High Hopes Labs

Carbon dioxide removal prepurchase application

Summer 2023

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 2023 summer purchase cycle. Include as much detail as possible but omit sensitive proprietary information.

Company or organization name

High Hopes Labs

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

Israel and Germany, with the first operating facility opening next year - likely in Southern USA , Australia or Southern Mexico

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

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Brief company or organization description <20 words

High Hopes Labs is the inventor and developer of a patented breakthrough high altitude direct air carbon capture technology (HACC)

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

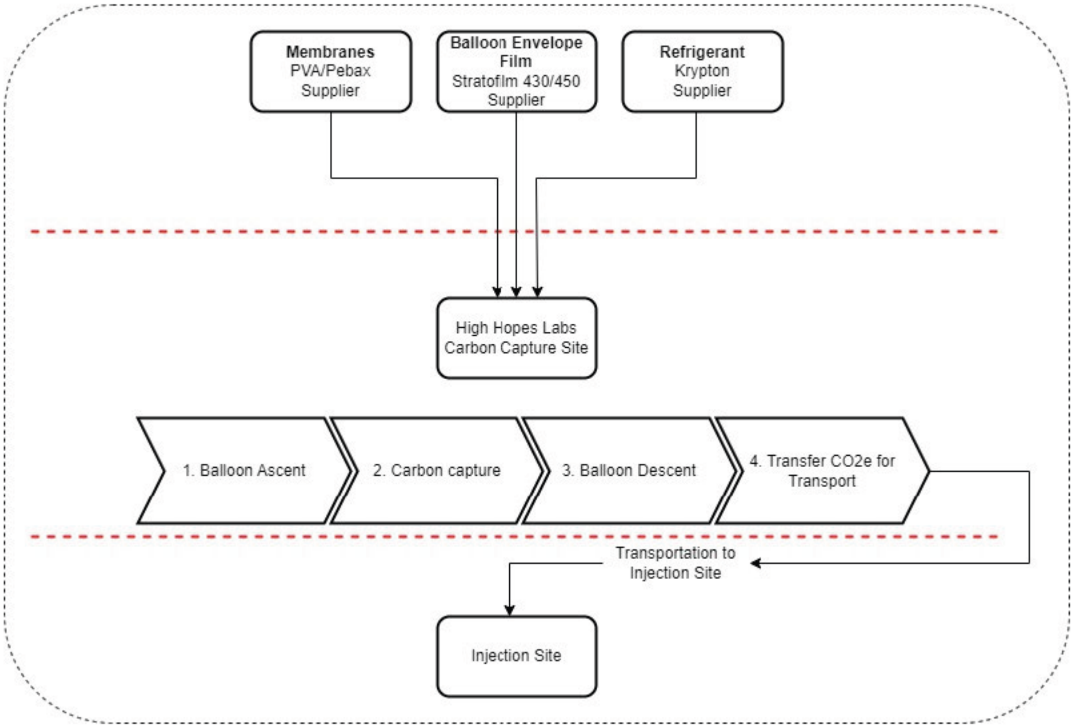
[1] We use "project" throughout this template, but note that term is not intended to denote a single facility. The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company.

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. Aim for 1000-1500 words.

1) High Altitude Carbon Capture (HACC) brings significant innovation versus any other existing carbon capture technology by using the energy efficiency potential of low temperatures, and high velocity winds found abundantly at high altitude, to capture carbon using membrane-based filtering and cryo-distillation. The result is a highly efficient carbon capture technology with a very low energy consumption/ cost per ton of CO_2 captured.
2) Our carbon capture technology is underpinned by two key methods performed at high altitude:
   A. Incoming high velocity air/wind is passed through tubes of porous materials with an internal lining of CO_2/N_2 membranes. The gas permeation unit (GPU) membranes provide a relatively efficient means to increase the CO_2 concentrations from the ambient ones (~400 ppm). Realistic enrichment factors allow to get to 1% with limited pressure losses and medium energy consumptions.
   B. Freezing and solidifying the carbon within the 'enriched' air using a Cryo-distillation method which is simply the transfer of heat outside of a gas to de-sublime it onto a surface. Since the high altitude provides an abundant low temperature reservoir, the temperature difference is lower, and the cooling performance better compared to when done on the ground.

