General Application

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

Company or organization name

Planetary Technologies Inc.

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

Dartmouth, Nova Scotia, Canada

Name of person filling out this application

Omar Sadoon, Jason Vallis, Brock Battochio, Kelly Wachowicz, Greg Rau, Will Burt, Mike Kelland

Email address of person filling out this application

[redacted]

Brief company or organization description

Planetary converts mine waste into alkalinity for OAE CO_2 capture

1. Overall CDR solution (All criteria)

a. Provide a technical explanation of the proposed project, including as much specificity regarding location(s), scale, timeline, and participants as possible. Feel free to include figures and system schematics.

Overview

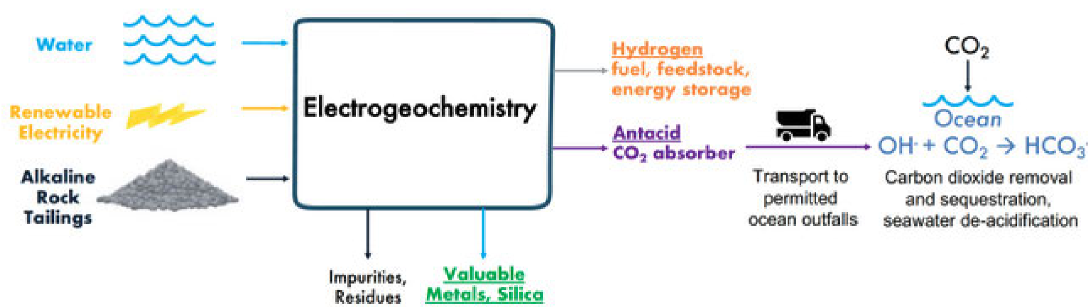
Planetary's approach to Ocean Alkalinity Enhancement involves the production and addition of a pure magnesium hydroxide (MH) to seawater via existing permitted outfalls.

While commodity products like hydroxides are already available on the market, the carbon footprint of these would negate much of the intended carbon removals. Therefore, Planetary started from scratch to find waste minerals (mine tailings) from around the world to use as a feedstock for purification and use in our electrochemical cell.

Using traditional metallurgical techniques we start by carefully extracting key parts of the mine tailings including recovering battery metals (like nickel and cobalt) and silica (sand) and then take 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.

It's from this point that we transport the pure, bulk alkaline material to our ocean outfalls site where the alkalinity is introduced to the surface ocean, that then draws in CO_2, sequestering it as already abundant bicarbonate and carbonate ions in seawater.

Summary Figure:



Project Locations:

Our mine tailings site is located in Quebec, Canada. The feedstock from this location represents megatons of CDR and was selected for accessibility to clean renewable energy and available transport for trans-atlantic shipping.

The permitted pilot outfall site for the Stripe project is a municipal wastewater treatment facility located in the southwestern UK. Development towards additional pilot sites in eastern Canada (Halifax, Nova Scotia) and southern US (Miami) are also underway.

Project Timeline & Scale:

Each deployment consists of a mine site and a permitted ocean outfall. The project outlined here encompasses both features and the timeline is between 2022-2028 while a scale of 301Kt CO2/ yr can be reached by 2027 as we develop additional permitted outfall partnerships and our production capacity of low CI MH is increased. The CDR scale further increases with each following year.

Project Participants:

Planetary - Technology Developer and Project Lead

Mining Partner (undisclosed) - Site owner and tailings supplier

Technology Partners (SGS & DST) - Existing mine site operator supporting technology pilotting

Dalhousie University - OAE research partner supporting MRV efforts

Canadian Federal Government - R&D funding partner

SouthWest Water - Outfall owner and wastewater treatment facility operator

Physical Footprint:

Planetary's process is focused on two locations. The mine site is where testing, validation, electrolysis, and MH production will occur. We expect these activities to be integrated into existing mine site operations with no additional site excavation or land use changes required.

Ocean outfall locations for dosing the produced alkalinity are also colocated with outfall operators sites and do not require land use changes. At pilot scale, the total footprint of our dosing system will include slurry storage at an estimated 15 m^3.

Capacity:

The capacity of the ocean reservoir is vast. 88% of Earth's surface C (37,800 Gt) already 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 capacity of our process to add carbon to this immense ocean reservoir is considerable. The pilot outfall site in the UK is a relatively small municipal wastewater facility. Our current listed capacity at this site (~1000 tCO2/y, see below) is constrained by a pilot-scale engineering report, whereas calculations based on water discharge and environmental considerations predict the maximum site capacity to be roughly ~100x higher (~100kt CO2/y). Innumerable outfalls exist around the globe, and many will have similar or considerably higher capacities. For example, a nuclear power station currently under construction in the UK will have a carbon capture capacity on the order of 2Mt/y. By developing a framework for locating, permitting, and developing outfall sites, we will compile an array of outfalls around the world, enabling our process to reach beyond Mt/y scale.

Durability:

Long. The mean residence time of alkaline C in the ocean is 100,000 yrs. The ultimate fate of half of this C is as solid $CaCO_3$ precipitated from seawater, with a mean residence time of many millions of years.

Verification:

Potentially challenging considering that OAE will only add a very small amount of C to an already massive C reservoir (see "capacity"). Use of advanced sensors, autonomous marine platforms, tracers, chemical proxies and modeling will provide MRV.

Cost:

Low at full scale, considering the multiple, valuable co-products and services Planetary generates and the revenue they produce.

b. What is your role in this project, and who are the other actors that make this a full carbon removal solution? *(E.g. I am a broker. I sell carbon removal that is generated from a partnership between DAC Company and Injection Company. DAC Company owns the plant and produces compressed CO_2. DAC Company pays Injection Company for storage and long-term monitoring.)*

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SouthWest Water - Outfall owner and wastewater treatment facility operator

c. What are the three most important risks your project faces?

The most important risks are improving the energy efficiency of our electrochemical cell, validating our OAE measurement, reporting and verification (MRV) protocol and building strong community partnerships.

