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Berkeley Lab's Comments - Carbon Removal Innovation Support Program (CRISP) Workshop

Please see comments attached.

Additional submitted attachment is included below.

BERKELEY LAB
Bringing Science Solutions to the World

May 4, 2023

Ilia Krupenich
California Energy Commission
715 P Street
Sacramento, California 95814

Re: Lawrence Berkeley National Laboratory Comments on Carbon Removal Innovation Support Program Workshop

Dear Mr. Krupenich,

On Wednesday April 19th, Commission staff hosted a workshop regarding the Carbon Removal Innovation Support Program. Berkeley Lab is pleased to present our comments in response to the aforementioned workshop.

For carbon removal, sequestration and utilization technologies, Berkeley Lab has existing as well as rapidly developing expertise in:

- Metal-organic frameworks and electrochemical methods/membrane separation for carbon capture, including direct air capture
- Coupling experimental data, mathematical modeling, and machine learning for predictive characterization
- Bioenergy with carbon capture and storage (BECCS) and carbon-to-products
- Process engineering, life cycle analysis
- Mineralization and ocean capture
- Terrestrial and geological sequestration, healthy soils for agriculture

Acknowledging that the focus of the CRISP program is on direct air capture (DAC) technologies, Berkeley Lab encourages the Commission to consider supporting, at the appropriate opportunities, use of state general funds to advance the broader suite of engineered carbon removal strategies, as these may offer significant opportunities to achieve removal at scale and favorable cost.

Berkeley Lab is pleased to provide answers to specific questions posed by staff during the workshop.

Research Test Center

What are some needs of DAC technology developers that the Research Test Center could cover?

Entrepreneurs and companies developing technologies often face challenges in accessing testing facilities as they progress towards commercialization. Berkeley Lab recognizes the

importance of testing and validation resources and facilities and supports California Energy Commission's goal to support an R&D testing facility for carbon removal technologies. Berkeley Lab in partnership with the University of California is part of the CEC funded CalTestBed program designed to connect entrepreneurs with the unique laboratory space and testing facilities in the UC System, including Berkeley Lab. The Lab appreciates the pivotal role this program has played in helping early stage entrepreneurs in making the leap from technology validation to commercialization.

How can a center become self-supporting?

The Commission is wise to pose this question, particularly given that the $75 million reserved for CRISP is one-time funding, and should carefully consider this issue as it evaluates proposals. It may be unreasonable to expect such a center to be self-supporting.

Without ongoing operational support from the Commission or other sources it will be hard to maintain staffing and other infrastructure. In the case of centers serving emerging growth industries, the user base may include a significant number of start up companies whose resources are limited. Further, particularly in light of the existence of other facilities such as the Department of Energy test center, demand for the services of this center may be unpredictable. The Industry-facing user facilities operated by Berkeley Lab typically rely on a combination of industry user support and ongoing support from the United States Department of Energy.

Applied Research and Demonstration

Since DOE is providing substantial grants for direct air capture projects, is allocation of funds between cost-share and applied grants adequate?

The U.S. Department of Energy's Carbon Negative Shot aims to spur innovation in carbon dioxide removal pathways that will capture carbon dioxide from the atmosphere and store it at gigaton scales for less than $100/net metric ton of carbon dioxide-equivalent. The development of more efficient processes is a critical goal. Consideration should be given to increasing the allocation to cost-share and applied research grants.

The Carbon Removal Innovation Program, created to advance "technology research, development and demonstrations, and prototype and pilot research test centers to remove atmospheric carbon" offers the State the opportunity to align with and leverage Department of Energy investments.

The staff presentation on CRISP implementation suggests that the purpose of the applied research and demonstration program would be "[p]ilot testing of most promising emerging direct air capture technologies for use in California." The development of carbon capture technologies is still at a very early stage and significant research and development is necessary to develop technologies capable of meeting the Department of Energy's Earthshot and goals.

The Commission has identified the advancement of energy efficient separation technologies as a goal in the EPIC investment program and may wish to clarify that the applied research program would cover applied research and development as well as demonstration and pilot testing. Further, the Commission may wish to significantly expand the portion of the CRISP program devoted to supporting applied research and development in California to ensure state leadership in the development, not just testing, of promising new DAC technologies consistent with state objectives for cost-effective carbon removal. Berkeley Lab recommends that the Commission reserve flexibility for itself to move some level of funding between the applied research category and the federal cost share categories in order to take advantage of emerging opportunities and changes in state and federal budgets.