3) The combination of these two techniques when utilized on a high-flying, low velocity platform such as a balloon or an airship, provide a simple, yet efficient solution for carbon capture, that does not rely on scarce energy and other resources - such as otherwise useful real-estate.
4) Our high-altitude carbon capture process is comprised of 4 key steps:
   a) Flying a balloon to a high altitude of ~15KM above ground where high velocity winds and cold air are abundant. Plot the balloon trajectory and control its path leveraging the variable wind direction at different altitudes (which are mapped and updated in real time every 3 hours by multiple organizations with API access).
   b) Funnel incoming high velocity air through a high gas permeation unit (GPU) membrane to slightly enrich the concentration of CO_2 in the air to about 1%, which will increase the effectiveness of the cryogenic distillation process to follow.
   c) Freeze the carbon in the air by cooling down the enriched air to a temperature of roughly -125C and collect the frozen carbon in batches into a designated pressure vessel.
   d) Slowly descend the balloon back to the ground landing station where the full pressure vessel can be removed, a new empty vessel installed, and the balloon is then maintained and readied for re-launch. The vessel containing the pressurized CO_2 gas (with over 99% purity) can then be easily transported for sequestration and storage for more than 1000 years. The flexibility provided by the ballooning site's layout and size allows us to construct it close to sequestration sites and thus minimize the operational carbon footprint.

Carbon capture process illustration



5) Using this technique, we can capture carbon at a very low cost of $70-85 per Ton of CO_2 captured (of which ~$42 is attributed to energy consumption)
6) As per a detailed life cycle analysis (LCA) which was conducted according to ISO 14044:2006, ISO 14067:2018, the project emissions represent 12% of the captured CO_2e, where 88% of the captured CO_2e from High Hopes Labs process can be sequestered. Currently, the solar energy is the highest contributor to the project emissions at 81%, followed by the transport to injection site at 16%. The emissions from the equipment and energy used for injection are unknown and excluded from the project emissions at this time.
7) HHL has secured the concept of capturing carbon at high-altitude (HACCing) with a patent with multiple claims that has already been granted in the US and other territories, while pending in others. The company has further applied for an additional pending patent for utilization and sequestration solutions of CO_2.
8) In addition to being a very cost-effective solution, High Hopes' technology is highly scalable due to the very limited land and ground infrastructure required, and, since each balloon farm can be established and run with very low capital, guaranteeing a high attractiveness also to investors/ franchisees that will enjoy a very short payback period (of around 2 years). Unlike many other technologies, there are no physical or other limitations on scalability.

a) **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 $100/t and 0.5Gt targets? What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. Aim for 1000-1500 words.

We are planning to build and operate our first commercial 'balloon farm' facility in 2024, with three high likelihood sites under consideration – Southern US, Southern Mexico, and Australia. These sites have been chosen based on our optimal site criteria, including relative proximity to the equator (where temperatures at high altitude are consistently the lowest), relatively low air traffic activity, and proximity to basic required infrastructure (e.g., roads, utilities, etc.).

This first operational facility will include our first-generation commercial balloons, each able to capture (conservatively and initially) 100 KG of CO_2 per 24 hours (which include 12 hours activity at target altitude and up to 12 hours for balloon travel time from/ to the ground).

At the time of operation launch, the balloon farm will initially operate 5 balloons, with a capture rate of 150+ Tons of CO_2/ year; the number of balloons, as well as the capture pace and efficiency of each balloon will grow over time, and within 3 years of operation's launch (2027) will operate 1000 balloons with increased capture efficiency of 400KG of CO_2 per day – and 140K Tons per year.

For conservative reasons, we have assumed no further improvement in the first-of-a-kind balloon farm's capture rate However, future built farms will continue to see significant increases in capture rate, namely:

- In 2028, the capture rate of each balloon will be increased to up to 1000KG of CO_2 per day – resulting in a total capture rate of 350K Tons per year per balloon farm
- In 2030, the number of balloons in operation in a farm will grow to 4000 balloons increasing the total capture rate of a balloon farm to 1.4M Tons per year

The expected cost per 1 Ton of CO_2 removed is estimated at thousands of dollars per Ton at initial operations launch (2024), rapidly decreasing to ~$330/ Ton as we reach the first major development milestone by 2027. Future balloon farms, given the further developments outlined above, will reach a much lower cost per Ton of CO_2 captured of about ~$70-85 by 2030 (of which ~$42 is attributed to energy consumption).

Starting from 2025, we intend to build and operate additional balloon farms to rapidly scale the total CO_2 captured with our technology, reaching a total of 200M Tons of CO_2 capture/ year by 2030, and surpassing 1Gt by 2035.

