Giner Labs

Carbon dioxide removal prepurchase application

Summer 2024

General Application

(The General Application applies to everyone; all applicants should complete this)

Public section

The content in this section (answers to questions 1(a) - (d)) will be made public on the Frontier GitHub repository after the conclusion of the 2024 summer purchase cycle. Include as much detail as possible but omit sensitive and proprietary information.

Company or organization name

Giner Labs

Company or organization location (we welcome applicants from anywhere in the world)

Newton MA

Name(s) of primary point(s) of contact for this application

Judith Lattimer

Brief company or organization description <20 words

Electrochemical R&D company developing energy-efficient Direct Air Capture technology.

1. Public summary of proposed project[1] to Frontier

a. **Description of the CDR approach:** Describe how the proposed technology removes CO_2 from the atmosphere, including how the carbon is stored for > 1,000 years. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar approach. If your project addresses any of the priority innovation areas identified in the RFP, tell us how. Please include figures and system schematics and be specific, but concise. 1000-1500 words

[1] We use "project" throughout this template, but the term is not intended to denote a single facility. The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company.

The proposed technology uses an air contactor to produce a potassium carbonate-containing feedstock for a state-of-the-art hydrogen-assisted carbonate electrolysis cell that can operate at low voltage to regenerate purified CO2 and KOH. The integrated CO2 capture and regeneration system captures CO2 from the air and releases it as a pure gas stream using only electrical energy, providing an ideal system for use with renewable energy sources. The capture solution is also regenerated and continuously circulated through the system, minimizing reactant usage, and the hydrogen is recycled from the cathode back into the anode, minimizing both the voltage and the hydrogen usage (Figure 1).

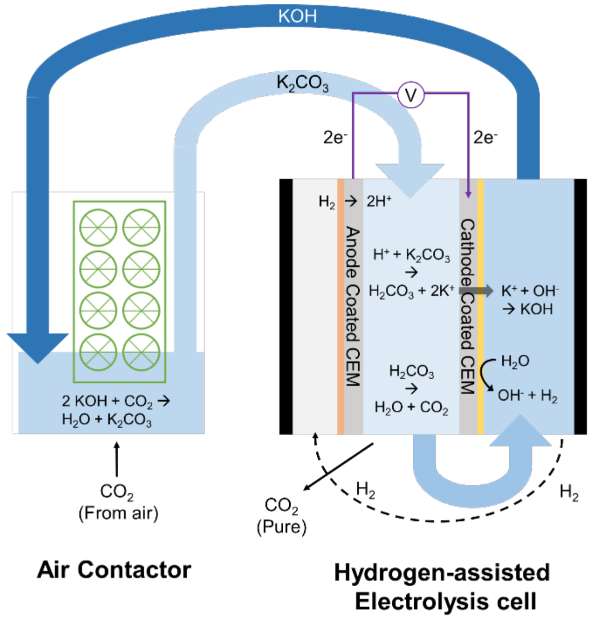

Figure 1. Schematic of proposed DAC/electrolyzer for CO_2 capture and regeneration from ambient air.

Our technology removes CO2 from the atmosphere through a sorbent-based air contactor, which captures the CO2 in a concentrated basic solution as potassium carbonate. The capture solution is then fed into our electrolyzer, where the CO2 is regenerated as a purified gas stream, which can be utilized or sequestered without any further processing. While our technology does not directly utilize or sequester the CO2, it provides a pure CO2 feedstock that can be integrated with any utilization or sequestration technology available, which would allow the CO2 to be stored for as long as that technology allows.

The air contactor is based on prior work from Carbon Engineering utilizing aqueous KOH as a capture medium for DAC. However, our system achieves the CO2 capture and regeneration for lower energy input and competitive cost compared with similar technologies, due to our innovative electrolyzer design which significantly reduces the voltage required to regenerate the CO2 compared with thermal technologies, and therefore reduces energy input. Because our electrolyzer also does not require any PGM catalysts, it can be built for significantly lower cost than comparable electrolyzer technologies.

The pure CO2 that we regenerate can itself be a value-added product for sale. Currently, there are emerging technologies in the green chemistry sector that require highly purified CO2 as a feedstock for producing green plastics, sustainable aviation fuel, or commodity chemicals. Our CO2 is a clean alternative to using fossil-fuel derived CO2 that could be provided to this industry for cost or at a green premium.

In addition, because our system is electrochemical, it is capable of flexible operation to match clean power generation or integration with renewables, both on and off grid. There is no thermal requirement for our system, making it easy to integrate and site, and allowing for flexibility of scale without impacting cost.

b. **Project objectives:** What are you trying to build? Discuss location(s) and scale. What is the current cost breakdown, and what needs to happen for your CDR solution to approach Frontier's cost and scale criteria?[2] What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. 1000-1500 words

[2] We're looking for approaches that can reach climate-relevant scale (about 0.5 Gt CDR/year at $100/ton). We will consider approaches that don't quite meet this bar if they perform well against our other criteria, can enable the

