Carbon Removal Purchase Application

General Application

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

Company or organization name

CO2-ZERO LIMITED

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

London, England

Name of person filling out this application

John Kenny

Email address of person filling out this application

eoinocionna@co2-zero.uk

Brief company or organization description

Experienced people focused on CO2 removal, quickly.

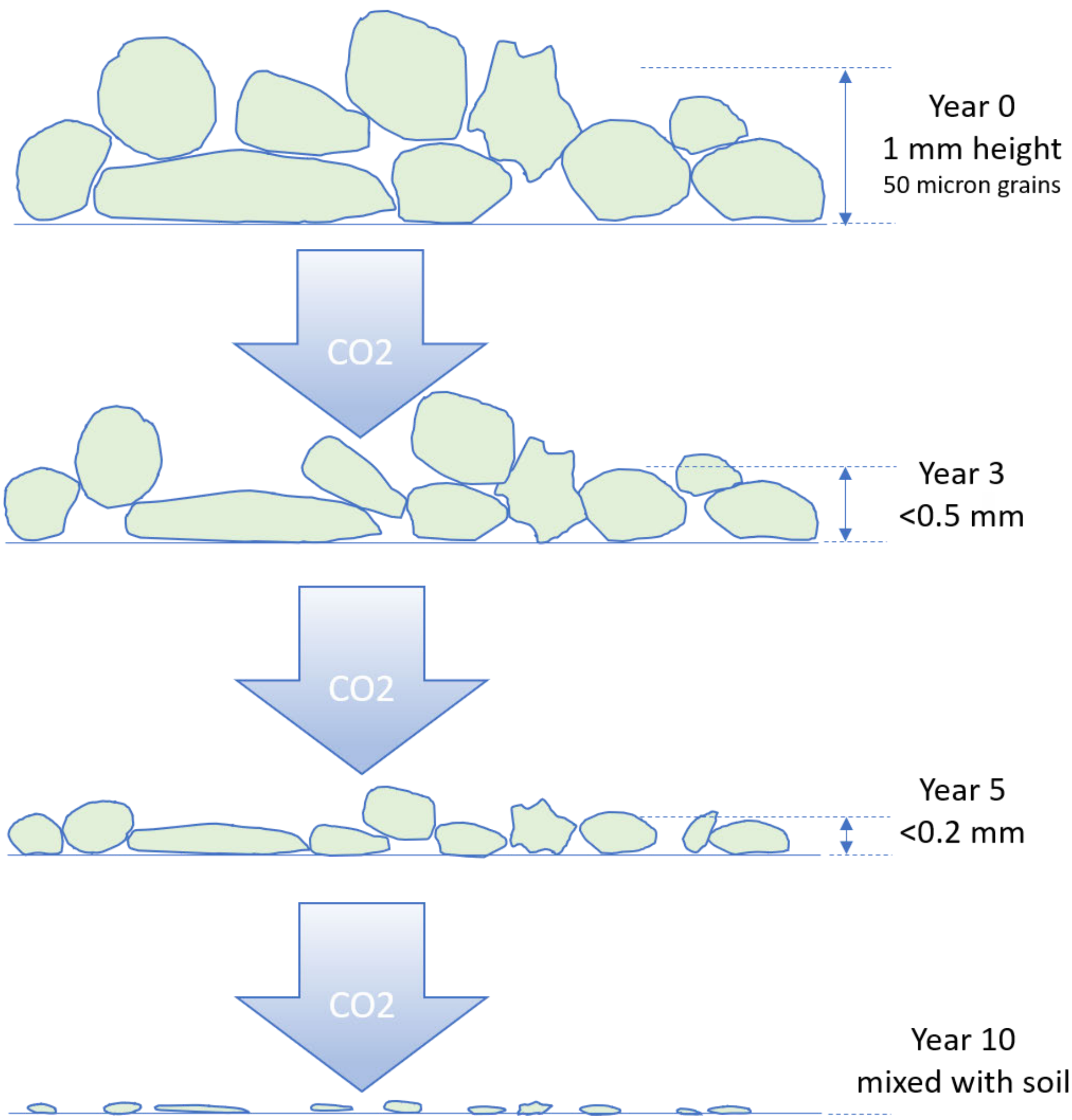
1. Overall CDR solution (All criteria)

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.

This CDR (Carbon Dioxide Removal) project uses enhanced weathering to turn CO2 into carbonate molecules. This well-known process as a solution to climate change is now being executed by Project Vesta, Greensands, 4401.earth, and others using Mg2SiO4 otherwise known as olivine. CDR using enhanced weathering is scalable, permanent, cheap, natural and low-tech.