Balloon and payload High level Illustration

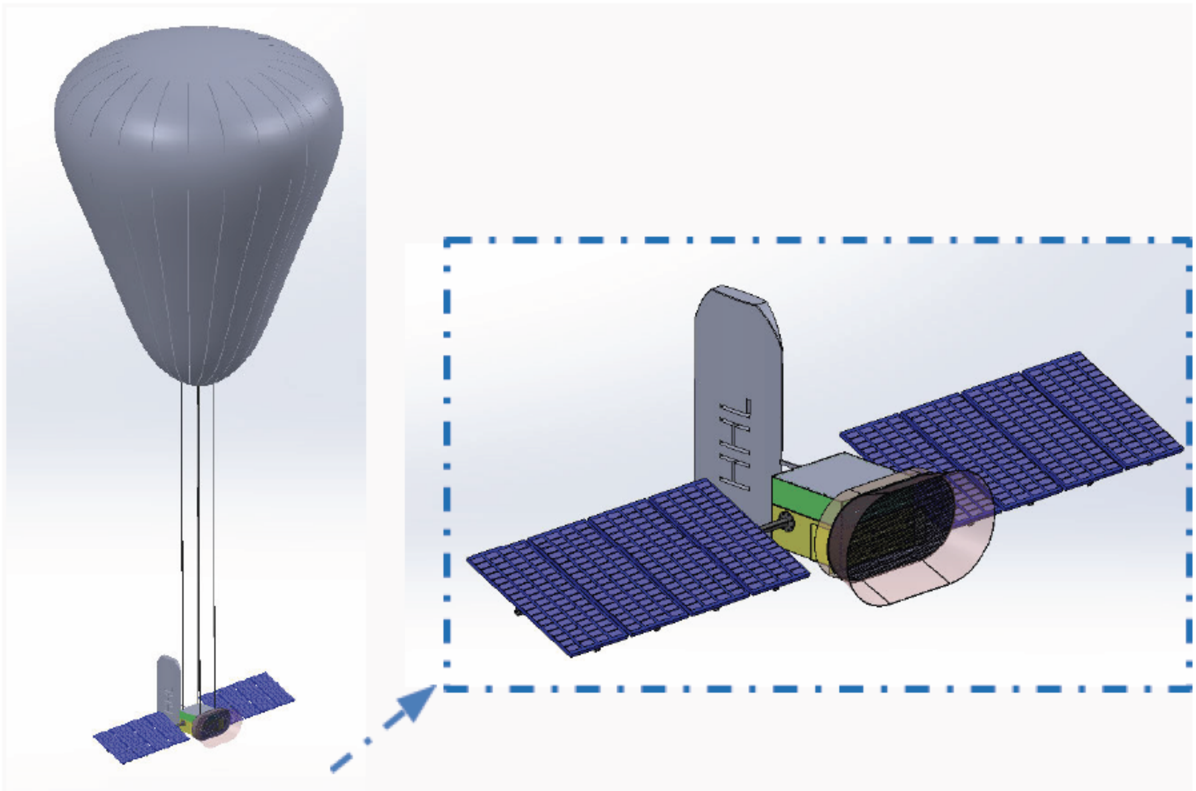
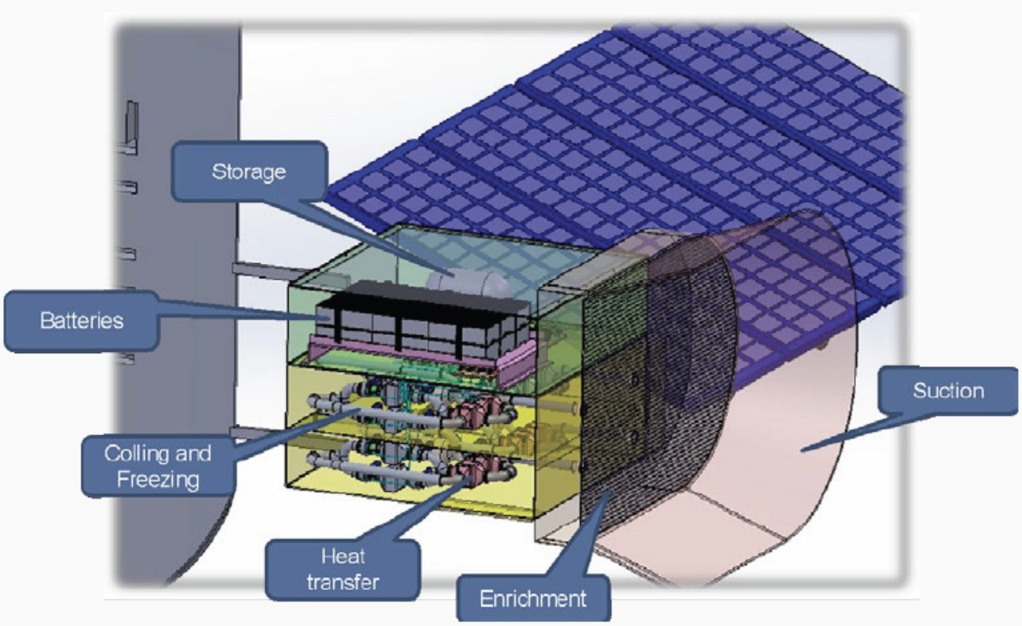
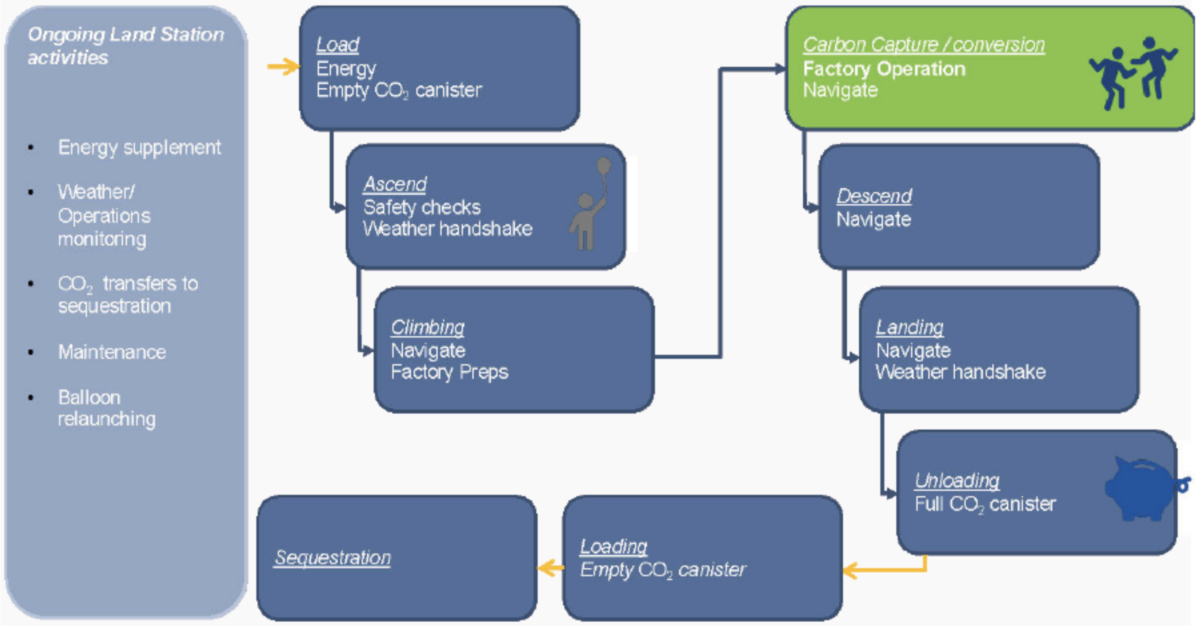