We are currently building a 1 ton/year prototype system, at our facility in Newton MA. Our next step is to scale up to a 1000 ton/year pilot plant, which we have not yet sited. Finally, we would further scale the technology to the 1M ton/year scale, pending successful operation of the pilot plant and financing for further development. Based on our TEA, the cost at that scale is $111/tCO2. The Capex costs account for $41/tCO2, fixed Opex costs are $10/tCO2, and the energy cost is $54/tCO2. The energy cost mostly comes from the electricity usage of the electrolyzer, which does have the potential to be reduced with improved performance. For our 1 MMT system, we have already projected some improvement to our current performance. The price of electricity is based on current utility PV costs, which has the potential for significant reduction depending on location and whether we operate on or off-grid. The risks in achieving this scale are mostly on the financing side – technologically, the system is largely derisked and we have demonstrated efficient operation of our electrolyzer. We do still need to optimize our operating conditions to ensure we are staying within the most efficient regime for CO2 regeneration, but that should be straightforward once we have our prototype integrated system operational. However, it does need to be scaled up, which will require some redesign and component procurement risks. Those should be minimal, however, as our system is similar to current PEM electrolyzers in terms of materials and design, and so we anticipate being able to take advantage of existing supply chains and commercial manufacturers to produce all the parts we will need.

We quantify the carbon removed by measuring CO2 concentration in the air that enters our air contactor and in the air that leaves the air contactor, along with the air flow rate, using a CO2 meter and anemometer. We also measure the CO2 concentration (in the form of carbonate and bicarbonate ions) in the capture solution throughout the capture process to quantify CO2 captured by the solution. This is done by neutralizing a sample of capture solution in a sealed container and measuring the volume of CO2 gas released. Finally, we measure the CO2 generated by our electrolyzer from the capture solution as a pure CO2 stream (verified by GC measurement) using a gas flow meter to quantify the CO2 regeneration rate. All of these measurements are taken together to quantify our carbon removal rate.

c. **Risks:** What are the biggest risks and how will you mitigate those? Include technical, project execution, measurement, reporting and verification (MRV), ecosystem, financial, and any other risks. 500-1000 words

The major technical risk that would cause us to rethink our approach would be if the process doesn't scale the way we expect, reducing the energy savings that we've demonstrated at the bench scale. If we are unable to operate our prototype system at relatively high current densities and low operating voltage, then our cost model becomes unsustainable. However, our preliminary data at the 50 cm^2 level is very promising. Using this data, and with fairly modest projections about improvements in performance and reductions in CAPEX with scale up, we have already demonstrated a path to $100/ton CO2 capture cost in our preliminary TEA.

The other main technical risk is system durability – while the components that we are using for our system have all been validated for thousands of hours of operation under various electrolysis conditions in other systems, we have not actually been able to do continuous, long-term testing of our integrated system yet to demonstrate durability. We plan to do this testing over the next year once our integrated 1 ton/year prototype is finished, so we should be able to mitigate this risk pretty quickly. If it turns out that there are components of our system that are not stable for long-term operation, we already have many alternative materials that can be used based on our prior electrolysis experience, which should mitigate that risk.

Our system is a self-contained capture/regeneration system, making it very straightforward to measure all relevant aspects of system performance. That makes it very low-risk from the measurement perspective – things like energy consumption and CO2 capture/regeneration rate are either measured directly (CO2 outlet flow rate, CO2 concentrations; air flow rate, current, voltage), or can be easily calculated from those metrics (power consumption, CO2 capture rate). This also makes

removal of hundreds of millions of tons, are otherwise compelling enough to be part of the global portfolio of climate solutions.

it easy to track how performance of the system varies under a wide array of variable operating conditions, including temperature, humidity, current density, capture solution concentration, air flow rate, liquid flow rate, etc. That will allow us to optimize operation for minimal power consumption, cost of CO2, durability, etc. In terms of project risk, we have a clear plan for scaling this technology and have a highly capable team to execute. With adequate funding to enable testing, along with finding appropriate partners for pilot plant siting and CO2 offtake, the risks for achieving the necessary scale (0.5 Gt CDR/year at $100/ton) can be mitigated. Our system uses minimal resources, as the KOH, H2, and water that make up the bulk of our reactants are all recycled through the system during operation. There may be some need to replenish the water due to evaporative losses, though optimizing the air contactor design will minimize those losses. In addition, there may be a need to replace the KOH capture solution at periodic intervals if impurities from air start to build up in concentration over thousands of hours of operation. Similarly, while we are projecting minimal parasitic loss of H2 during continuous operation, we still need to validate that assumption during long term testing, and there may be a need for small amounts of H2 to be supplied to the system periodically to maintain performance. These are all relatively easily sourced and inexpensive materials, however, and should not be an impediment for pilot or larger-scale facility siting. In addition, as an electrolysis system operating close to RT, it does not require thermal heating and is compatible with flexible operation (ie, variable power, intermittent operation), and so can easily be integrated with renewable or other electricity sources, including off grid resources.

d. **Proposed offer to Frontier:** Please list proposed CDR volume, delivery timeline and price below. If you are selected for a Frontier prepurchase, this table will form the basis of contract discussions.

Proposed CDR over the project lifetime (tons) *(should be net volume after taking into account the uncertainty discount proposed in 5c)*	7,056
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	2037
Levelized cost (\$/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	$6,554
Levelized price (\$/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	200

[3] This does not need to exactly match the cost calculated for "This Project" in the TEA spreadsheet (e.g., it's expected to include a margin and reflect reductions from co-product revenue if applicable).