Risk 1 - Energy Requirements:

Over 80% of the energy requirements for our process are driven by our novel electrochemical cell which generates low CI alkalinity for OAE as well as other byproducts. Our technology development roadmap sees us reducing this energy requirement by 60% through piloting optimization. This energy also needs to be renewable and surplus to demand. We are relying on hydro-capacity of the Quebec grid for this project.

Risk 2 - Measurement, Reporting and Verification Protocol:

Our business model relies on certifying carbon removals and selling by-products (hydrogen, metals) as well as mine waste remediation services to bring down the cost of carbon removals below \$50/tonne CO_2 at commercial scale.

Certifying carbon removals via OAE means validating our ocean models and outfall suitability assessment tools and working with independent verifiers. We are currently moving from bench scale tests to aquatron level (pool sized controlled alkalinity addition at Dalhousie University) to validate our measuring and dosing protocols while working in three locations (Cornwall, Halifax, Miami) to conduct background studies, modelling, and eventually permitted outfall alkalinity addition that will validate models needed to certify carbon removals.

Risk 3 - Social License:

It's important to acknowledge the sensitive nature of doing work within the ocean. While existing evidence indicates that alkalinity addition will have neutral to beneficial impacts on marine biology and the environment*, Planetary and others are further testing that assumption on relevant organisms/sites. Additionally, we are establishing a scientific steering committee and engaging with community stakeholders, including development of a 'two-eyed seeing' approach with local indigenous organizations.

* Albright et al. (2016) https://www.nature.com/articles/nature17155

d. If any, please link to your patents, pending or granted, that are available publicly.

https://patents.google.com/patent/US20210340681A1/en

https://patents.google.com/patent/US20220002889A1/en

https://patents.google.com/patent/US10113407B2

https://patents.google.com/patent/US8764964B2/en

e. Who's the team working on this? What's your team's unfair advantage in building this solution? What skills do you not yet have on the team today that you are most urgently looking to recruit?

The project team includes Planetary's engineers, metallurgists and scientists as well as site partners in Quebec and permitted outfall owner SouthWest Water - UK.

Our team's fair advantage is our unique, patented CDR approach combined with our depth of technical and business experience, supported by an agile product development framework and strong leadership (mouthful but true!).

Our CTO, Dr. Greg Rau, has 40+ years of experience in basic and applied carbon cycle research and CO_2 management technologies. He has spent the past 14 years developing the Planetary process and has authored 100+ papers, and is a listed inventor or co-inventor on six awarded US patents, including those on which our technology is based.

Our CEO, Mike Kelland, and CFO, Kelly Wachowizc have decades of experience starting, building and scaling successful companies in both the technology and ocean space. They support the technical teams advancing both Planetary's alkalinity production and OAE MRV protocol development.

Our technical teams are led by extremely knowledgeable and highly networked practitioners. Green Team - piloting alkalinity production is led by Alex Mezei, Director of Metallurgy with 40+ years of experience. This engineering team is complemented by technology development partners including SGS Mineral Services Canada (metallurgical and electrochemical testing) and Dundee Sustainable Technologies (mine site piloting partner).

Blue Team, developing OAE MRV protocols is led by Dr. Will Burt, Senior Marine Chemist and former professor of Oceanography at University of Alaska Fairbanks. This team is working closely with academic and research institutions including Dalhousie University, Plymouth Marine Laboratories and the University of Miami to advance OAE MRV protocols. We are most urgently recruiting additional metallurgical and electrochemical specialists to accelerate our current piloting activities within the Green team.

2. Timeline and Durability (Criteria #4 and Criteria #5)

a. Please fill out the table below.

	Timeline for Offer to Stripe
Project duration *Over what duration will you be actively running your DAC plant, spreading olivine, growing and sinking kelp, etc. to deliver on your offer to Stripe? E.g. Jun 2022 - Jun 2023. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	*Mid 2023 - End 2028*
When does carbon removal occur? *We recognize that some solutions deliver carbon removal during the project duration (e.g. DAC + injection), while others deliver carbon removal gradually after the project duration (e.g. spreading olivine for long-term mineralization). Over what timeframe will carbon removal occur?* *E.g. Jun 2022 - Jun 2023 OR 100 years.*	*End of 2029* *Removal <=1 year after addition*
Distribution of that carbon removal over time *For the time frame described above, please detail how you anticipate your carbon removal capacity will be distributed. E.g. "50% in year one, 25% each year thereafter" or "Evenly distributed over the whole time frame". We're asking here specifically about the physical carbon removal process here, NOT the "Project duration". Indicate any uncertainties, eg "We*	5% - 2023-2026 -trials underway at UK site, with resulting carbon capture reserved for other creditors. Limited additional MH production capacity due to demo plant construction. 45% in 2027, 50% in 2028

anticipate a steady decline in annualized carbon removal from year one into the out-years, but this depends on unknowns re our mineralization kinetics".	Dramatic increase in MH production facilitates full operating capacity at UK pilot outfall site.
Durability *Over what duration you can assure durable carbon storage for this offer (e.g, these rocks, this kelp, this injection site)? E.g. 1000 years.*	Average 100,000 years

b. What are the upper and lower bounds on your durability claimed above in table 2(a)?

10,000 — >1,000,000 years

c. Have you measured this durability directly, if so, how? Otherwise, if you're relying on the literature, please cite data that justifies your claim. *(E.g. We rely on findings from Paper_1 and Paper_2 to estimate permanence of mineralization, and here are the reasons why these findings apply to our system. OR We have evidence from this pilot project we ran that biomass sinks to D ocean depth. If biomass reaches these depths, here's what we assume happens based on Paper_1 and Paper_2.)*

We rely on a mean residence time of alkaline C in seawater of about 100,000 years as calculated by Middelburg et al. (Middelburg, J. J., Soetaert, K., & Hagens, M. 2020. Ocean alkalinity, buffering and biogeochemical processes. Reviews of Geophysics, 58(3), e2019RG000681), and by Renforth and Henderson (Renforth, P. & Henderson, G. 2017. Assessing ocean alkalinity for carbon sequestration. Rev. Geophys. **55,** doi: 10.1002/2016RG000533).