The basic process: olivine + carbon dioxide + water --> magnesium carbonate + silica.

What matters for CO2 removal is: MgO + CO2 = MgCO3. The net effect is:

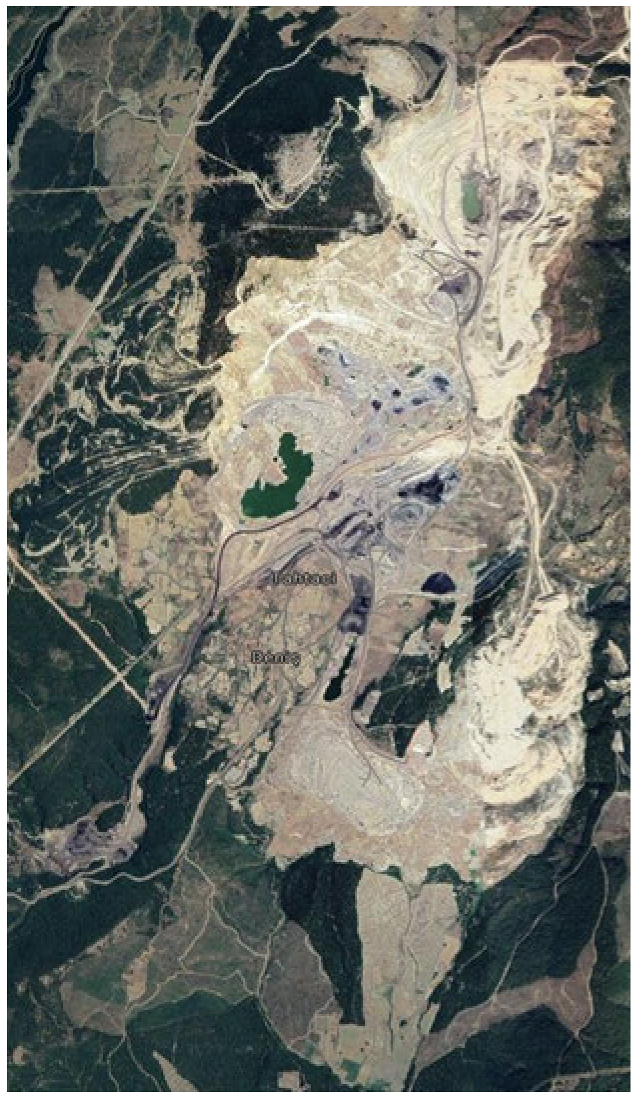


CO2 sequestration is by nature a geological process, which keeps continuing after the material is applied. So, after applying the olivine the reaction will continue for a long time, but at a reducing rate. The exact rate depends on particle size, temperature, and some minor items.

Fortunately, weathering rates of gravel and sands are much higher than for solid rocks – and we are starting with a “technogenic deposit” (meaning it is human-made) easily accessible and ground to a small size.

LOCATION

On this project, CO2-Zero is in partnership a Partner, long established and well-respected olivine quarry operator.



Partner have existing, already milled, olivine available at Torbali, 50km from Izmir, in western mediterranean basin. These olivine grains do not need to be mined or quarried and are available to the project (aerial picture of the facility, top-right, shows the olivine).

There are an estimated 80,000 tonnes of finely milled 300-micron olivine onsite “ready-for-use”.

Our goal is to spread this olivine onto an area previously used by extractive industries, but now requiring reclamation. Several target areas known to Partner have already been mined or quarried and spreading olivine on them will have a beneficial environmental impact as it will help de-acidify the soils. These mined areas have already been subjected to environmental permitting which greatly simplifies our project.

These areas are within easy reach of Torbalı – the target area shown (bottom-right) is 150km.

