## CALDAC Letter of Intent

UC Berkeley submitted this letter to DOE on February 17, 2023. The letter provides an early description of the project we intended to propose in the full application. Posted online on January 31, 2024.

Berkeley Law

Center for Law, Energy, & the Environment

**Project Title**: Community Alliance for Direct Air Capture (CALDAC)

**Lead Organization**: University of California, Berkeley

**Organization Type**: University

**Has the application been previously submitted to DOE**: No

**% of effort contributed by the Lead Organization**: 30%

**The Project Team**:

- **Project Manager**: Dr. Louise Bedsworth, Executive Director, Center for Law, Energy and the Environment, Berkeley Law, University of California, Berkeley

- **Technical and Social Feasibility Planning:** Lawrence Berkeley National Laboratory (LBNL); Electric Power Research Institute (EPRI); AECOM; Clean Energy Systems (CES); Fresno State University; UC Merced; Cal State University Bakersfield; Project 2030; Data for Progress; Carbon180; PSE Healthy Energy; World Resources Institute

- **Technology Companies: DAC:** Mosaic, Capture6, Origen, AirMyne; **$CO_2$ Conversion Technologies:** Blue Planet, CarbonBuilt; and **Energy Storage:** Rondo

- **Host of Sites(s) to Be Considered:** Up to three bio-energy to power conversion facilities owned by Clean Energy System located throughout the San Joaquin Valley of California: Delano Plant in Kern County, CA; Mendota Plant in Fresno County, CA; and Madera Plant in Fresno County, CA.

- **Senior/Key Personnel:** Ken Alex; Michael Kiparsky; Daniel Kammen (UC Berkeley); Jens Birkholzer, Newsha Ajami, Hanna Breuning; Blake Simmons (LBNL); Adam Berger, Rob Trautz (EPRI); Bill Steen (AECOM); Rebecca Hollis, David Henson (CES); Karl Longley (Fresno State); Sarah Kurtz (UC Merced); Liaosha Song (Cal State University Bakersfield); Diane Doucette (Project 2030); Celina Scott-Buechler (Data for Progress); Vanessa Suarez (Carbon180); Seth B.C. Shonkoff, Lee Ann Hill (PSE Healthy Energy); Dan Lashof, Angela Anderson, (World Resources Institute); Nathan Gilliland (Mosaic, Baker Hughes); Lydia Le Page (Capture6); Dustin Pool (Origen); Mark Cyffka (AirMyne); Laura Berland-Shane (Blue Planet); Sal Brzozowski (CarbonBuilt); Arvind Menon (Rondo)

**Technical Topic Area**: TA-1, Feasibility

**Abstract**:
The goal of this project is to conduct a detailed feasibility study of a community-centered Direct Air Capture (DAC) Hub situated in the southern part of California's San Joaquin Valley. We refer to this hub as **CALDAC**: **C**ommunity **AL**liance for **D**irect **A**ir **C**apture**.** CALDAC will pioneer an innovative model for community partnership and co-production from feasibility phase to hub design, construction, ownership, and operation. By centering equity, community benefits, and environmental justice in all phases of the project, this model can provide a new paradigm for community-led and community-focused energy transitions. The DAC hub needs to be anchored in strong technical and technological capacity, while also fully capturing the needs and concerns of the community. Therefore, it is vital to establish a strong working relationship with stakeholder groups who will experience the benefits and risks of such an endeavor. The hub will provide an inclusive platform for collaboration and cooperation among stakeholders, with explicit emphasis on facilitating the voices of environmental justice organizations, labor organizations, academic institutions and technology providers. The proposed feasibility study will place a strong focus on ensuring environmentally responsible development which is particularly important in a region like the southern San Joaquin Valley where communities are heavily affected by chronically poor air quality and extreme water shortage.