Are there specific research projects that should be prioritized?

In the state-of-the-art post combustion or direct air carbon capture approach, an aqueous amine or basic solution is used to capture CO2. However, both amine solution adsorbents and aqueous basic solutions in use today possess high adsorbent regeneration energies, low CO2 cycling capacities, and exhibit thermal and oxidative solvent degradation, limiting their efficiency.

Berkeley Lab is focused on developing energy efficient processes for DAC. Our portfolio of technologies include both solid adsorbents as well as aqueous sorbents for the processes for carbon capture.

Aqueous approach

Our scientists are attempting to improve the energy efficiency of alkaline sorbent regeneration. Specifically, our scientists are developing an electrolysis method that captures CO2 while cogenerating H2.

Aqueous alkaline CO2 sorbents (e.g., NaOH solutions) enable direct CO2 capture from air (DAC). The fundamental challenge with commercial DAC processes, is the energy cost to regenerate absorbent that typically use thermal methods to achieve this. It requires very high heat, around 800 degrees Celsius. That is one of the reasons that current systems cost as much as $600 per ton of CO2 captured (although some companies have published claims that their technology costs under $200 per ton).

Electrochemical regeneration of the alkaline CO2 sorbents enables complete process electrification (allowing sole use of renewable energy input), and process simplification that avoids solids handling. At Berkeley Lab, we are building new technologies that leverage the ionic current already flowing in water electrolyzers to regenerate DAC media while co-producing scalable, low-cost, carbon-negative H2 with the goal to improve energy efficiency and cost of CO2 capture from air over other competing processes. Using a rough, back-of-the-envelope calculation, we've estimated that if all goes well, our system can cost in the range of $100 per

ton of CO2 captured. For this approach, Berkeley Lab is addressing materials design challenges: the need for sustainable membranes that enable fast, selective ion transport; earth abundant catalysts that provide fast reaction kinetics at low overpotentials; and a quantitative understanding of multi-phase and multi-mode transport phenomena, all in the presence of carbonate ions, which are not present in typical water electrolyzers as well as membrane and catalyst durability are also key challenges.

Solid Absorbents

Solid adsorbent materials, such as carbonaceous materials, silicas, zeolites, and metal-organic frameworks, have been proposed as alternatives to improve the performance of the CO2 capture process, and are promising. Among these solid sorbent materials, metal-organic frameworks (MOFs) are especially promising, exhibiting the greatest internal surface areas, as well as structural and chemical diversity and tunability. This tunability allows for major flexibility in how these materials may be designed and optimized at the molecular level. MOF-based materials may also be tailored for separation and remediation of other molecules and heavy metals, including environmental pollutants, from air and water, and therefore have great potential for addressing challenges facing communities long burdened by pollution. UC Berkeley/Berkeley Lab is home to the leaders in the development of these materials and is where some of the most promising materials have been discovered.

Challenges for solid sorbent materials like MOFs include synthesizing them at sufficient scales to replace amine solutions, and also durability and timescales associated with CO2 cycling. Research in these areas typically falls between the standard DOE funding streams and would be an important and welcome investment by CEC.

Hybrid Engineered CDR Technologies

In developing a research center that does not duplicate federal investments, the Commission may wish to consider a center that also supports hybrid engineered CDR solutions, i.e. those that couple engineering solutions with the services of the natural environment. For example, enhanced rock weathering that uses alkaline silicate materials, either natural rocks or industrial by-products like steel slag or concrete waste, as a means to capture CO2. This can be done either in fully engineered reactor systems or in hybrid systems where material is prepared through an engineered process for the maximum reactivity and subsequent distribution onto working lands. These types of systems should be part of an ecosystem of technologies that make up an interdependent CDR testbed and future CDR economy.

Any research testbed should also have the ability to test different monitoring, reporting and verification (MRV) technologies and frameworks alongside developing technologies. It is widely acknowledged that the CDR industry will largely succeed or fail on the quality and acceptance of MRV frameworks. Therefore these should be developed and tested alongside new technologies.

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Berkeley Lab appreciates the opportunity to provide these comments in response to the Carbon Removal Innovation Support Program Workshop.

Sincerely,

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