SCALE

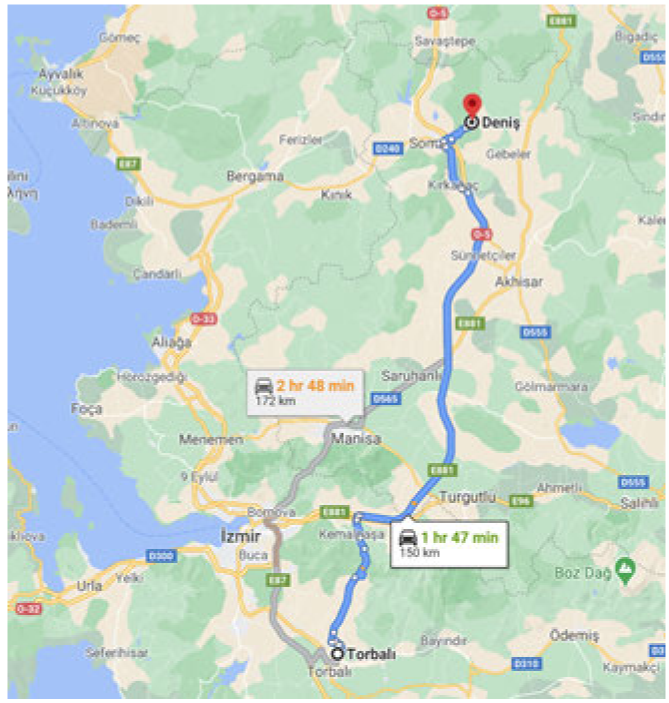
It is a geochemical fact that each tonne of olivine can capture up to 1.25 tonnes of CO2. For our economic modelling, we assume 1.2 tonne of CO2 is captured by 1 tonne of olivine, therefore we can sequester up to 80,000t x 1.2 = 96,000 tonnes of CO_2.

Once this initial olivine sequestration project is underway in mediterranean basin, Partner – who are very experienced and knowledgeable about their region – will work with us to repeat the process by sourcing olivine from others.

We aim to identify c.1 million tonnes of olivine in mediterranean basin that can be utilized for CDR from late 2022 onwards.

TIMELINE

Our lead time is 6 months: we can commence dispersal of Partner's olivine - and thus CDR – from 31 August 2021, subject to permitting, equipment sourcing and staff training.



CARBON REMOVAL EFFICIENCY

Moving 80,000 tonnes of olivine the 150km from Torbalı to the dispersal site(s) can be done with 5 trucks per day at 24t/truck = 120 t/day for 700 days.

The ratio of CO_2 sequestered to CO_2 emitted is over 20:1 as we deploy 1t olivine capable of sequestering 1.2t CO_2 versus 0.03t of CO_2 emitted (see LCA below), resulting in a "carbon efficiency" of 95%.

The necessary dispersal equipment to handle the olivine (by tipping, spreading and grading) is standard agricultural grade can be sourced rapidly from suppliers.

Olivine's density = 3.4t/m3, therefore 80,000t will occupy 24,000m3. We will disperse this at an average depth of 1mm (1,000 micron) over a disused mining area and occupy 24km2 (2,400 ha, 24 million m2).

If we grind the average size to 50 microns, over 90% of the olivine is carbonated within 5 years permanently sequestering 89,000t of CO_2. The resulting CDR land intensity use = 7.4 tonnes of CO_2/hectare (tCO_2/ha) every year.

This compares well with CDR rates for trees: 0.8 to 2.4 t/ha p.a. in boreal forests, 0.7 to 7.5 t/ha p.a. in temperate regions and 3.2 to 10 t/ha p.a. in the tropics (Brown et al., 1996).

In theory, we can relay another layer of olivine (from another source) over the same 2,400 hectares and commence the 5-year carbon capture cycle again. Staying longer onsite improves logistics, mechanical efficiencies, local community involvement, and environmental knowledge.

Over 3 decades, 5 or 6 cycles of 80,000 tonnes of olivine can be applied, absorbing up to 500,000 tonnes of CO_2. The capture intensity rate remains high at 500,000/2,400 = 7 tCO_2/ha p.a.

PARTNERS

We have negotiated a partnership with Partner, as they are a well-regarded olivine mining operation. This company is family-owned, environmentally aware, and has been operating olivine quarries for decades.

We are examining with them a short list of dispersal sites which offer ease of access, wind properties, permitting and monitoring.

Stripe's procurement of our CDR solution will result in:

- deployment of a project capable of sequestering 96,000 tonnes of CO2; and
- similar scale roll-outs in at least 2 other locations in mediterranean basin and in 3 other countries; and
- accelerate our learning curve on variables like grind size, moisture exposure, ideal depth of granules and consequent sequestration rates.

The above are incremental knowledge topics, important for commercialisation and global roll-out.

We will share what we learn with the "mineral sequestration community" and through our certification procedures with Gold Standard. This increases CDR via mineralization projects in general and give all operators – including CO2-Zero – access to large scale finance (both debt and equity).

b. What is your role in this project, and who are the other actors that make this a full carbon removal solution?

- CO2-Zero: initiate, plan, finance, manage projects, distribute CO2e offsets.
- Partner: provide olivine, identify title holders of ex-mining sites.
- University of St Andrews – measuring CO2 sequestration.
- Gold Standard – certification of net CO2 captured.
- SRK Consulting (mediterranean basin) – mineralogy and monitoring of environmental impacts.