Responding to Technical Area 1 (Feasibility Study) of FOA DE-FOA-0002735, the work scope comprises the following major tasks:

- Development of the DAC Hub structure and assessment of the technical feasibility of the DAC Hub, including technology partners, location, business model, and $CO_2$ storage/utilization option(s), and
- Assessment of the social and governance feasibility of an innovative, community-led ownership model and community benefits plan that engages local stakeholders as core partners.

Together, these two tasks will ensure cost-effective, efficient, equitable, and environmentally responsible development of CALDAC. The project is led by the Center for Law, Energy & the Environment at UC Berkeley and co-led by Lawrence Berkeley National Laboratory, in collaboration with NGO and local academic partners.

**CALDAC Vision**

CALDAC will be a community-centered and community-informed DAC Hub situated in the middle to southern part of California's San Joaquin Valley, spanning a region between north of Fresno in Madera and Fresno County to Kern County north of Bakersfield. We envision this hub as part of a coordinated regional cluster of carbon dioxide removal facilities that incorporates multiple technologies embedded within shared energy resources, storage options, infrastructure and equipment. CALDAC also envisions development of a community-centered governance model for the development and ultimate operation of the hub. This will include design of a community benefits plan that provides opportunities for community ownership, generational wealth building, transparency, and accountability to the community.

**CALDAC Sites**

Preliminary plans for siting CALDAC envision co-location with three biomass carbon removal and storage (BiCRS) plants that are currently in development in the San Joaquin Valley. The Clean Energy System BiCRS process uses a gasification-based process that can be optimized and configured to produce electricity, thermal energy, and hydrogen in proportions that are most beneficial to the hub. The three sites are the Delano plant in Kern county, the Mendota plant in Fresno county, and the Madera plant in Madera county. The nearly 360 acres of land provided by the sites can host the four or more DAC technologies that will be responsible for meeting the development goal of 1 million tons captured from air. Each site overlies a deep stack of sedimentary strata that provide considerable capacity to store $CO_2$. Hosting CALDAC on BiCRS sites has multiple advantages: clean carbon-negative thermal and electrical energy from BiCRS can be provided to partially power the DAC systems, the $CO_2$ captured from air can be stored in the subsurface reservoirs that are being developed and permitted in the vicinity of the BiCRS plants, and infrastructure such as utility systems, carbon purification, $CO_2$ transportation and $CO_2$ storage can be shared. Further, integration of BiCRS and DAC can increase the carbon negativity achieved by the project.

Aside from a few larger cities, the region offers plenty of acreage for direct air capture system installations. Intensive agricultural production and sustainable forest management removing biomass from the nearby Sierra Nevada mountains (removed for wildfire protection) provide large amounts of biowaste available as feedstock for the BiCRS plants that would host CALDAC and partially power the DAC installations. The many agricultural fields in the region also offer ample opportunity for application of enhanced weathering approaches on agricultural working lands.

**Regional Context**

California’s San Joaquin Valley includes eight counties spanning approximately 27,000 square miles. The San Joaquin Valley is home to approximately 4 million people and nearly 25 percent of residents live below the poverty line. The San Joaquin Valley experiences the worst air quality in the nation due to the presence of emissions-heavy industries like oil and gas, agriculture, and warehouse distribution. The San Joaquin Valley has been out of compliance with the National Ambient Air Quality Standards (NAAQS) for decades. Fresno and Bakersfield, two of the largest cities in the San Joaquin Valley, rank in the top four most polluted U.S. cities and first and second for cities most polluted by particle pollution (American Lung Association, 2022). Fresno County is home to the most disadvantaged census tract in the State of California as measured by CalEnviroScreen 4.0, a spatial tool that identifies communities most affected by pollution, health vulnerability, and concentrated poverty (Office of Environmental Health Hazard Assessment, 2021).