These findings can be applied to any specific system because they are based on fundamental understanding of the marine carbonate system. Additionally, our initial experimentation indicates that CO_2 uptake is not 100% efficient (see section 3b), meaning that after CO_2 uptake is complete, the seawater alkalinity is elevated relative to its carbon content, which will further buffer against any subsequent conversion back to atmospheric CO_2.

d. What durability risks does your project face? Are there physical risks (e.g. leakage, decomposition and decay, damage, etc.)? Are there socioeconomic risks (e.g. mismanagement of storage, decision to consume or combust derived products, etc.)? What fundamental uncertainties exist about the underlying technological or biological process?

Our process relies on stably altering seawater chemistry, thus we avoid risks related to leakage, decomposition, or decay.

One potential durability risk is alkalinity loss due to biotic or abiotic calcification via: Ca^{2+} + $2HCO_3^-$ ---> $CaCO_{3s}$ + H_2O + CO_{2g}. Calcification and subsequent carbonate burial happens naturally, but at an extremely low rate, resulting in an annual loss of less than 0.003% of the ocean's resident alkaline carbon reservoir. (Middelburg et al. 2020).

Moras, C. A., et al. 2021. Ocean Alkalinity Enhancement - Avoiding runaway CaCO3 precipitation during quick and hydrated lime dissolution. Biogeochemical Discussions. https://doi.org/10.5194/bg-2021-330.

e. How will you quantify the actual permanence/durability of the carbon sequestered by your project? If direct measurement is difficult or impossible, how will you rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)*

We will rely on the fact that: 1) dissolved alkaline carbon in seawater permanently stores CO_2 on a 100,000 yr time frame (Sec 2c), and 2) this chemical partitioning greatly favors durable CO_2 storage in the ocean vs in the atmosphere by some 50/1 even though the ocean's CO_2 is in quasi equilibrium with the atmosphere. We are simply adding to ocean alkalinity to further, stably partition more CO_2 out of the atmosphere and into the ocean. This OAE in effect mimics the Earth's natural response to elevated CO_2 and CDR through rock weathering and ocean alkalinity production over geologic time scales. Using electrogeochemistry, Planetary Technologies instead makes OAE's durable CDR relevant on human/biological time scales.

3. Gross Capacity (Criteria #2)

a. Please fill out the table below. **All tonnage should be described in metric tonnes here and throughout the application.**

	Offer to Stripe (metric tonnes CO_2) over the timeline detailed in the table in 2(a)
Gross carbon removal Do not subtract for embodied/lifecycle emissions or permanence, we will ask you to subtract this later	1,892 tonnes between 2027-2029
If applicable, additional avoided emissions e.g. for carbon mineralization in concrete production, removal	For every tonne of carbon removal via OAE we generate 45 kg of green hydrogen, 26 kg of nickel and 12 kg of cobalt in addition to remediating 2 tonnes of hazardous mine tailings.

would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production	The green products we produce displace carbon intensive processes thereby avoiding emissions.

b. Show your work for 3(a). How did you calculate these numbers? If you have significant uncertainties in your capacity, what drives those? *(E.g. This specific species sequesters X tCO_2/t biomass. Each deployment of our solution grows on average Y t biomass. We assume Z% of the biomass is sequestered permanently. We are offering two deployments to Stripe. X*Y*Z*2 = 350 tCO_2 = Gross removal. OR Each tower of our mineralization reactor captures between X and Y tons CO_2/yr, all of which we have the capacity to inject. However, the range between X and Y is large, because we have significant uncertainty in how our reactors will perform under various environmental conditions)*

Capacity at our current permitted outfall site (SouthWest Water, UK) = 946 tonnes CO2/year. To arrive at that number: Maximum operational capacity at the SWW site (based on our 2021 Engineering Design Report) = 100 kg of Magnesium Hydroxide (MH) dosed per hour (kg MH/hour) or 876 tonnes MH/y Accounting for a 10% drop from the maximum operational capacity drops this to 788tMH/y. Based on a widely-used marine chemistry model (CO2SYS), the ratio of CO_2 captured per unit MH should be approximately 1.37 once diluted in typical seawater, However, our early experimental data suggests this ratio is slightly lower, likely due, in part, to incomplete dissolution of the MH. Based on this, we use a more conservative ratio of 1.2. 788 tMH/y * 1.2 = 946 tonnes CO2 captured per year. We anticipate reaching full capacity at our current pilot outfall site beginning in 2027.

c. What is your total overall capacity to sequester carbon at this time, e.g. gross tonnes / year / (deployment / plant / acre / etc.)? Here we are talking about your project / technology as a whole, so this number may be larger than the specific capacity offered to Stripe and described above in 3(b). We ask this to understand where your technology currently stands, and to give context for the values you provided in 3(b).

At this time, our capacity is limited by production of low carbon intensity MH and access to permitted outfalls.

In 2024, removal capacity increases to 1200 tCO_2/yr based on the production of MH from our pilot plant in Quebec, Canada. This assumes that additional outfall capacity comes online between now and 2025.

In 2027, following construction of our first commercial scale plant in Quebec, Canada, overall MH production capacity will allow for up to 301 $ktCO_2$/yr depending on the capacity of the outfalls fully characterized at that time.

d. We are curious about the foundational assumptions or models you use to make projections about your solution's capacity. Please explain how you make these estimates, and whether you have ground-truthed your methods with direct measurement of a real system (e.g. a proof of concept experiment, pilot project, prior deployment, etc.). We welcome citations, numbers, and links to real data! *(E.g. We assume our sorbent has X absorption rate and Y desorption rate. This aligns with [Sorbent_Paper_Citation]. Our pilot plant performance over [Time_Range] confirmed this assumption achieving Z tCO_2 capture with T tons of sorbent.)*

Our solution's capacity is dependent on:

1. Metallurgical process to extract pure mineral salt from mine tailings (including removal of impurities such as heavy metals);
2. Integrated electrochemical process to efficiently split this mineral salt into an acid, base (alkalinity), H_2 and O_2; and
3. Uptake of CO_2 by seawater following addition of produced low CI alkalinity.

