Planetary
Carbon dioxide removal prepurchase application
Summer 2023

General Application

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

Planetary Technologies Inc.

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

24 Orion Court, Unit 24#1A/B Dartmouth, Nova Scotia B2Y4W6 Canada

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

Pete Chargin, VP Commercialization and Community Relations Mike Kelland, Chief Executive Officer Kelsey Cuddihy, Sr. HR and Administration

Brief company or organization description

Planetary Technologies harnesses the ocean's natural ability to remove carbon dioxide from the atmosphere using low carbon alkalinity.

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. Aim for 1000-1500 words.

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[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.

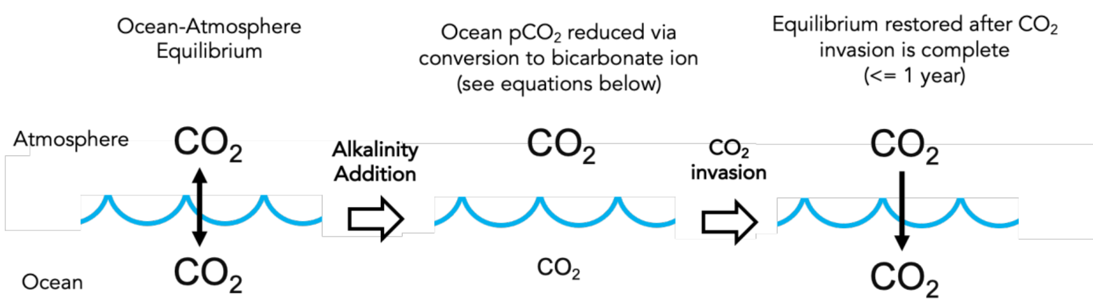
Overview

Planetary Technologies is developing the world's first carbon removal system that turns coastal outfalls into carbon removal machines. We propose to structure an Advance Market Commitment transaction with Frontier for permanent carbon removal totaling 2,000 tonnes to take place in 2023/2024 across up to three project sites located in Cornwall, UK, Halifax, Nova Scotia CA, and in Vancouver, British Columbia CA.

Through a process known as Ocean Alkalinity Enhancement (OAE), we add a pure and mild form of antacid or "alkalinity" to the ocean such as magnesium hydroxide (MH). Once added, this alkalinity neutralizes acidic CO_2 present in seawater by converting it into carbonate and bicarbonate. As ocean CO_2 is converted, the ocean absorbs CO_2 from the atmosphere to bring the air and ocean back into equilibrium. As an added benefit, OAE reduces ocean acidification in the local area, potentially providing ecosystem restoration benefits.

Our process is inspired by nature's own rebalancing process. In the geologic carbon cycle, rain erodes alkaline rock, transferring alkalinity from land into the ocean, which then transforms dissolved CO_2 present in the ocean into carbonate and bicarbonate. Due to an imbalance with the air, atmospheric CO_2 is drawn into the ocean and permanently stored in ocean chemistry. However, the Planetary process works in a matter of months rather than the millenia required by the geologic carbon cycle. The diagram below (***Figure 1***) illustrates our proposed carbon removal process and sequestration in ocean chemistry.

Figure 1: *Basic chemistry of OAE by MH addition*



Full Equation[1]: $Mg^{2+} + 2OH^- + 1.65(CO_{2aq}) \dashrightarrow Mg^{2+} + 1.48(HCO_3^-) + 0.17(CO_3^{2-}) + 0.18(OH^-)$

coefficients vary with pH, T, S, and P. Values shown for pH=8.1, 20°C, 35ppt, 10dB

Simplified Equation: $OH^- + CO_2 \rightarrow HCO_3^-$

Figure 1 *Basic chemistry of OAE by MH addition*

We have demonstrated alkalinity enhancement using magnesium hydroxide ($Mg(OH)_2$) slurry from a simulated outfall at mesocosm scale. We have also completed an OAE field trial in the UK in September 2022 which successfully validated carbon dioxide removal by OAE using our MRV protocol.

Our proposed transaction aims to fund the removal of up to 2,000 tonnes of CO_2 through a second trial at our Cornwall, UK site, and at new trial sites in Halifax, Nova Scotia expected to begin operation in August and Vancouver BC in 2024. By Q4 2024, our goal is to have the capacity to remove over

10,000 tonnes annually through the two initial project sites and 1-2 additional sites brought online subsequently. Planetary's 5-year goal is to secure removal capacity for 1M tons of CDR, with minimum actual removals of 50k tonnes per year. Removal volumes for the targeted capacity will be determined by the availability of low CI, low cost alkalinity. However, even at the lower end of the range, we will activate our distribution network to remove up to 1M tons of CO2 annually, in time for Planetary's own commercial scale production of low CI, low cost magnesium hydroxide.