Six of the eight counties in the San Joaquin Valley are among the top 10 agricultural producers in the United States, with Fresno County holding the top position with nearly $8 billion in sales in 2018. Annual rainfall across the San Joaquin Valley ranges from approximately 5 inches in its southern part to about 20 inches in the north, and agriculture is heavily dependent on

California's complex system of dams, reservoirs, levees, canals, pumps, and pipelines to provide millions of acre-feet of irrigation water from both groundwater and surface water resources. The combination of climate change, intense droughts, and unsustainable agricultural management practices have led to endemic water shortage in the Valley, which has resulted in widespread depletion of groundwater resources and severely impacted ecological systems.

The San Joaquin Valley also has a long history of oil and gas production, most of it in Kern County in the south. In 2019, Kern County ranked as the #7 oil-producing county in the nation. However, California's plan to reach carbon neutrality includes a sharp phase down of in-state oil and gas production. Geologically, the San Joaquin Valley has high potential and large capacity for geologic carbon sequestration both in depleted oil and gas reservoirs and in deep saline aquifers.

CALDAC is being developed to take full consideration of this regional context. Our intention is to assess the technical feasibility to a DAC hub aligned with a carbon neutral future that maximizes community benefits. If designed well, deployment of a DAC hub in this region could provide important community-wide economic and environmental benefits to low-income, energy-burdened communities that will experience the economic impacts from a shift away from historical reliance on fossil fuels and impacts of climate disruption on the agricultural economy.

**Technologies Under Consideration**

The Hub is intended to support the validation at scale and large-scale deployment of DAC and enabling technologies. Technology and system integration, resulting in the initial hub configuration and final hub vision will start with four DAC technology partners and two CO2-to-products technology providers.

***DAC Technology Partners***

The DAC technology providers currently included in CALDAC represent a distinct set of important direct air capture approaches. Because of the early-stage of most DAC companies, a diverse approach is considered with several different technology approaches selected. The common elements in the technologies are the sound technical backing and path to large-scale deployment. While the companies below are the initial technical partners, it is expected that other technology partners may join the hub during the course of development.

- ***Mosaic (Solid Sorbent Approach)***
  Mosaic, a division of Baker Hughes, has developed a long-lived material with high capacity for $CO_2$ sorption under dilute conditions, and has been confirming its operating parameters since 2016. Mosaic's amine functionalized sorbent is a derivative of the $M_2$(*m*-dobpdc) metal-organic framework (MOF) initially developed at UC Berkeley and Lawrence Berkeley National Laboratory, now tuned for dilute $CO_2$ removal. Mosaic has developed patent-pending manufacturing techniques to cost-effectively make these adsorbents. The materials have been tested since 2016 at a laboratory scale. Following lab-scale testing, Mosaic has been operating a 1 TPY TRL5 DAC prototype in its facility in Alameda, California since March 2022 to validate all performance characteristics. At present, Mosaic is completing the final

design and assembly of a larger DAC scale system which will be deployed in Houston, Texas in 2023.

- ***Capture6 (Carbon Mineralization Approach)***
  Capture6 has developed a DAC and mineralization approach for permanent carbon dioxide removal that uses salt water (seawater, saline groundwater (brine), or desalination effluent brine) to produce a capture solvent. They react the sodium hydroxide solvent with atmospheric $CO_2$ to form carbonates for storage, and fresh water for further use. Capture6 is headquartered in Berkeley, CA and Rotorua, New Zealand, and has a global pipeline of facilities in development. They have brought together several industrial partners and high TRL technologies including a collaboration with the global corporation Veolia Water Technologies and Solutions. They have begun work on a demonstration facility in Palmdale, CA.

- ***Origen (Carbon Mineralization Approach)***
  Origen has a path to giga-tonne scale carbon removal by unlocking the power of lime, an abundant mineral, for Direct Air Capture. Lime is a product of limestone, and naturally reacts with CO2 to remove it from ambient air; however, the production of lime releases more carbon than lime can currently remove. Origen's core technology combines two proven industrial processes - oxy combustion and flash calcination - to create lime that is purpose-built for CDR, while sequestering high purity $CO_2$ emissions for permanent storage. In 2022, Origen, with air contactor partner 8 Rivers, won pre-purchased removal credits from the Frontier fund. Origen is currently commissioning a pilot in the UK with ~1000 TPY removal capacity, alongside its strategic partner in the lime industry. The pilot is scheduled to deliver first carbon removals with 8 Rivers in 2024.