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

RISKS
1. The average magnesium content of the tailings is diluted by extra silica and is thus lower than forecast and sequesters less CO_2 per tonne than estimated.
2. Environmental permits are not forthcoming in a suitable form (unlikely since we are talking about using existing abandoned quarries) or timely manner.
3. Auditing sequestration effects over time on the dispersal site may prove harder than forecast.

MITIGATION
1. Refine on site and remove the silica so that higher grade olivine is transported. A reverse circulation tank will do this using gravity at a modest carbon cost. We have experience in removing unwanted elements from olivine.
2. Provide detailed mineralogical and microscopic data and analysis of minerals used and any contaminants that might be there. We are not introducing alien minerals but replacing them into their natural environment. The presence of other elements, such as chrome, is therefore an issue that can be managed.
3. As our mineralogical test work allows us to know the sequestration capacity, we can design an algorithm that takes account of weather and other factors to determine how much CO_2 will actually be carbonated and at what speed. On-site, for instance, there will be specially designed trays where olivine samples of different grain sizes are exposed to the elements and measured regularly.

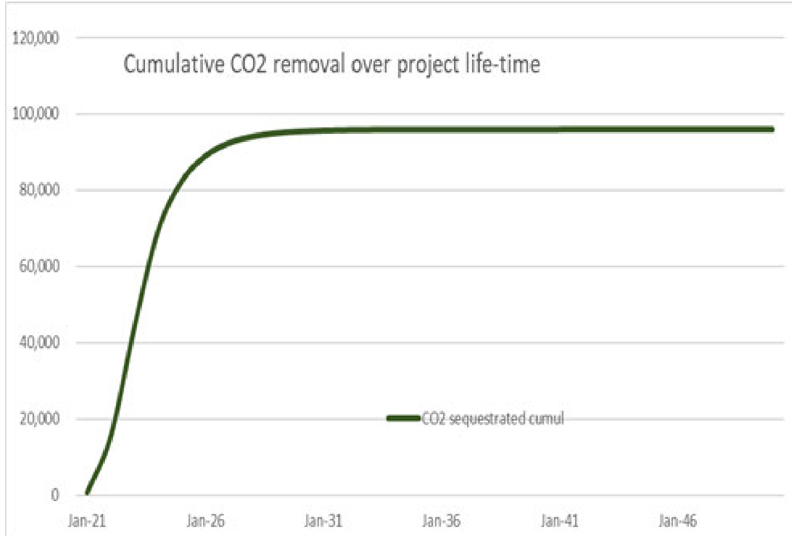
d. If any, please link to your patents, pending or granted, that are available publicly.

N/A we have no patents.

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

a. Please fill out the table below.

	Timeline for Offer to Stripe
Project duration	3 years. Monitoring for up to 10 years.
When does carbon removal occur?	CDR begins immediately. 90% of it will happen within 5 years.

Distribution of that carbon removal over time	 Based on 80,000t deployed at 120tpd, 300 micron average initial size, milled to 50 microns: Year CDR CDR% 1. 15,400 16% 2. 44,075 46% 3. 69,356 72% 4. 82,358 86% 5. 89,015 93%
Durability	Permanent, geological storage through the formation of magnesite ($MgCO_3$).

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

Lower bound: 100,000 years. Upper bound: 100 million 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.

The durability of $MgCO_3$ is scientific and geological fact as is well documented. We refer to the common sources used by the CO_2 removal via carbonation community.

Sources used include Project Vesta (www.projectvesta.org/science), and those below:

Title	Author(s)
Geoengineering potential of artificially enhanced silicate weathering of olivine. Proceedings of the National Academy of Sciences of the United States of America, 107(47), 20228–20233.	Köhler, P., Hartmann, J., & Wolf-Gladrow, D. A. (2010).
Enhanced Weathering: An Effective and Cheap Tool to Sequester Co2. Climatic Change, 74(1), 349–354.	Schuiling, R. D., & Krijgsman, P. (2006).
Enhanced chemical weathering as a geoengineering strategy to reduce atmospheric carbon dioxide, supply nutrients, and mitigate ocean acidification. Reviews of Geophysics, 51(2), 113–149.	Hartmann, J., West, A. J., Renforth, P., Köhler, P., Rocha, C. L. D. L., Wolf‐Gladrow, D. A., Dürr, H. H., & Scheffran, J. (2013).
Carbon Dioxide Sequestration, Weathering Approaches to. In T. Lenton & N. Vaughan (Eds.), Geoengineering Responses to Climate Change: Selected Entries from the Encyclopedia of Sustainability Science and Technology (pp. 141–167). Springer New York.	Schuiling, R. D. (2013).
Environmental life cycle assessment of co2 sequestration through enhanced weathering of olivine.	Koornneef, J., Nieuwlaar, E., (2011).

