Planet Savers

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

Planet Savers, Inc.

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

Tokyo, Japan

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

Kei Ikegami

Brief company or organization description <20 words

Japanese first Direct Air Capture startup with Tokyo University's novel zeolite 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

We target removal of CO_2 from the atmosphere through deployment of our novel DAC technology combined with the existing CO_2 storage facilities. We are developing two groundbreaking technologies:

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[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.

1) an innovative DAC adsorbent based on zeolite, and

2) a DAC machine optimized for zeolite use. Our research and development efforts are carried out both independently and in collaboration with a laboratory at The University of Tokyo, which is renowned for being one of the worlds' top three labs in zeolite synthesis technology and holds strong patents in this field.

According to our research, there are around 80 DAC startups in the world at present, however with the drawback of high CO_2 capturing costs ranging between $400-1,000/ton.

On successful commercialization and scaling-up of our technology, reduction of CO_2 capturing cost is expected to reduce to $100 by 2030, furthermore it will have the following three advantages over the existing DAC technologies:

(1) Low adsorbent costs

Solution-based adsorbents and amine-bearing solid adsorbents like MOF, which are currently the mainstream among DAC technologies, are relatively expensive, have low durability, and need frequent replacement (once every several months to a year). In particular, oxidative degradation to which organic matter and organic groups are subjected is inherently difficult to resolve. In this regard, zeolite is an inorganic material, which is highly durable and does not need to be replaced for about 10 years. Our Co-Founder Kenta has reported the method for creating ultra-durable zeolite, which is considered to be one of the most durable zeolites existing to date. In addition, zeolite also naturally exists as a material and is significantly cheaper than other adsorbents. Therefore, together with its durability (=lifetime cost), the cost of adsorbent can be reduced to 1/10.

(2) No Use of Heat

Solution-based adsorbents and current solid adsorbents absorb CO_2 through chemisorption, which requires a large amount of heat energy for CO_2 desorption, increasing the overall cost of CO_2 recovery (about half of the total cost). For instance, in the case of alkaline solutions, nearly 900 °C of heat is required. In this regard, the zeolite we use recovers CO_2 through physical adsorption, so no heat is used (or significantly less), and desorption is possible only with pressure. Our zeolite incorporated DAC system, with no/less heat consumption, is estimated to reduce the energy required for removal to about 550 kWh/t-CO_2 in the future, compared with the existing DAC method, which requires about 4,000 kWh/t-CO_2 of heat.

(3) No Use of water

Solution-based adsorbents and current solid adsorbents require a huge amount of water in the DAC process. For instance, we understand that Carbon Engineering's Alkali aqueous solution requires the use of 1-13 tons of water to capture 1 ton of CO_2, which is not sustainable considering increasing water consumption around the world. However, our Zeolite based approach does not require water in the process. Rather, we might be able to produce water while capturing CO_2 from the atmosphere as a co-product.

In Japan, it is difficult to store CO_2 underground, so we will collaborate with companies who have the technology to store CO_2 into concrete bricks (see section 2 for potential partners in this domain). Meanwhile, we plan to seek opportunities abroad where CCS is available to store CO_2 underground, especially in APAC (such as Malaysia and Australia).

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

Planet Savers will develop the first DAC + Storage facility in Tokyo, Japan, which uses our first prototype DAC system that captures 300 tons/year at a cost of around $500/ton-$CO_2$.

In Japan, underground CO_2 storage is difficult, therefore collaboration with companies with CO_2 storage facilities into concrete bricks is sought upon (see potential partner companies' names in section 2).