- ***AirMyne (Liquid Solvent Approach)***
  AirMyne's patent-pending system uses high-efficiency electric fans to bring atmospheric air into contact with a solution chemistry that captures carbon dioxide from air by adsorbing it onto the process fluid. The chemistry is recyclable & reusable, and leverages existing supply chains. The captured carbon dioxide is then passed through a steam-heated zone at moderate temperature followed by a purifying step to release pure carbon dioxide. The pure carbon dioxide is compressed for geological sequestration or used as a feedstock in manufacturing processes. AirMyne is based in Berkeley, CA and since its founding in February 2022, AirMyne has demonstrated its capture process at kg/day scale.

In addition to these four core DAC technology partners on the project team, CALDAC has discussed potential partnerships with other DAC companies that value the community-centered vision of CALDAC (e.g., Heirloom) and may join the hub during this effort or future phases.

***$CO_2$ To Products Technologies***

One critical aspect of this feasibility study phase for CALDAC is to assess, design, and then build and deploy integrated technologies capable of efficiently capturing (e.g., DAC) and converting CO2 into products. These conversion technologies will benefit from the co-produced syngas, hydrogen, heat and electricity that the site will provide. Current CO2-to-products partners include:

- ***Blue Planet***
  Blue Planet's technology combines carbon dioxide with calcium sourced from waste to manufacture synthetic limestone aggregate that permanently and safely sequesters $CO_2$. The aggregate is then used to produce low-embodied carbon or carbon negative concrete. Each tonne of Blue Planet's aggregate permanently mineralizes 440 kg of $CO_2$, preventing it from ever leaking or accumulating in the atmosphere. Blue Planet's process can use dilute $CO_2$ from any source, at any concentration, and turn it into valuable building materials to enable carbon capture at a profit. Based in Los Gatos, California, Blue Planet is building its first commercial production facility to use its patented carbon mineralization technology in Pittsburg, CA.

- ***CarbonBuilt***
  CarbonBuilt is an XPRIZE-winning company that enables the production of ultra low-carbon concrete products, starting with concrete masonry units (CMU), with no impact on price, performance, or ongoing plant operations. CarbonBuilt's technology reduces the carbon footprint of CMUs by 70% to over 100% through both avoided emissions and permanent carbon removal. A single production line retrofitted with CarbonBuilt's technology can permanently mineralize about 500-1000 tonnes of $CO_2$ per year. CarbonBuilt is based in Los Angeles, CA and works with concrete product producers across the country. They are currently completing the retrofit of their first commercial plant (Blair Block, near Birmingham, AL) and preparing for a few similar retrofits in other locations.

***Other Associated Carbon Removal Technologies***

While outside the scope of this proposal, CALDAC will also include two additional carbon removal technologies: BiCRS and enhanced soil carbon sequestration through enhanced weathering. The carbon removed by these technologies is in addition to the $CO_2$ captured through the DAC technologies in the initial buildout (> 50,000 TPA) and final buildout (> 1 million TPA) of CALDAC. Per FOA definition, the BiCRS and soil carbon sequestration elements of CALDAC are not eligible to receive funding from this grant opportunity. However, the BiCRS technology provider CES serves as a host for and as a clean energy provider to the hub, and as such will receive funding for the hub planning and integration work scope.

While the feasibility study will start with this initial group of technology partners, CALDAC will be open for additional partners to join as the project progresses. We view a diverse portfolio approach of DAC technologies as essential for the success of a hub, to both reduce risk of and to exploit beneficial synergies between individual technologies.

