies and protocols to remove and

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<sup>1</sup> Snæbjörnsdóttir, S.Ó., Sigfússon, B., Marieni, C. et al. (2020). "Carbon dioxide storage through mineral carbonation." *Nat Rev Earth Environ* 1, 90–102. Retrieved from <https://doi-org/10.1038/s43017-019-0011-8>

<sup>2</sup> Clarke, L., Y.-M. Wei, A. De La Vega Navarro, A. Garg, A.N. Hahmann, S. Khennas, I.M.L. Azevedo, A. Löschel, A.K. Singh, L. Steg, G. Strbac, K. Wada, 2022: Energy Systems. In IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.008.

<sup>3</sup> Matter, J.M., Stute, M., SNÆBJÖRNSDÓTTIR, S.O., et al. (2016). "Rapid carbon mineralization for permanent disposal of anthropogenic carbon dioxide emissions." *Science*. Retrieved from <https://www.science.org/doi/10.1126/science.aad8132>.

securely store CO<sub>2</sub>. With this change, the LCFS could play an even more critical role in accelerating development and deployment of climate technologies.

### **Alternative Actions**

In addition to including mineralization as a storage option within the CCS Protocol, CARB could incorporate mineralized CO<sub>2</sub> from DAC facilities into California's cap and trade program. Currently, CARB allows companies within the cap and trade program to use investments in carbon offsets, like managing forests, as small portions toward their compliance obligations each year. CARB specifies that these offsets must be permanent and additional. Mineralization is a permanent solution to store CO<sub>2</sub> with lower leakage risks compared to other storage options. Mineralized CO<sub>2</sub> from DAC facilities also delivers additionality or emissions reductions that would not have otherwise occurred by removing CO<sub>2</sub> from the atmosphere. As a result, DAC technologies that mineralize CO<sub>2</sub> meet CARB's strict standards and could be included within the cap and trade program. To accelerate deployment and investment in carbon dioxide removal (CDR) in the long-term, we recommend CARB consider tech-neutral approaches that are high-quality, safe, and durable, as outlined in the comments submitted by the Carbon Removal Buyers and Sellers regarding the November 9 workshop.

### **Conclusion**

The LCFS is an excellent tool to reduce emissions in California today. Expanding the LCFS to mineralization would help CARB scale durable CDR in the short-term while deploying carbon management technologies in a safe and equitable way through CARB's new Carbon Capture, Removal, Utilization, and Storage Program, as established in [SB 905](#). As CDR companies with subject matter expertise in mineralization and storage, we would like to offer our support and resources to CARB in implementing these proposed changes. **We are willing and able to consult with CARB to provide research and findings to inform evidence-based regulatory changes on the LCFS and mineralization.**

We look forward to partnering with you to deploy safe, rigorous, and evidence-based approaches to remove carbon emissions and store them for millennia.

Thank you.

Capture6

CarbonCure Technologies