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?

We face zero durability risks as the olivine grains will immediately begin to be sedimented into the soil. $MgCO_3$ is often used as a fertilizer. There is no leakage or decay (as with forestry) involved in olivine's carbon capture – it is permanent.
Socio-economic risks include dust management, and impact of logistics.
There is an unlikely possibility of chrome isotope-6 being present – which can be managed.
Nickel may also be present in trace quantities (<50ppm) locked in the grains; therefore precipitation is very unlikely and the risk is minimal.
There are no fundamental uncertainties about the process, simply the time it will take.

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?

Regular, systematic measurement of chemical composition of the olivine distribution will be aided by having multiple (c. 100 each 1m2 in area) shallow boxes containing olivine. These “trays” make it easier to measure the carbon sequestrated in the same place year after year and will be inspected weekly and immediately after high winds or heavy rain.
Samples will be removed from the trays every quarter or as is otherwise needed for independent external auditing. Olivine outside the trays will be measured at multiple locations, especially where it piles up due to local hydrology, wind and at ditches, cliffs and clefts.
We will place a range of olivine rock sizes (500 microns to 50cm) at the dispersal site as a control.
We can provide:

1. Carbon intensity/lifecycle analysis from our olivine suppliers and processing partners.
2. Verification of receipt/transport of the olivine to our dispersal site from our sources (normally a JV).
3. Verification of the olivine dispersal on the target site from 3rd parties.
4. Regular lot-sampled olivine composition analysis to confirm carbon content and formation of magnesite, aided by “multiple trays” on site that enable rapid, accurate sampling.

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	30,000 tonnes CO2.
If applicable, additional avoided emissions	0

b. Show your work for 3(a). How did you calculate these numbers? If you have significant uncertainties in your capacity, what drives those?

Each tonne of olivine sequesters up to 1.2t of CO2.

Schuiling etc estimate that in warm humid conditions, at least 10 microns of an olivine grain are carbonated every year, working from all surfaces inwards. They even make the case that 20 μm/yr is more likely.

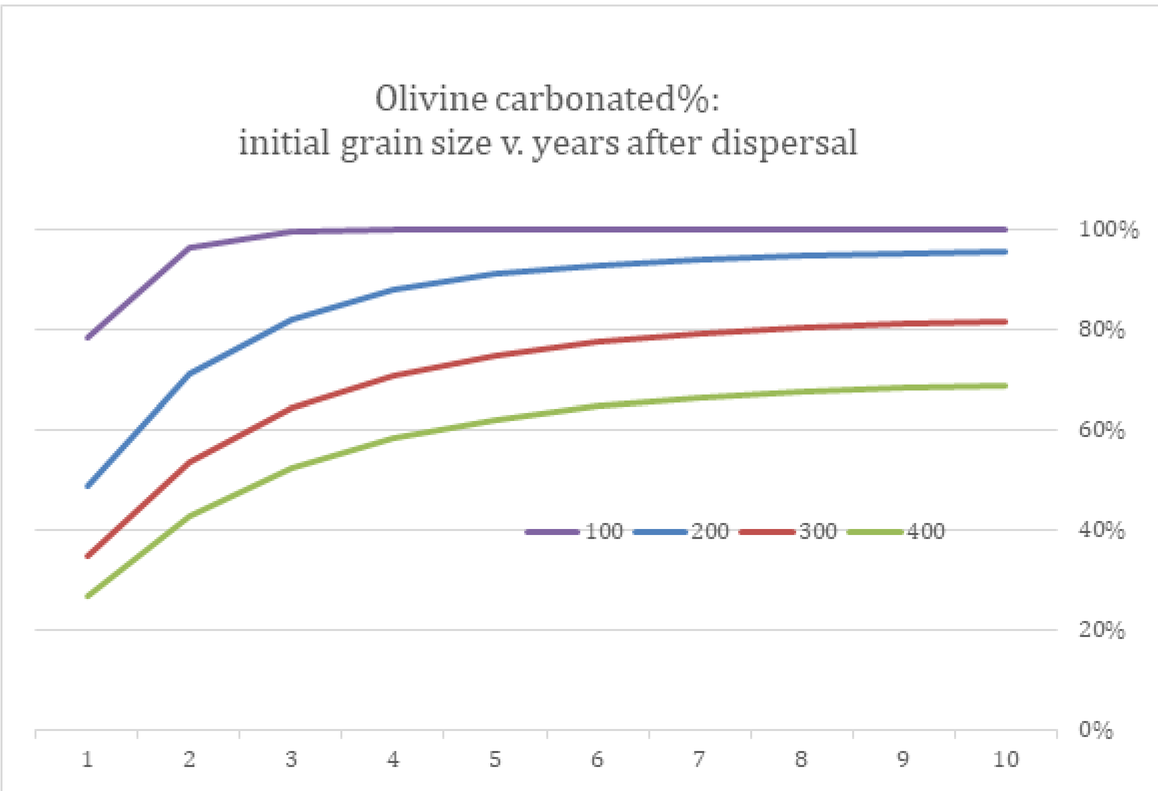
We begin with average grain sizes of 300 microns and assume each grain is a perfect sphere (a worst case). Therefore, a shell of 10 μm (10 microns) is dissolved every year.