**Feasibility Assessment**

The proposed feasibility assessment has two key, interrelated elements. The technical feasibility assessment will explore the effectiveness and resource needs of proposed technologies, impacts on the environment, and financial feasibility. The social and governance feasibility assessment will examine the potential for community governance and ownership models that will advance equity in the region. The San Joaquin Valley experiences high concentrations of poverty and has a long history of pollution. Therefore, development of a carbon removal economy in the region needs to be undertaken in a manner that centers community benefit and equity.

The technical and social/governance feasibility assessments will be connected through stakeholder engagement and information and data sharing. The diverse project team will be co-producing research questions and scenarios related to the social, environmental, and technological implications of a DAC hub in order to ensure that any technological solutions that are on the table and various design structures are fully vetted before deployment to ensure they are socially responsible and in line with community needs and values. In addition, the social and governance feasibility assessment will shape the business model and financial plan and inform go/no-go decisions.

***Technical Feasibility Assessment***

The Technical feasibility study will have two major components: individual technology development plans and hub integration and balance of plant. In phase 0A, the individual DAC and CO2-to-products technologies will provide the performance and assessment information to the integration team. The integration team, including host site CES and enabling energy storage and supply will work with the project partners to define the initial configuration options for the DAC hub and anchor DAC tenants. All process tie-ins will be identified and will be evaluated for integration options including options for shared utilities, shared CO2 processing and compression, transportation, and storage. In Phase 0B, this initial configuration will be assessed through an options analysis and Pre-FEED to assess the expected performance, system inputs and outputs, cost, and impact. The individual technology providers will provide support for these efforts through process modifications to improve integrated hub performance and more detailed analyses of expected initial and full-scale performance.

The technical feasibility assessment will evaluate the resource demands for each of the technologies being considered for the hub. This will include examination of energy supply and storage; land needed for the hub and potential geologic storage; and water inputs and outputs. In particular, the team will identify optimal pathways to provide clean, affordable electricity to the hub, including co-locating with BiRCS plants to meet initial electricity demand. Since the hub will ultimately have greater electricity demand than the BiRCS plants can meet, CALDAC will explore multiple pathways for powering the hub. We have partnered with: Berkshire Hathaway Energies (BHE) to explore the use of solar and possible wind energy for the hub; Rondo Energy to examine aggressive deployment of energy storage at the hub; and Bloom Energy to examine the potential to convert hydrogen into low carbon heat and power for DAC and CO2-to-products plants. The latter option would take advantage of ARCHES, a major proposal to establish a regional hydrogen hub in California. The result of these partnerships will be integrated into the concept for the DAC hub implementation at a final scale of at least 1,000,000 tons of CO2 captured from the atmosphere per year.

Understanding the environmental impacts and mitigation for the hub will be critically important given the high pollution burden in the region. During the feasibility assessment, we will work closely with community groups, residents, and other stakeholders to characterize potential environmental, health and safety hazards associated with CALDAC. Evaluations will consider both the construction and operational phases of CALDAC and will include characterization of potential air quality impacts, chemical management issues, mitigation strategies, and community air monitoring requirements. We will also closely examine water needs and potential impacts, including evaluation of the use of unconventional water sources, such as agricultural drainage water, municipal wastewater, brackish water, and possibly brine extracted from the $CO_2$ storage reservoir. Physical hazards (e.g., noise) and safety hazards will also be evaluated.

***Social and Governance Feasibility Assessment***

CALDAC will have a governance model that engages local communities and stakeholders as core partners from concept through operation. Within the first nine months of the feasibility study, the project will develop a community-centered ownership model that is tailored to support underserved communities, minimize environmental impacts, and promote workforce development (a hub by the community for the community). To ensure the social feasibility of the planned hub endeavor, several community groups including local environmental justice organizations will join CALDAC as active project team members. We are working with partner organizations to explore different models of public authority, including a range of community-based public-private partnership models that could best operate a DAC Hub as a public good.