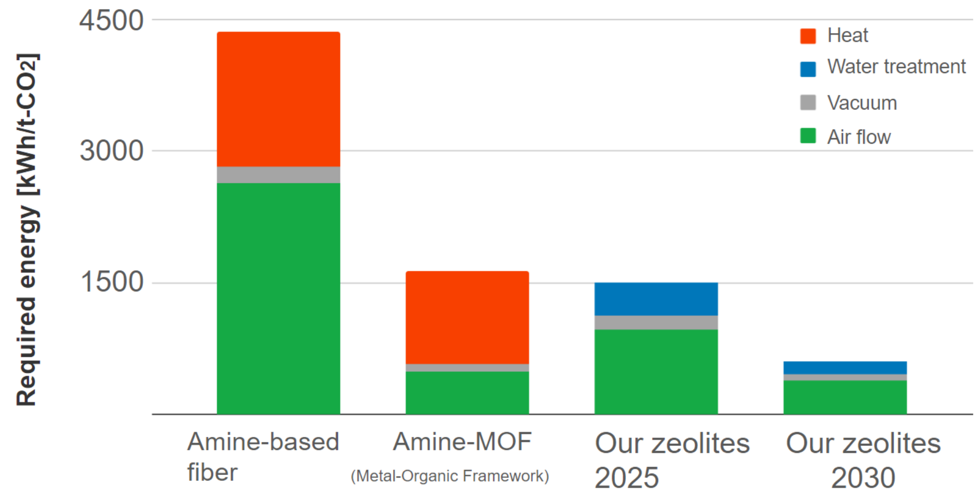
Monitoring and Quantification of CO_2 gas streams generated by the DAC machine will be performed utilizing Sensor technology.

In the beginning, the cost of (1) the machine (CAPEX) and (2) energy used to flow air are still high (e.g. around 25% of life cycle cost), but through R&D we expect to decrease it.

This first DAC prototype testing will allow us to collect more data to improve our technology for scaling up and reducing cost when we plan to start our mass production in 2029.

By 2030, we expect our mass production model DAC system, which is expected to capture 1,000 tons per year, to be around $130/t-$CO_2$. As we expect our DAC system to run for at least 20 years, the CAPEX cost and energy cost (OPEX) would be $25/ton of CO_2 and $34/ton CO_2 respectively including CO_2 adsorption, desorption, water treatment, etc.

Energy required for the zeolite-based DAC system is estimated to be around 1,500 kWh/ton-CO_2 in 2025 and 550 kWh/ton-CO_2 in 2030. We estimate that our net CO_2 reduction per unit would be over 600 kg-CO_2 in 2025 and 850 kg-CO_2 in 2030 by removing 1 ton of CO_2. Key assumptions for these calculations are; life-time: 20 years, operating days: 330 days per year, removed CO_2 per day: 1 ton, electricity cost: 12 JPY per kWh, CO_2 adsorption capacity @ 25 °C: 1 mmol/g.



Our ultimate goal is to get 1.5million DAC units deployed by 2050, which would achieve an annual CO_2 turnover of 0.5 giga tonnes and account for 50% of the expected total global DAC volume of 1 billion tonnes. We plan to focus on being a manufacturer and seller of the DAC system so that deployment can be conducted by DAC operators all over the world and the technology can be scaled up faster.

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

We mainly anticipate 6 key risks in the short term, and below are our plans to address them.

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

1. Risk: High pressure drops in the zeolite adsorption stage require large and high-power pumps. Solution: Pressure drops during adsorption depends on the shape of adsorbents and we have already communicated with some companies that can produce special shapes. 2. Risk: Cost of water removal treatment prior to the CO_2 adsorption since zeolite might adsorb water rather than CO_2. Solution: We have a unique water treatment system for which we have already applied for a patent. 3. Risk: Scaling up of the system to 1 ton-CO_2/d might be difficult. Solution: We are already running lab-scale (100g-CO_2/d) as well as a pilot scale machine (10kg-CO_2/d). The data obtained from these systems will be used for larger scale deployment. 4. Risk: Securing enough renewable energy might be difficult Solution: In the short term, we will coordinate with power suppliers to secure 100 % renewable energy through the market. Meanwhile, we are pursuing PPA agreements and developing on-site renewable energy capabilities for the future. 5. Risk: Japanese regulation might not support our DAC based CO_2 removal. Solution: We will communicate with the regulatory bodies in Japan and provide input with our recommendations to advocate for policies that are favorable for DAC businesses. 6. Risk: We might not be able to secure enough financing to develop our DAC system. Solution: We have already received $1.5M from a VC. In addition, we will apply for both global and Japanese local grants such as the Japanese Green Transformation Startup Grant ($3-4M). Also, we will keep communicating with other VCs to be prepared for bridging the financial gap if necessary.

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)*	700
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	2028
Levelized cost ($/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	$524 including storage cost
Levelized price ($/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	$714

[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).