Our target sites in mediterranean basin have warm humid summers and cold freezing winters, with significant rainfall. Freezing temperatures alternating with hot summers cause cracking and spalling. These cracks allow water to permeate the grains, leading to further surface areas being exposed.

We can confirm our approach via Strefler J. et al, Environmental Research Letters, 13, 2018 who put forward the equation $R_{co2}(x) = m \cdot d(x) \cdot p$.

As there is a "surface effect" as the outer shell gets carbonated, we can model this by saying initial CO2 carbonation is high (say 20 microns) but drops off rapidly.

Smaller grains help a lot see graph:



Crucially, even with large grain sizes of 300 microns (the red line above) 75% of possible CDR has happened. Our economic model assumed a 10 micron/year carbonation rate and no surface effect..

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).

Over 10 years, CDR = 78,800 tCO2 ÷ 2,246 hectares average = 3.4 tCO2/yr/ha.

Over 20 years, CDR = 91,700 tCO2 ÷ 2,299 hectares average = 2.0 tCO2/yr/ha.

Total overall capacity = 1.2 tCO2/t x 80,000t = 96,000t in theory, but CDR rates fall off with 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!

Our assumptions are based on reading and conversations with professionals and academics.

Title	**Author**
A review of mineral carbonation technologies to sequester CO2.	Maroto-Valer M 2014 Royal Society of Chemistry
Geological Mapping and Characterization of Possible Primary Input Materials for the Mineral Sequestration of Carbon Dioxide in Europe.	Kremer D. 2019 RWTH Aachen University
Carbon Sequestration via Mineral Carbonation	Herzog H. 2002 MIT Laboratory
Engineered carbon mineralisation in ultramafic rocks for CO2 removal from air.	Kelemen P. 2020 Dept. of E&ES Columbia Uni.
Enhanced Weathering: An Effective and Cheap Tool to Sequester Co2. Climatic Change.	Schuiling, R. D., Krijgsman, P. (2006)

Based on the above, we took 10 microns per annum from the surface inwards as the likely weathering rate. Taking a worst case – a perfect sphere of olivine - we can determine carbonation p.a. as in the table below for 300 microns (0.3 mm) and 50 microns (0.05mm).

Years	% carbonated 0.3mm grain	% carbonated 0.05mm grain
0	0%	0%
2	19%	46%
4	47%	86%
6	65%	96%

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.

We are part of the "mineral sequestration community" (of which two are already funded by stripe). ● Greensands.nl –sales of olivine in the Netherlands to domestic houses and for public authorities show no negative environmental impacts; ● Olivine-against-climate-change-and-ocean-acidification.pdf. R.D.Schuiling and Tickell, O. https://climitigation.org/wp-content/uploads/2017/10/Olivine-against-climate-change-and-ocean-acidification.pdf ● Geoengineering potential of artificially enhanced silicate weathering of olivine. Peter Köhler, Jens Hartmann, and Dieter A. Wolf-Gladrow ● Strefler, J., Amann, T., Bauer, N., Kriegler, E., & Hartmann, J. (2018). Potential and costs of carbon dioxide removal by enhanced weathering of rocks. Environmental Research Letters, 13(3), 034010. https://doi.org/10.1088/1748-9326/aaa9c4. ● www.sciencedirect.com/topics/earth-and-planetary-sciences/weathering-rate.