During this feasibility phase, CALDAC will explore the feasibility of establishing a Public Authority to oversee the operations and financing of a DAC hub. A Public Authority, much like a Port Authority, Transit Authority, or Municipal Utility District would operate the DAC hub as a public good – one that maximizes safety and the strongest environmental standards while minimizing costs. A public authority would ensure that CALDAC is operated as a public good, have access to public financing, operates with data transparency and performance tracking, and takes a long-term outlook.

Since the State of California is committed to removing legacy emissions and permanently sequestering them, California is an ideal place to develop this innovative model. Creating a Public Authority in California – with its unique geological sequestration resources and strong environmental standards could serve as a model for the creation of DAC Hubs nationally. This innovative structure will facilitate competitive DAC services and prevent this essential infrastructure from being dominated by a monopoly incumbent industry.

**Community Benefits**

Delivering real and meaningful benefits to the communities where a DAC hub might be located is a central goal of the CALDAC project. The resulting Communities Benefits Plan will address labor and workforce development; diversity, equity, inclusion, and accessibility; and environmental justice. To realize these benefits, we will explore community- and public-ownership and governance models that place the benefits at the forefront of hub design and operation.

The Community Benefits Plan will include analysis and recommendations for orienting governance and management in ways that help to alleviate the region's pollution burdens and environmental vulnerabilities. In order to ensure broad community participation and engagement throughout this project, we will establish a Community Advisory Council that will include stakeholders, residents, and representatives from historically disadvantaged and environmental justice community groups. The council will provide feedback and direction to the project team, help coordinate public engagement activities, and inform key project decision-making points. All members of the Council will be compensated. The data collected and the input provided by the Community Advisory Council will directly inform the feasibility assessment of the hub and design considerations. The design will be tested under various scenarios that would consider the environmental, economic, and social impacts of the hub. We will verify the effectiveness and possible environmental and social footprint of various innovative technologies that would be included as part of the DAC technology portfolio through an inclusive engagement process.

We will identify and collect community-relevant data to inform the hub design process and help monitor, track and verify social and environmental goals. We will establish baseline data and data transparency processes through collaboration with community groups. This will include timely sharing of project performance data in an easily understandable and regionally-relevant manner with the public.

Through our engagement processes, we will work with businesses and local labor representatives to assess and identify potential for jobs and employment opportunities in a DAC hub. Several of the major industries in the southern San Joaquin Valley face pressure under changing climate conditions, which will affect workers and the local economy. The oil and gas industry is a large employer in Kern County, where it is also an important source of revenue to local governments. Agriculture is also an important employer, but faces pressure due to changing climate conditions including drought and increasing temperatures. Therefore, the DAC hub can provide meaningful transition pathways to high quality employment opportunities. We will work with local educational institutions and other partners to identify workforce development opportunities.

The Southern San Joaquin Valley has a high concentration of disadvantaged communities, including the highest-ranking census tract in the state, as measured by CalEnviroScreen 4.0. As a result, several state and local programs are working in the region to advance environmental justice plans and projects. To the extent possible, we will leverage these existing environmental justice activities and investments in the region. Some recent activities include three Community

Air Protection grants to support development of community air monitoring programs and projects in Southwest Fresno (Fresno Co.), Shafter (Kern Co.), and Arvin/Lamont (Kern Co.). The City of Fresno received a $66.5 million grant under the Transformative Climate Communities program that has supported integrated infrastructure and workforce development projects.

The CALDAC governance model will be designed through a collaborative process to maximize community benefits. We will develop a business plan for the DAC hub that includes community and/or public ownership models, revenue streams and sharing models, and collaborative governance structures. To achieve a bottom-up community-informed collaborative, we will include community representatives as equal and compensated members of the project team. The goal of this process is to develop a new paradigm and model for community ownership, accountability, transparency, and generational wealth building that centers communities and people as the beneficiaries of the energy transition.

**References**

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