We have ground truthed our method by:

1. Conducting a year of bench-scale tests of our metallurgical process proving overall recoveries of 78% for MH as well as 83% and 69% for nickel and cobalt present in the sample tailings. We are now scaling these tests from 100's of kg of representative tailings to multiple tonnes.
2. Developing a prototype salt splitting cell to establish baseline energy requirements and purity of produced MH; and
3. Adapting ocean models to estimate CO_2 flux given a known permitted outfall and data from a wastewater treatment plant (SouthWest Water, Hayle, UK) in addition to several bench-scale MH addition to seawater tests at Dalhousie University, University of Miami and our own research lab located in Dartmouth, Nova Scotia.

A full patent for the electrochemical and metallurgical processes has been submitted, but not yet published. Preliminary outfall modeling results are linked in the next section.

e. Documentation: If you have them, please provide links to any other information that may help us understand your project in detail. This could include a project website, third-party documentation, project specific research, data sets, etc.

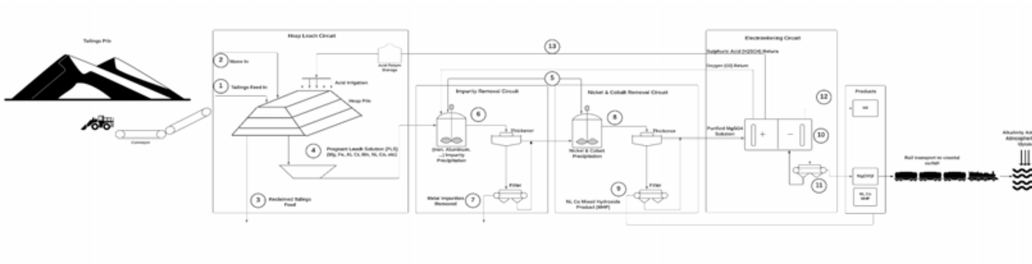
- *Planetary Pilot Study - Hydroxide Dispersion Modelling_Jan22.pdf*
- *Planetary_FEED_study_outfall_Hayle_9Dec21.pdf*
- *Planetary_Verification Report by UM_28Jan22.pdf*
- *Planetary_metallurgical technical report_31Jan22.pdf*
- *Planetary_GGR_final_report_10Jan22.pdf*

4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

a. Please fill out the table below to help us understand your system's efficiency, and how much your lifecycle deducts from your gross carbon removal capacity.

	Offer to Stripe (metric tonnes CO_2)
Gross carbon removal	1,892
Gross project emissions	184
Emissions / removal ratio	0.10
Net carbon removal	1,708

b. Provide a carbon balance or "process flow" diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the CDR Primer, Charm's application from 2020 for a simple example, or CarbonCure's for a more complex example).* If you've had a third-party LCA performed, please link to it.



c. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system?

The boundary conditions encompass the entire process from hydrometallurgical processing of tailings to the addition of alkalinity at an outfall site and include scope 1, 2 and 3 emissions. Emissions from the Quebec electricity grid are accounted for in the metallurgical and electrolysis processes as well as the UK grid for alkalinity dispersion via wastewater treatment.

d. Please justify all numbers used in your diagram above. Are they solely modeled or have you measured them directly? Have they been independently measured? Your answers can include references to peer-reviewed publications, e.g. [Climeworks LCA paper](#).

The above numbers are modeled using existing literature regarding carbon intensity regarding various different aspects of the process.

All metallurgical and electrolysis activities occur in Quebec, and as such use renewable energy [1]. Transportation to and from work spaces, as well as operation of yard equipment is also modeled [2,3].

The marginal amount of energy required for office space in Nova Scotia and to operate the dosing system in the UK is also accounted for [4].

The carbon intensity for the manufacturing of the electrolyser and storage is based on “Life-cycle assessment of a hydrogen-based uninterruptible power supply system using renewable energy” in the Journal of Life Cycle Assessments [5].

The carbon intensity of the magnesium hydroxide and the lime slake is based on an IPCC Mineral Industry Emissions paper [6].

Transportation of the magnesium hydroxide to outfall sites is calculated based on available rail and marine vessel shipping routes and tools to calculate their associated emissions for transportation [7].

[1] kgCO2e / MWh for Quebec's 99% Hydro Grid

[2] Specific Carbon Dioxide Emissions of Various Fuels

[3] Fuel Consumption Ratings

[4] kgCO2e/MWh Nova Scotia Electricity Grid

[5] Life-cycle assessment of a hydrogen-based uninterruptible power supply system using renewable energy

[6] Mineral Industry Emissions

[7] Carbon Calculator Emission Factors

e. If you can't provide sufficient detail above in 4(d), please point us to a third-party independent verification, or tell us what an independent verifier would measure about your process to validate the numbers you've provided.

Please see the details provided above. A third-party assessment was completed on our original electrochemical process in 2020; however this needs to be updated to include the integration of the metallurgical process and our updated project scenario.

A 'blind' LCA was submitted as part of our XPRIZE Carbon Removal milestone submission on February 1st using Carbon Direct's template. We expect to have the results of this analysis in the coming weeks.