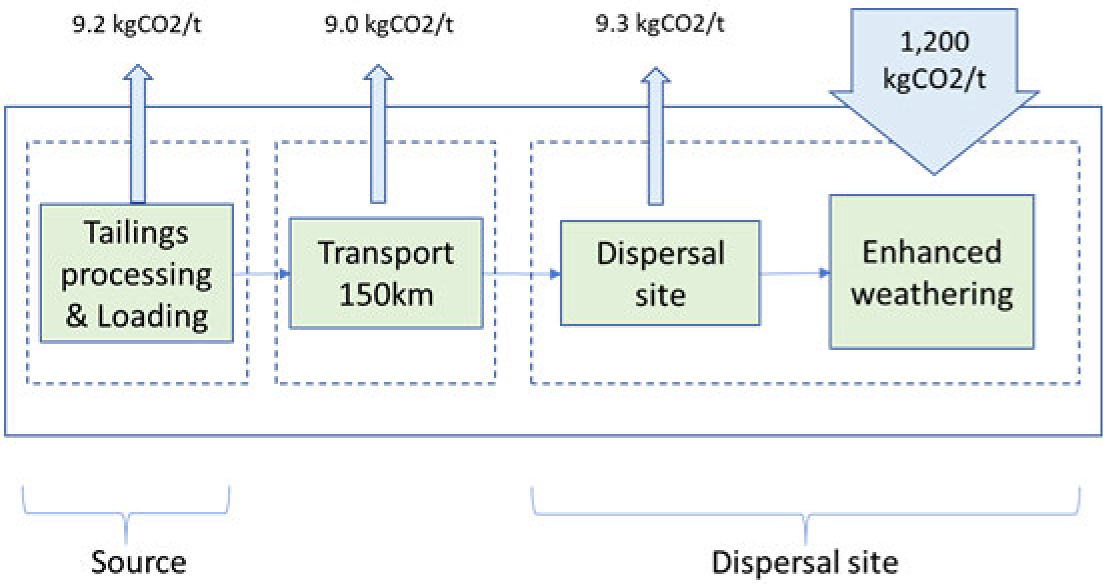
4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

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	30,000 tonnes
Gross project emissions	2,652 tonnes of CO2 (lifetime of project)
Emissions / removal ratio	4.9% based on Life Cycle Analysis in section 4(b)
Net carbon removal	Over 95%

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. If you've had a third-party LCA performed, please link to it.

LIFE CYCLE ANALYSIS - OPERATIONS



SOURCE

Our olivine source is a “technogenic deposit” wholly owned by Partner, our business partner. It does not need to be extracted from the earth.

Processing = grinding existing grains from an average 300 micron to 50 microns (speeds up carbon capture on the target site). CO_2 emissions = 1% of CDR assuming diesel power (500gCO2/kWh) is used.

This can be reduced by using biodiesel (100gCO2/kWh or wind-power (30gCO2/kWh).

TRANSPORT

The transportation component creates 9 kg of CO_2 per tonne of olivine. Heavy duty trucks in mediterranean basin must meet Euro 6 regulations since 2015, this means low NOx, particulates, HC and CO emissions.

Sources: “Emissions from Volvo’s trucks” for 2018 from the company show emissions of CO_2 per ton-km.

TARGET (DISPERSAL) SITE

Upon arrival at the dispersal site, the crushed olivine is decanted into a simple hopper, and then smaller loads are brought by tractor over the dispersal area and spread to an average depth of 1mm.

Labour, unloading spreading and moving expends another 9.28 kgCO2/t.

OVERHEADS

Project management, SG&A (Sales General and Admin) is assumed to equal 10% each of the above operations or a further 5.34 $kgCO_2/t$. Explicitly third party services such as Insurance are not counted.

LIFE CYCLE ANALYSIS TABLE - OPEX

Source	Input	Units	Input	Units	$kgCO_2/t$	$kgCO_2/d$	Ratio @120tpd
Monitoring	20	Km	130	gCO_2/km	0.02	3	0.00%
Processing	17	kWh/t	500	gCO_2/kWh	8.72	1,046	0.90%
Loading	1	kWh/t	500	gCO_2/kWh	0.5	60	0.10%
Transport							
Standing	300	Km	300	trips/year	0	0	0.00%
Fuel Out	150	Km	126	$kgCO_2/trip$	5.24	629	0.50%
Fuel Return	150	Km	90	$kgCO_2/trip$	3.77	452	0.40%
Target site							
Labour	1	kWh/t	130	gCO_2/kWh	0.13	16	0.00%
Unloading	3	kWh/t	800	gCO_2/kWh	2.4	288	0.20%
Spreading	10	kWh/t	500	$gCO_2/ton\text{-}km$	5	600	0.50%
Moving	1	kWh/t	800	gCO_2/kWh	0.8	96	0.10%
Monitoring	100	Km	130	gCO_2/km	0.11	13	0.00%
Maintenance	10%	Km	130	gCO_2/km	0.84	101	0.10%
Site Ops					26.69	3,304	**2.80%**
Overheads	Input	Units	Input	Units	$kgCO_2/t$	$kgCO_2/d$	Ratio @120tpd
Project Mgmt	10%				2.67	320	0.30%
SG&A	10%				2.67	320	0.30%
Insurance	0%				0	0	0.00%
Total all Ops						**3,944**	**3.30%**

LIFE CYCLE ANALYSIS TABLE – CAPEX

Capex = US$450,000 over 2 years for hoppers, trailers, grinders and machinery. As a proxy, assume that every $1 spent of Capex caused a litre of diesel fuel to be consumed (1:1 ratio).