Our projects will utilize Planetary's OAE-MODOM (MOdular DOsing and Monitoring) V2.0 systems to more accurately measure and verify our carbon removal impact. This system will integrate alkalinity deployment technology (pumps, storage tanks, agitators, and variable dosing devices) with chemical monitoring (chemical probes with telemetry), and forward the resulting data streams to Planetary's software platform for analysis and reporting.

We continue to partner with Dalhousie University to study the efficacy and marine impacts of OAE via a 3-year NSERC Alliance grant. Investigation into the effects of OAE on Oceanic Primary Production (phytoplankton) is currently underway in partnership with Planetary Technologies, Dalhousie University, and the National Research Council of Canada.

In order to remove large volumes of CO_2 we will ultimately need large volumes of low CI, low cost alkalinity. Our second Cornwall trial will use a natural mineral form of brucite purchased from a North American supplier. Based on CI estimates and brucite costs, alkalinity costs range from $1500 - $1600/net CDR tonne. We are projecting a 50% reduction in removal costs over the next year through optimization of mineral transportation (currently 40% of embodied emissions), operational efficiencies at outfall locations and pre-treatments, such as calcination of brucite, to increase reactivity rates. We expect our alkalinity sourcing strategy to continue to evolve as we experiment with various alternatives in our quest to achieve the lowest carbon intensity and cost possible (see **Confidential Information #1**).

Concurrent to scheduled OAE trials, we are scaling-up our own process to electrochemically produce $Mg(OH)_2$ from asbestos mine tailings from Thetford, QC and other mine wastes. Using traditional metallurgical techniques we extract battery metals (nickel and cobalt), silica (sand) and other impurities. We then add the remaining purified metal salt solution into an electrolysis cell. There, using clean, renewable electricity, the metal salt and water are split to make green hydrogen (a clean, emissions-free fuel), oxygen, an acid and a pure alkaline hydroxide. The acid and oxygen are used internally in the upstream metallurgical process. The pure alkaline hydroxide ($Mg(OH)_2$, or magnesium hydroxide) is then transferred to the ocean for OAE through permitted outfalls.

We have demonstrated electrical efficiencies that would yield $150/t CDR (without co-products) for production of Planetary's magnesium hydroxide in the lab and are now in the pilot phase to bring this process to commercial scale. This internally produced alkalinity source will be the highest volume, lowest carbon intensity, and lowest cost approach to alkalinity sourcing for CDR. This solution has the potential for multi-billion tonne annual carbon removals at a cost below $50 per tonne of CO2 removed in the 5-7 year time-frame.

Summary Figure:

Figure 2: Alkalinity Production with Planetary's Proprietary Electrochem Cell

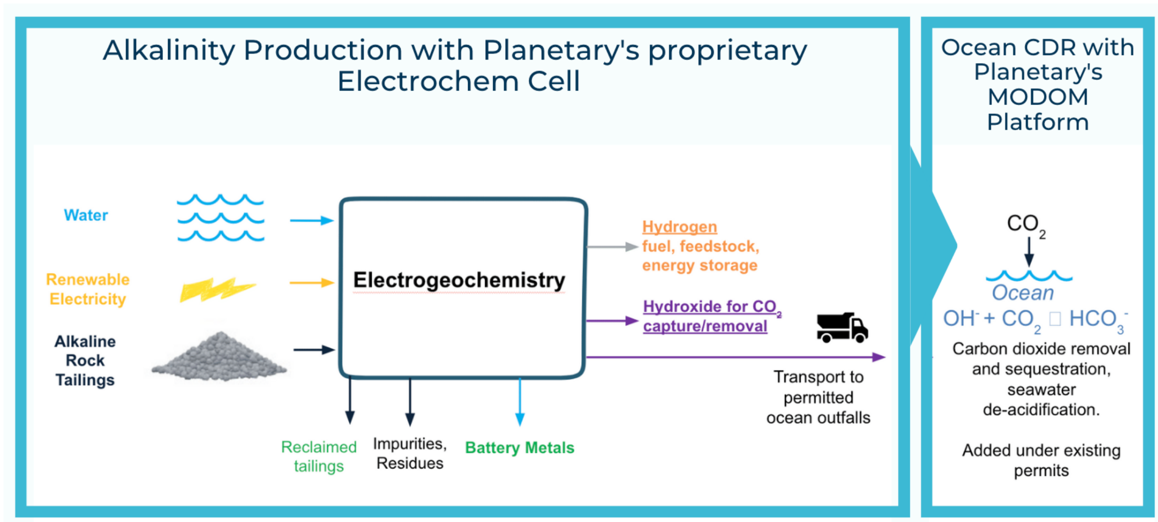


***Figure 2**: This figure describes the end to end process of Planetary's production of magnesium hydroxide, from alkaline rock tailings through to Ocean CDR*