5. Learning Curve and Costs (Backward-looking) (Criteria #2 and #3)

We are interested in understanding the learning curve of different carbon removal technologies (i.e. the relationship between accumulated experience producing or deploying a technology, and technology costs). To this end, we are curious to know how much additional deployment Stripe's procurement of your solution would result in. (There are no right or wrong answers here. If your project is selected we may ask for more information related to this topic so we can better evaluate progress.)

a. Please define and explain your unit of deployment. (*E.g.* # of plants, # of modules)

Currently our unit of deployment is based on the number of mine sites tested for which we could develop a project as well as the number of permitted coastal outfalls that we have access to and can characterize.

b. How many units have you deployed from the origin of your project up until today? Please fill out the table below, adding rows as needed. Ranges are acceptable.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2022	4	$7500/tonne	800 - 100,000 / tCO_2 each year*	Discussions are ongoing to bring online two additional outfall sites in Miami and Halifax. The STRIPE purchase will help to fund and expedite the development of these sites.
2021	4	$7500/tonne	800 - 100,000 / tCO_2 each year*	Mine waste from three sites tested and one outfall modelling study completed. *Note that unit gross capacity is not based on natural or regulatory limits but rather the sizing of the dosing equipment selected for the outfall and the existing flowrates of effluent discharges (for wastewater treatment). Much larger capacity is possible using cooling water from power plants for example.

c. Qualitatively, how and why have your deployment costs changed thus far? *(E.g. Our costs have been stable because we're still in the first cycle of deployment, our costs have increased due to an unexpected engineering challenge, our costs are falling because we're innovating next stage designs, or our costs are falling because with larger scale deployment the procurement cost of third party equipment is declining.)*

Our deployment costs are based on the CAPEX and OPEX of building and running our 1200 tCO_2/yr pilot plant in Quebec, Canada. These costs include all of the monitoring and ongoing testwork to optimize and refine the process and are not indicative of a commercial scale plant operating over many years.

d. How many additional units would be deployed if Stripe bought your offer? The two numbers below should multiply to equal the first row in table 3(a).

# of units	Unit gross capacity (tCO_2/unit)

2	946 tCO_2/unit

6. Cost and Milestones (Forward-looking) (Criteria #2 and #3)

We are open to purchasing high cost carbon removal today with the expectation the cost per ton will rapidly decline over time. We ask these questions to get a better understanding of your potential growth and the inflection points that shape your cost trajectory. There are no right or wrong answers, but we would prefer high and conservative estimates to low and optimistic. If we select you for purchase, we'll expect to work with you to understand your milestones and their verification in more depth. If you have any reservations sharing the information below in the public application format, please contact the Stripe team.

a. What is your cost per ton of CO_2 today?

$7500

b. Help us understand, in broad strokes, what's included vs excluded in the cost in 6(a) above. We don't need a breakdown of each, but rather an understanding of what's "in" versus "out." Consider describing your CAPEX/OPEX blend, non-levelized CAPEX costs, assumptions around energy costs, etc.

$7500/tonne CO_2 removed includes the CAPEX and OPEX to build and operate our 1200 tCO_2/yr plant. It includes energy costs assuming commercial rates at the mine site in Quebec, Canada.

c. How do you expect your costs to decline over time? Specifically, what do you estimate your cost range will be as you reach megaton and then gigaton scale? We recognize that at this point, these are speculative and directional estimates, but we would like to understand the shape of your costs over time.

Costs are expected to come down to $40-80/tonne CO_2 removed and permanently stored as we improve the efficiency of our electrochemical cell (energy costs account for 80% of forecasted OPEX), as well as scale-up our metallurgical process. Larger scale plants at the mine site will allow for the sale of by-products such as Ni and Co, as well as green H2 which will bring down the net cost of removals. To a lesser degree streamlining our project development, MRV and manufacturing costs will also bring down CO_2 removal costs overtime. Given that we generate Ni, Co and green H2, while remediating mine waste and restoring ocean health, it is possible to remove CO_2 at a net-zero cost when factoring in the price of these byproducts and environmental services (assuming a low cost for renewable energy).

d. Where are the primary areas you expect to be able to achieve cost declines? E.g., what are the primary assumptions and sensitivities driving your cost projection? What would need to be true for a long-term cost of <$100/ton to be achievable with your technology? (i.e., you are able to negotiate an x% reduction in CAPEX at scale and purchase renewable electricity at $y/kWh)

The primary areas we expect to be able to achieve cost declines are both the scale of the MH production (metallurgical + electrochemical process) and the overall efficiency of the electrochemical cell.

The quantity of revenue generating by-products (Ni, Co, green H_2) is determined by the overall scale of the MH production at a given mine site. Depending on the market rates - which are expected to increase as demand for battery metals increases, these commodities can offset 50% - 100% of the carbon removal cost.

We assume a decreasing premium on green hydrogen reaching $3/tonne by 2030.

We assume Ni and Co prices continuing to increase 5% annually reaching $34,000 and $70,000/tonne respectively by 2030 due to the high growth in electrical vehicle sales projected globally .

Reaching removal costs below $100/tonne will require significant improvements in the energy efficiency of our electrochemical cell combined with inexpensive and likely purpose built renewable energy developments ($32 USD/MWh).

Compared to our current bench-scale prototype cell, energy consumption needs to decrease by 50% to meet these cost targets. This is well within theoretical limits, and we have already seen a 10% decrease in energy consumption from our first gen to our second gen prototype.

Our model also assumes increasing revenue from mine site remediation ($5 - $8/tonne of tailings processed, which equals ~ 2:1 for carbon removal credits).

CAPEX will reduce overtime as the manufacturing of our electrochemical cell ramps up. We've assumed a learning rate of 20% which is comparable to green hydrogen or chlor alkali electrolyzer production.

We have not factored in potential revenue from ocean restoration as a result of deacidifying local outfalls. We are working with partners at the University of Miami to measure the net benefits of alkalinity addition to coral reefs impacted by climate change.

e. In a worst case scenario, what would your range of cost per ton be? We've been doing a lot of purchasing over the past few years and have started to see a few pieces that have tripped people up in achieving their projected cost reductions: owned vs leased land, renewable electricity cost, higher vendor equipment costs, deployment site adjustments, technical performance optimization, supporting plant infrastructure, construction overruns, etc. As a result, we'll likely push on the achievability of the cost declines you've identified to understand your assumptions and how you've considered ancillary costs. We would love to see your team kick the tires here, too.