Illustration of the Payload's main components



The balloon farm 'land station' will provide the required infrastructure to operate and maintain the balloons, as well as manage the transpiration of captured CO2 to nearby sequestration facilities for sequestration and storage.

High Level ground station activities overview



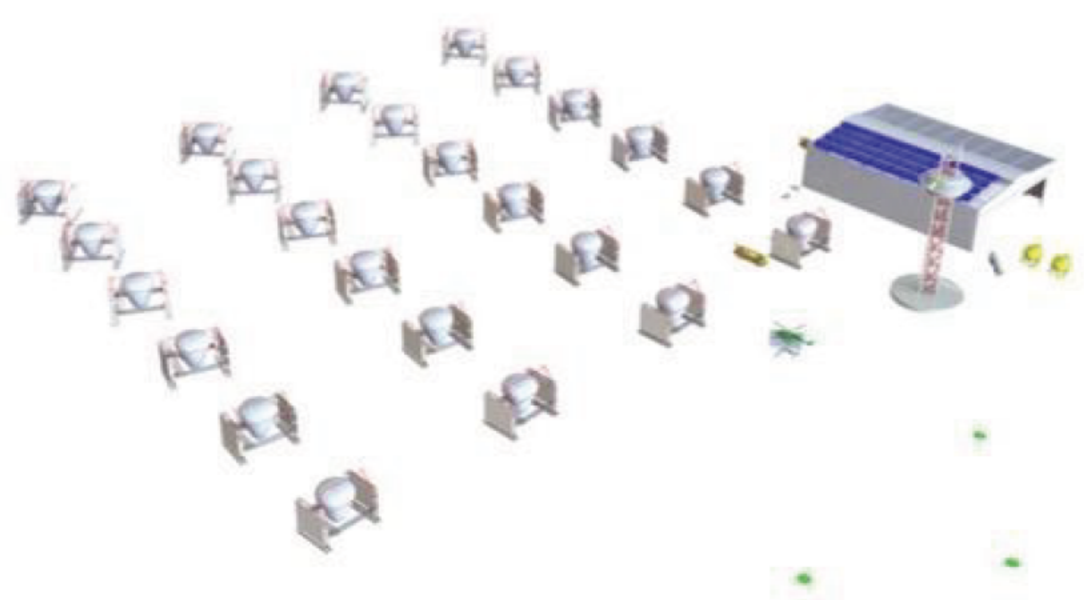
To deliver on these outlined activities, the balloon farm ground station will consist of the following main facilities:

- **A launch pad or platform**: This is a designated area where the balloon is prepared for launch and lifted off the ground. The launch pad should be large enough to accommodate the balloon and any associated equipment and should be strong enough to withstand the weight and forces involved in the launch process. We are using Google Loon project as a reference point and knowledge base.
- **A landing pad or platform**: This is a designated area where the balloon is captured by a drone for getting down to the ground. The landing pad should be large enough to accommodate the drone/ retraction system and the balloon.
- **A control center**: This is a central location where the launch team can monitor and control the various systems and equipment involved in the launch. The control center should be equipped with communication and control systems, as well as monitors and other equipment for operating, tracking, and monitoring the balloon (launching/ landing/ and its flight).
- **Power and utilities**: The ground station will need a reliable source of power and utilities, including electricity, water, communication, LTA gas supplies and other gasses for general purposes.
- **Weather monitoring equipment**: To optimize balloon farm's efficiency, we'll have equipment in place to monitor and forecast local weather conditions. This includes sensors and instruments

for measuring temperature, humidity, wind speed and direction, as well as other factors that can affect the launch.

- **Safety systems**: Safety is a critical concern in any balloon farm, so it is important to have various safety systems in place to protect personnel and equipment. These may include fire suppression systems, emergency communication options and evacuation systems, and other safety measures.
- **Access roads and transportation**: The launch site will need to be accessible by road and may also require additional transportation infrastructure to move personnel and equipment to and from the site.
- **Support facilities**: the farm may require additional support facilities such as offices, visitor's hall, laboratories, storage facilities, workshop, and other amenities.

Balloon farm ground station high level illustration



b) **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. Aim for 500-1000 words.

As with any new technology, the key uncertainty for our project lies in 4 main areas:

1. Technological aspects - We have a very clearly outlined roadmap and clear optimization levers we are pursuing under a prioritized roadmap, however as with any new technology, there is a

risk with regards to our ability to continue and optimize our technology and resolve various engineering challenges (such as scaling challenges by moving to a larger balloon) to achieve the required efficiency and capture rate at the proposed timelines/ cost. 2. Regulation aspects – There are some challenges with regards to our ability to secure all required regulatory approval to operate high altitude unmanned flying balloons in our designated operational facilities locations. However, we believe this to be a very small risk given that the regulatory burden we are required to comply with is very straightforward across most geographies, and we are partnering with very experienced local partners to further mitigate this risk. In addition, our ability to operate in many geographies and locations further mitigates the risk by ensuring we have a long and robust pipeline of alternative locations. 3. Business aspects – Our main business risk revolves around three themes: – Funding requirements: uncertainty regarding our ability to secure the required funding to launch the project at the required timeframe (we have significant interest from multiple investors, including CVCs, VCs and investment banks to name a few – but securing investments can always be a lengthier process than anticipated) – Uncertainty regarding the actual carbon credit price in the longer term– as with all green economy projects, our longer-term financial performance is closely tied to the carbon credit long term pricing – although our low cost per Ton ensures we are very viable under most scenarios. – CDR new technology disruption: Similar to every other scientific/ technological innovation, , there is a potential 'risk' that an alternative and new breakthrough technology is developed that allows the capture of billons of ton of carbon at a lower cost than High Hopes. 4. Other execution risks, including ability to source local labor, expertise, etc., have been significantly reduced given our local partnerships in all likely destinations (e.g., partnership with a leading local company that is serving as our design partner and allowing us to leverage their existing infrastructure, know how, supplier power, access to employees, etc.).

c) **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)*	Total estimated over project lifetime (50 years) for this project is 5M+ Tons of CO2 captured (after taking a conservative 20% discount as outlined below). Over the delivery window (2023-2027) the total expected CO2 capture amount is: ~129K Tons of CO2.
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	Upon full delivery, by 2027
Levelized Price (\$/ton CO_2)* *(This is the price per ton of your offer to us for the tonnage described above)*	\$700

** 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).*