Tech status:

Our ocean carbon dioxide removal development is at a current TRL 7. We have demonstrated alkalinity enhancement using $Mg(OH)_2$ slurry from the actual outfall we plan for these removals at a smaller scale. We have also developed the first known creditor-approved (Shopify) OAE MRV protocol. Our MRV is publicly posted through GitHub for comment and review.

This past September we completed a 3-day OAE field trial in the UK which successfully validated 4 tons of gross carbon dioxide removal by OAE using our MRV protocol. **Figure 3** demonstrates the OAE monitoring process used during this trial.

Figure 3: Planetary's OAE Monitoring Process

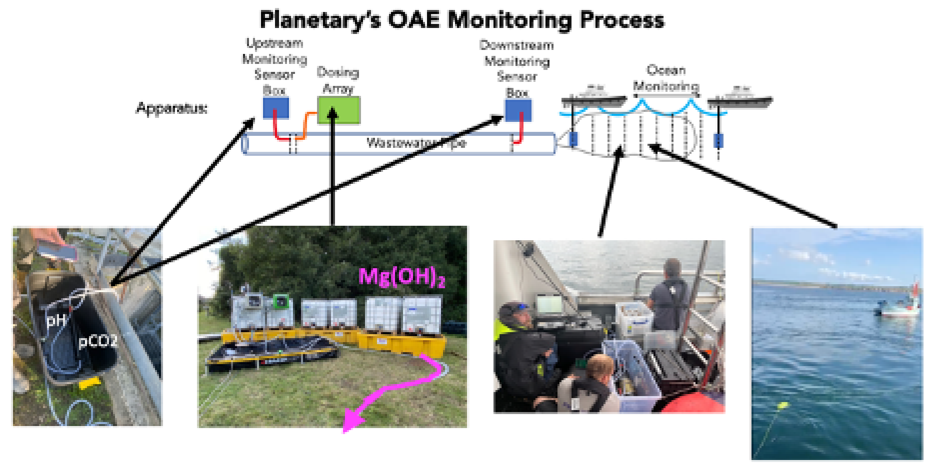


Figure 3 This diagram shows the process used to dose and monitor alkalinity added during the September OAE trial in the UK. This process allowed us to successfully receive a clear signal of CO2 removal and became the basis for our OAE MODOM.

The result of the methods test was a clear signal of carbon removal within the pipe. As seen in **Figure 4 ,** CO_2 data collected from the wastewater pipe, you can visualize the carbon removal evidenced here by the space between the blue (upstream) and red (downstream) data points. The three black lines indicate when alkalinity dosing occurred and aligns with the % drops. Evidence of ocean alkalization was also measured from a vessel near the outfall. This was a resounding success, and has convinced our partner and the regulator in the UK to engage with Planetary in future prolonged trials in 2023 at this same UK site and beyond.

Figure 4: %CO2 differences in a wastewater pipe

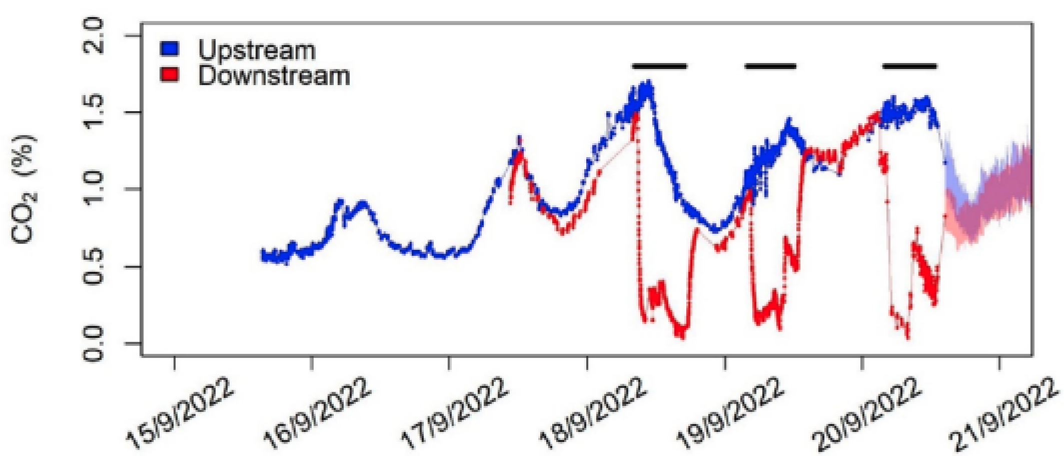


***Figure 4.** %CO2 differences in a wastewater pipe measured upstream (blue) and downstream (red) of MH addition. Black horizontal lines indicate the periods of MH addition during the 3-day test. pCO2 is approximately equal to %CO2 x 1000 µatms/% at 1 atm total pressure.*

Figure from Kitidis et al. (2023).