If we do not realize the sale of by-products or remediation services at commercial scale the cost would be closer to $500/tonne CO_2. This cost doubles if we cannot certify removals via OAE and have to rely completely on land-based carbonation of MH. This is due to the rate of carbonation in seawater vs. air. In seawater a greater proportion of the hydroxide is converted to bicarbonates locking up double the carbon for every unit of alkalinity added.

f. List and describe **up to three** key upcoming milestones, with the latest no further than Q2 2023, that you'll need to achieve in order to scale up the capacity of your approach.

Milestone #	Milestone description	Why is this milestone important to your ability to scale? (200 words)	Target for achievement (eg Q4 2021)	How could we verify that you've achieved this milestone?
1	Completion of pre-pilot optimization of metallurgical process (currently testing two methods to leach desired products from tailings using dilute acid from electrochemical cell).	The results from our current scaled-up metallurgical tests (scaled from 100's of kgs to multiple tonnes of tailings) will determine the most economical means of completing the first phase of our process. The optimization work involves ensuring the process works at the next scale increment while also optimizing the time it takes to leach the tailings vs. the energy input required.	Q3 2022	The metallurgical pre-pilot optimization testwork is underway and is scheduled to be completed by August 2022. The team has weekly meetings to discuss interim results and a site visit to each of the testing locations could be arranged to witness the testwork in progress. Test reports could also be provided.
2	Completion of 2nd generation electrochemical cell and next series of MH production tests.	Our first prototype cell was used to determine the viability of our approach to directly electrolyze the	Q4 2022	Weekly progress meetings. Site visits. Final test reports.

		$MgSO_4$ using an electrowinning approach. These tests proved successful leading to the design and build of a second gen prototype that will be used to run a series of tests aimed at increasing the electrical efficiency as well the yield and purity of MH produced by the cell. These results are important for scale up as we need to half the energy consumption of the cell and ensure high yields prior to scaling up and integrating with the metallurgical process as part of our end-to-end demonstration.		
3	Completion of Ph 1 of outfall background studies (field work) and first MH addition trial at the SouthWest Water wastewater treatment facility in Hayle, UK.	This study builds on a year of modeling and engineering studies commissioned by the UK government as part of the Greenhouse Gas Removal program. These results will be important for scale up as they will validate and inform our measurement, verification and reporting approach (MRV) which will	Q1 2023	Potential site visit during monitoring period (field studies) as well as during MH addition tests. Report from Plymouth Marine Laboratories documenting the background studies, modeling approach and results of MH

		allow for future crediting by third-parties. It is a major milestone for us as a company, but also for Ocean CDR as a sector as it will be the first controlled addition of alkalinity in a permitted outfall that has been first modeled and then verified.		addition tests.

i. How do these milestones impact the total gross capacity of your system, if at all?

Milestone #	Anticipated total gross capacity prior to achieving milestone (ranges are acceptable)	Anticipated total gross capacity after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	946 tonnes CO_2/year	No change in total gross capacity after achieving this milestone.	N/A
2	946 tonnes CO_2/year	No change in total gross capacity after achieving this milestone.	N/A
3	946 tonnes CO_2/year	Possible change in total gross capacity after achieving milestone based on 1) measurements from MH dosing trial 2) continued outfall modeling and 3) consideration of logistical and engineering constraints during trial	We have used a very conservative number for tonnage based on the capacity of the dosing equipment and wastewater treatment facility flowrate. There is a very likely scenario where we learn that this capacity is underestimated by up to an order of magnitude following these trials.

g. How do these milestones impact your costs, if at all?

Milestone #	Anticipated cost/ton prior to achieving milestone (ranges are acceptable)	Anticipated cost/ton after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	$7500	Achieving this milestone will lead to the preferred metallurgical process for our 1200 tCO_2/yr demonstration plant.	N/A
2	$7500	Achieving this milestone will further the development of the electrochemical cell ultimately leading to the increases in energy efficiency required to meet our 50% improvement target.	N/A
3	$7500	Achieving this milestone will prove the MRV aspect of OAE but will not have a significant reduction on costs that are primarily driven by alkalinity production.	N/A

h. If you could ask one person in the world to do one thing to most enable your project to achieve its ultimate potential, who would you ask and what would you ask them to do?

Jennifer Morgan Executive Director at Greenpeace, to publicly endorse OAE as a required solution in the global climate change portfolio

i. Other than purchasing, what could Stripe do to help your project?

We would encourage Stripe to further educate the public and its partners on how ocean based CDR can be a major part of the broader climate solutions portfolio.

7. Public Engagement (Criteria #7)

In alignment with Criteria 7, Stripe requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to do the following:

- Identify key stakeholders in the area they'll be deploying
- Have mechanisms to engage and gather opinions from those stakeholders and take those opinions seriously, iterating the project as necessary.

The following questions are for us to help us gain an understanding of your public engagement strategy and how your project is working to follow the White House Council on Environmental Quality's draft guidance on responsible CCU/S development. We recognize that, for early projects, this work may be quite nascent, but we are looking to understand your early approach.

a. Who have you identified as your external stakeholders, where are they located, and what process did you use to identify them? Please include discussion of the communities potentially engaging in or impacted by your project's deployment.