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 $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.

Project Locations:

Our current alkalinity addition sites are a municipal wastewater treatment facility located in Hayle, Cornwall, UK and a cooling water loop from a thermal power plant in Halifax, Nova Scotia.

Discussions are underway to add sites in Vancouver, Houston and Connecticut.

We have completed qualification testing on three sources of brucite that meet environmental, yield and carbon intensity targets to allow our OAE trials to commence in Q2 2023. We are now in contract discussions with a major North American mineral supplier to deliver our trial alkalinity. In the medium-term, we expect to source alkalinity from multiple sites around the world, with different sources being optimal for given outfall locations based on a number of factors.

For our own alkalinity production process, we have secured rights for up to 180M tonnes of mine tailings located in Thetford Mines, Quebec, Canada, which could remove approximately 70-90M tonnes of carbon from the atmosphere over time.

Capacity:

Our proposed CDR targets for the Frontier purchase at our project sites in the UK and Canada, totalling 2,000 tonnes, represent a small fraction of the ultimate capacity at the two sites, estimated to be more than 500,000 tonnes per year on a combined basis.

The capacity of the ocean reservoir to store CO_2 is vast. 88% of Earth's surface carbon (37,800 Gt) exists as bicarbonate and carbonate ions in seawater. Adding 1 Gt C/yr to this reservoir would increase the reservoir size by <0.003%/yr. The scalability of our process to add carbon to this immense ocean reservoir is considerable, with negligible impact on the ocean itself.

Durability:

The mean residence time of alkaline carbon in the ocean is 100,000 yrs. This is a common textbook understanding (e.g. Emerson and Hedges, 2008) based on a mass-balance approach that considers inputs, outputs, and the mean concentration of alkaline carbon in seawater.

Verification:

We announced the release of the world's first Ocean Carbon Dioxide Removal (oCDR) Monitoring, Reporting and Verification (MRV) Protocol for OAE Carbon Removals in February 2023. This protocol is designed to allow our Ocean Alkalinity Enhancement projects to deliver carbon removal credits, ensuring their accuracy and transparency.

This open-source protocol provides clear guidelines for developing ocean CDR projects, including how to calculate carbon removal and estimate lifetime storage, including use of a holdback contingency factor to support initial conservatism in calculating net CDR and gradually improving accuracy over time. It also includes a standardized measurements protocol for assessing the carbon removal performance, which increases trust and drives further investment. Planetary intends to engage third party verification of our carbon removals and retirements including independent assessment of our LCA calculations and resultant net removals achieved.

Cost:

The single largest cost driver in OAE CDR is driven by the cost of suitable alkalinity, currently priced at $1500 - $1600 / tonne of CO_2 removed on the open market. Our goal is to drive the cost of alkalinity down to under $150 / tonne of CO_2 removed by using a portfolio approach to secure alkalinity from multiple sources between 2023 and 2027 and to $50 / tonne of CO_2 removed by 2029 using Planetary's proprietary technology to produce low CI, low cost alkalinity at commercial scale.

Our portfolio approach to sourcing alkalinity will enable us to remove atmospheric CO_2 now while building the distribution network required for scaled production of our own lower cost alkalinity in 2029. Each medium-term source is expected to offer a minimum scale of 100,000 tonnes per year, whereas Planetary's first alkalinity production facility will aim to deliver 1M tonnes per year.

While we believe that our process will provide the highest volume and the lowest cost, our portfolio approach will reduce risk, increase scale, and speed deployment.

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. Aim for 500-1000 words.

Technical Risk	Mitigation Strategy
There is a chance that the specific batch of MH that is delivered does not meet purity requirements.	• Engage with suppliers to thoroughly test each lot before shipment. • Test each lot on delivery with an accredited and licensed lab for elemental analysis. • Hold bad lots for future processing to increase purity

Project Execution Risk	Mitigation Strategy
Delays in selecting and contracting a supplier for MODOM DoseBox components may delay project schedule	• Functional specification (based on initial Cornwall experiment in September 2022) already completed; • Potential vendor identification has commenced
Alkalinity delivery and preparation may face unforeseen operational challenges	• Partner with an experienced handler (Garrison Minerals) to arrange initial deliveries and operational set-up with fixed price contract and liability protections
Operating two dosing sites continuously at a higher scale could result in logistics delays and would leave little capacity to address multiple operations issues concurrently (ex. alkalinity supply deliveries, equipment failures, host-site challenges)	• Recruit dedicated project managers for each site (we currently have one for Cornwall, but will need to hire an additional project manager to increase the capacity of the operations team.
Data production and analysis problems	• Duplicate/back-up sensors with regular sensor maintenance checks in the event that a sensor goes offline

Regulators are unhappy with project reporting and/or trial results	• Communicate implementation plans clearly, confirming regulatory reporting requirements, and maintain frequent communication throughout the trial process at each site
	• Ensure that local government officials are fully aware of our projects and plans
	    ○ UK: 4 MPs, the county councilor for environment, members of the GGR task force, etc.
	    ○ Canada: the Minister of Environment, Nova Scotia Department of Environment and Climate Change

Public opposition to CDR trials could prevent or interrupt project trials	• Implement community engagement processes that offer transparency to our process and state of knowledge, communicate risks and opportunities, and incorporate community feedback (Community outreach has commenced at the two pilot sites.)

Ecosystem Risk	**Mitigation Strategy**
Uncertainty over ecological and environmental impact of $Mg(OH)_2$ discharge impacts regulatory and public acceptance.	• $Mg(OH)_2$ is generally accepted as benign in the marine environment; • We've partnered with Dalhousie University on experimental work on phytoplankton toxicity (NSERC Alliance grant); • We've conducted and have included biological/ecological baseline survey and monitoring as part of our deployment plans;
Specific concerns have been expressed as to the impacts of undissolved particle settlement in the benthic environment and any potential impacts on the marine environment.	• We are working with local stakeholders to build pre-addition quantifiable data to baseline our trial going forward • Extensive experimentation testing impacts of Mg(OH)2 on benthic microbiology (e.g. microbes, bacteria) and fauna (seafloor creatures) will begin in the UK and Canada in 2023.
Precipitation would alter seawater chemistry, possibly impacting biota.	• Implement dosing regimens that ensure that dosing remains well below precipitation thresholds

Financial Risk	**Mitigation Strategy**
Delay in completing the sale of catalytic carbon credits may delay the project.	• Engage with Frontier to complete purchase quickly • Be prepared to allocate other sources of Planetary funding to finance alkalinity purchase
CDR removal efficiency is less than projected, increasing cost on a net removal basis.	• Complete testing of alkalinity before shipment to site, to minimize risk of mistaken composition and efficiency projections • Negotiate contract provisions that place composite risk on alkalinity seller

Other Risk	Mitigation Strategy
Inability to achieve sufficient dilution of the alkaline discharge to remain within environmental quality standards may limit dosing rate scale-up and ability to measure as signal within the outfall. Excessive loss of non-CO_2-equilibrated alkalinity from the surface ocean mixed layer reduces CDR effectiveness.	• Use of $Mg(OH)_2$ instead of alternative alkalinity (e.g. NaOH) reduces discharge pH to a maximum of ~9.5 when dissolved in seawater. Initial dilution modeling studies confirmed that the required dilution factor is achieved with diffusers in a minimum of 5m water depth; • $Mg(OH)_2$ product specification will include limits on particle size distribution; • Expected loss through particle sinking will be defined for each site as part of the existing Measurement Reporting and Verification (MRV) protocol; • Natural mineral dissolution risk addressed through lab testing, low temperature post-processing (e.g. dehydroxylation) can further mitigate dissolution risk. • Loss of non-CO_2-equilibrated alkalinity covered by efficiency factor and holdback in the MRV
Some community members may attempt to stop the project due to lack of knowledge, lack of trust, other concerns regarding the impacts on the local environment, or "not in my backyard" sentiment.	• Engage with the community and identify appropriate community channels. Work with community groups to identify areas of concern and co-develop a plan to mitigate those concerns. Communicate proactively on the project intent and scope. Engage with the regulatory bodies as the representatives of the community.

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 (tonnes) *(should be net volume after taking into account the uncertainty discount proposed in 5(c))*	2,000 net tonnes CDR (Note, volume as associated with project delivery window, not total project lifetime)
Delivery window *(at what point should Frontier consider your contract complete? Should match 2(f))*	May 2023 - December 2024, or when 2,000 tonnes have been certifiably delivered.
Levelized Price ($/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	USD$1600 / net tonne CDR

** 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).*