> At the mine site location in Quebec, Canada, Planetary works with the local economic development agency and high school career training programs to engage youth interested in cleantech entrepreneurship. This primarily French speaking community has a long and complex history with extractive industries, which attracted Planetery's process to remediate those lasting effects, while also making use of North America's cleanest electrical grid for energy.
>
> At Planetary's coastal sites, we partner with leading oceanographic academic institutions, oyster hatcheries, and centers for ocean innovation to develop funded projects and local interest. The driver behind these projects is to understand how OAE can play a central role in revitalizing a sustainable ocean economy and supporting vibrant communities. Protecting hatchery sites, lobster/ shellfish populations, and adapting to new climate threats has been a central topic in Maritime and Atlantic coast public discussions. Planetary purposely located its head office in The Maritimes to stay closely connected to these discussions and learn about the issues facing Canada's largest ocean community.

b. If applicable, how have you engaged with these stakeholders and communities? Has this work been performed in-house, with external consultants, or with independent advisors? If you do have any reports on public engagement that your team has prepared, please provide. *See Project Vesta's community engagement and governance approach as an example.*

> In 2021, Planetary engaged Canada's Ocean Supercluster to participate in the Indigenous Career Pivot Program. Through this, we have retained a full-time Head of Community Stakeholder Engagement with a lived and academic background in Indigenous Affairs.
>
> Also in 2021, a research partnership was formed between Dalhousie University, Planetary, and Mallet Oysters. A funding grant of $1.2million CAD was deemed meritorious by Canada's

Natural Sciences and Engineering Research Council to study the effects of OAE on shellfish populations, physical oceanography, and biological effects. Stage reports to be published and a final research report to follow completion.

c. If applicable, what have you learned from these engagements? What modifications have you already made to your project based on this feedback, if any?

As a startup, the pressure to move quickly and demonstrate value and scale is strong. It's primarily thanks to working closely with external stakeholders (local business, academia, Indigenous communities, and grassroots environmental groups) that we've learned to temper this pressure against the importance of moving the technology and community together.

In 2022, Planetary is prepared to move from the lab into the ocean environment but these trials have been adapted to allow more time for public engagement and feedback. "If you want to go fast go alone, if you want to go far go together" - African Proverb

d. Going forward, do you have changes planned that you have not yet implemented? How do you anticipate that your processes for (a) and (b) will change as you execute on the work described in this application?

Going forward, Planetary and our Community Stakeholder Engagement Lead will be working closely with external consultants on better engaging the local community in a dialogue about OAE. To date, some of these discussions have been organic and irregular, but in order for Planetary to increase its ocean deployment we will need the support and advocacy of stakeholders at the citizen level all the way up to Indigenous and Municipal leaders.

8. Environmental Justice (Criteria #7)

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders?

The handling and remediation of mine tailings impacts those living near our mine site. A recent report by Quebec's environmental agency found that unremediated mine tailings were impacting water quality in the Chaudiere-Appalaches region where our mine site is located. A separate report by the same agency found that there was potential for mine tailings to impact air quality.

Commercial fishing is an important economic activity for many coastal communities, and as such continued monitoring and communication for potential impacts is important.

b. How do you intend to address any identified environmental justice concerns?

Planetary's rock leaching and electrochemical processes will nullify hazards contained in the tailings and will extract metals valuable for battery energy storage - nickel and cobalt. This eliminates the toxicity of the tailings and can have positive impacts on water quality and air quality as a result.

Our metallurgical process is being developed in cooperation with the Quebec local community and with oversight from their governmental environmental agency BAPE (Bureau d'audiences publiques sur l'environnement). The aim is, over time, to return the site to park and forest land for the benefit of the community. To this end, the Planetary process entombs any toxins remaining after the extraction is complete and leaves only benign products at the surface.

Planetary is partnered with leading oceanographic academic institutions with research objectives specific to the addition of hydroxide and the effects on marine food web and life. We are partnered with a commercial oyster hatchery as well as the aforementioned academic institutions to better understand how our activities can contribute to improved health of marine life as a result of combatting ocean acidification, which would in turn also contribute to a stronger ocean economy.

Planetary recognizes the disproportionate impacts of climate change on marginalized communities, and has a Head of Community Stakeholder Engagement in order to ensure that there is open dialogue to address concerns and ensure full participation of citizens, businesses, and community leaders throughout our process.

9. Legal and Regulatory Compliance (Criteria #7)

a. What legal opinions, if any, have you received regarding deployment of your solution?

Because our solution is deployed through existing outfalls and fits within the currently permitted uses, we do not currently expect to face any particular legal contest to our operations, and thus have not sought to secure any form of legal opinion to support our work. We would be open to doing so upon the advice of any of our accredited partners including our mining and outfall partners, our mining consultants including SGS, and/or our oceans research partners including Dalhousie University and the University of Miami.

b. What domestic permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? Please clearly differentiate between what you have already obtained, what you are currently in the process of obtaining, and what you know you'll need to obtain in the future but have not yet begun the process to do so.

Prior to commencing operation of the pilot plant in Quebec we will apply for a permit from Quebec's environmental agency for either ministerial authorization or an exemption from an environmental assessment. At the outfall sites, the hydroxide addition will be well within permitted discharge pH and turbidity limits. If required for offshore monitoring, the installation of fixed buoys would require a permit from the Harbour Master of Bedford Basin in Halifax and

an application to the Marine Management Organization (MMO) for a Marine License in Hayle. Planning permissions will also be required for construction of the plants.

c. Is your solution potentially subject to regulation under any international legal regimes? If yes, please specify. Have you engaged with these regimes to date?

Canada is a signed member of the London Convention and implements the London Protocol through the *Canadian Environmental Protection Act*. However, our proposed activity does not meet the definition of waste or dumping outlined in either the London Convention or London Protocol and as such does not apply.

d. In what areas are you uncertain about the legal or regulatory frameworks you'll need to comply with? This could include anything from local governance to international treaties. For some types of projects, we recognize that clear regulatory guidance may not yet exist.

There is potential for new regulations regarding OAE to be enacted in the future, as of now there is no clear current regulatory guidance aside from local pH and turbidity limits for outfalls, which Planetary's discharge will be well within. BAPE's report on mine tailings recommends enacting clear policy surrounding the handling of mine waste, including for activities similar to the ones we are proposing at our mine site in Quebec. While there is currently very little regulatory guidance outside of the environmental assessment process, this is something that could be enacted in the near future.

e. Has your CDR project received tax credits from any government compliance programs to-date? Do you intend to receive any tax credits during the proposed delivery window for Stripe's purchase? If so, which one(s)? (50 words)

We have not received any tax credits from any government compliance programs to date, and do not plan to during the proposed delivery window for Stripe's purchase.

10. Offer to Stripe

This table constitutes your offer to Stripe, and will form the basis of our expectations for contract discussions if you are selected for purchase.

	Offer to Stripe

Net carbon removal *metric tonnes CO_2*	1708 metric tonnes CO_2
Delivery window *at what point should Stripe consider your contract complete?*	*End of 2029*
Price (\$/metric tonne CO_2) ***Note on currencies:*** *while we welcome applicants from anywhere in the world, our purchases will be executed exclusively in USD (\$). If your prices are typically denominated in another currency, please convert that to USD and let us know here.*	*\$2000 USD*

Application Supplement: Ocean

(Only fill out this supplement if it applies to you)

Physical Footprint (Criteria #1)

1. Describe the geography of your deployment, its relationship to coastlines, shipping channels, other human or animal activity, etc.

Deployment is from a municipal wastewater outfall located near the southwestern tip of the UK (Hayle, England). The outfall is approximately 2km offshore in water depths of approximately 25m. As such, the deployment is relatively close to human and animal activities, but despite significant biogenic loads already present in this wastewater, there appears to be no negative impacts on nearby human/animal activities. This is likely due to the tidal currents and consequently rapid dilution that occurs here. Generally, our approach will focus on the use of permitted ocean outfalls, so deployment will typically be proximal to the coast.

2. Please describe your physical footprint in detail. Consider surface area, depth, expected interaction with ocean currents and upwelling/downwelling processes, etc.
   a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

Given the 12km distance between the SouthWest Water treatment plant and the ocean outfall, the MH added will also certainly dissolve entirely before entering the ocean. This means the enhanced alkalinity signal will follow local/regional ocean currents. This site is subject to very large tidal currents that will rapidly dilute the signal. For example, our modeling results from this site show that within 100m of the pipe the alkalinity signal dilutes by a factor of 500-2700 depending on the tidal stage. During strong tidal flows the plume rapidly spreads vertically across the entire water depth, while at slack tides the plume is constrained to the top 5-10 meters.

This rapid dilution/dispersion means the surface area where alkalinity is increased and CO_2 influx occurs is large (~300 sq-km within 6 months of deployment according to model results). However, the magnitude of the signal within this area is very small, and the footprint of measurable change using current technology is modeled to be within a 50mx50m box (0.0025 sq-km). Regional circulation in SW UK indicates the added alkalinity should remain in surface waters and be transported in a coastal current northeast along the UK continent towards the North Sea.

3. Imagine, hypothetically, that you've scaled up and are sequestering 100Mt of CO_2/yr. Please project your footprint at that scale, considering the same attributes you did above (we recognize this has significant uncertainty, feel free to provide ranges and a brief description).

    a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

At our UK pilot site (1ktCO2/yr, see above), strong tidal currents disperse the alkalinity rapidly, thus the physical footprint is very large, but the measurable footprint is very small (see above). Scaling up from this pilot site by a factor of 100,000 to reach 100Mt/y would generate a physical footprint of 30 million square kilometers, roughly half the surface area of the Atlantic Ocean. However, the measurable signal scales only to 250 sq-km, roughly the area of Seattle.

At this particular site, staying well within environmental (turbidity) limits and accounting for rapid dispersion, we calculate that this particular site could scale up to ~100ktCO2/y removal. Therefore, to scale up to 100Mt/CO2/y we will secure numerous permitted outfalls, including some with much larger capacities (e.g. capacity in cooling water outfall for nuclear power plant = 2Mt/y). These sites will all have differing regional currents and dispersion rates near the pipe. Given the somewhat extreme conditions of our pilot site, the overall physical footprint described here should be considered an upper limit, whereas the measurable footprint should be considered a lower limit.

Potential to Scale (Criteria #2 and #3)

4. Building large systems on or in the ocean is hard. What are your core engineering challenges and constraints? Is there any historical precedent for the work you propose?

Because our approach involves the use of permitted outfalls, infrastructure of alkalinity addition will take place at established sites on land (e.g. wastewater facilities and power plants), presenting relatively few engineering challenges. The logistics of delivering, storing, and subsequently dosing large amounts of MH into the outfalls is a challenge, which is what limits our current pilot site to 1ktCO2/y, despite environmental limits suggesting a capacity 100x larger. After demonstrating this process at pilot scale, building infrastructure to support larger capacity at this site and others should present relatively few engineering challenges relative to processes conducted at sea.

Also, significant historical precedent exists for the type of engineering we propose. Wastewater facilities already dose their systems with numerous chemicals to maintain a certain water chemistry that facilitates water treatment and safe disposal. Storage silos (e.g. for coal) are common structures at power generation facilities.

Externalities and Ecosystem Impacts (Criteria #7)

5. How will you quantify and monitor the impact of your solution on ocean ecosystems, specifically with respect to eutrophication and alkalinity/pH, and, if applicable, ocean turbidity?

Planetary is currently undertaking research in partnership with Dalhousie University in Halifax to assess the biological and chemical effects of MH addition on coastal environments, including the establishment of parameters to prevent precipitation of carbonate, and MRV and prediction of CO_2 uptake and sequestration.

Dosing from our pilot plant will stay well below 100 mg/L $Mg(OH)_2$, and the Canadian eco toxicological threshold (LD50, 96 hr for rainbow trout) for this substance is 775 mg/L. Our current research also includes assessments on biological responses, like growth and community composition, of marine biota such as coastal phytoplankton and commercially grown oysters to hydroxide/bicarbonate enrichment. The addition of hydroxide to coastal seawater was shown to restore coral calcification in the Great Barrier Reef (Albright et al., 2016), and other marine life could see benefits from the potential reversal of ocean acidification.

As for human safety, it is important to note that MH is the primary ingredient in milk of magnesia, a remedy for digestive tract disorders that has been safely ingested by millions. The mouse oral LD50 is 8500mg/kg, orders of magnitude above the dose we intend to dilute into the ocean.