At $1/litre, à Capex $450,000 = 450,000 litres diesel.

CO_2 intensity 1 litre diesel = 2.62 kgCO_2/l à 450,000 x 2.62 kgCO_2 = 1,179 tonnes CO_2 embodied.

From section 3(c) above, CDR = 78,800 tCO_2 in 1st 10 years à ratio = 1,179/78,800 = 1.5%

Therefore, estimated LCA of all Opex and Capex = 3.3% + 1.5% = **4.9% over 10 years**.

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?

Boundary condition:

- Trucking distance and transport links - from source to target site must be reasonable to transport at least 100t in one day.
- Use of land at the target site is minimal or no impact. Ex-mining sites are ideal.
- Weather at target site. Dry summers and cold winters.

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.

All numbers are modeled, using publicly available data. Worst case CO_2 emissions are assumed – substituting biodiesel alone would dramatically reduce our carbon footprint.

GRINDING/PROCESSING: $W = 10\ W_i\ (1/(\sqrt{P}) - 1/(\sqrt{F}))$ is the work required to grind the olivine.

Work Index Wi olivine	kWh/t	12.38
Feed grain size	microns	300
Product size	microns	100
Work required	kWh/t	5.23
Power @30% efficiency	kWh/t	17.44

TRANSPORT
Truck and trailer fully loaded = 38 tons total with 24 tons payload has fuel consumption of 32 l/100km on outward leg. On return trip, truck is empty, consumption is 23 l/100km. Source: Volvo.

CO_2 emissions =

Description	Out	Return	Units
Total truck wt.	38	14	tonnes
Payload	24	0	tonnes
Distance	150	150	km
Fuel cons rate	32	23	l/100km
Avg fuel cons	28		l/100km
Fuel cons	48.0	34.5	litres
Diesel	2.62	2.62	kgCO2/litre
CO2	125.8	90.4	kgCO2/trip
CO2 rate	22.1	43.0	gCO2/ton-km

Note: heavy duty trucks in mediterranean basin meet Euro 6 regulations since 2015, meaning low NOx, particulates, HC and CO emissions. Sources: "Emissions from Volvo's trucks" 2018 and www.thetruckexpert.co.uk/truck-operating-costs-report-for-2018

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. (We may request such an audit be performed.)

There is no cutting edge technology involved in this project, or new discoveries to make. Each stage involves simple, conventional operations (grinding, transportation, spreading) we have a high confidence that variations will be relatively small.

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

We are interested in understanding the [learning curve](https://en.wikipedia.org/wiki/Experience_curve_effects) 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 your progress.)

a. Please define and explain your unit of deployment. (*E.g.* # of plants, # of modules) *(50 words)*

Olivine technogenic deposits are location based: The first project will involve the transport by truck of 80,000t (30,000 m3) of olivine to a dispersal site – and each “unit of deployment” is 24 tonnes (8 m3). This will be the first commercial project deployed on land. We expect initial costs to be of the order of $34/t (opex and capex) and over time reduce to $25/t. We are investigating another 3 sources in mediterranean basin.

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 if necessary.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2021	Zero			
…				

c. Qualitatively, how and why have your deployment costs changed thus far?

We are currently at the pre-deployment stage. We expect our cost per tonne of CO2 captured to decline over the project’s lifetime, but we do not expect an order of magnitude reduction in those costs. The innovations are incremental and straightforward: e.g. better use of existing machinery, more efficient spreaders, more economical transport, remote monitoring.

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)
1,000	24t x 1.2 CO2/t = 2.88t of CO2 sequestered per unit. Total offer = 30,000 tonnes

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

We ask these questions to get a better understanding of your growth trajectory and inflection points, there are no right or wrong answers. If we select you for purchase, we'll expect to work with you to understand your milestones and their verification in more depth.

a. What is your cost per ton CO_2 today?

Estimated costs today = $34/tCO2

Opex = $28/tCO2 and capex = $6/tCO2.

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."

We have included every operation cost element we know of.

Source: Purchase	$6.00 /t	
Source: Monitoring	$0.50 /t	Frequent measurement at source
Source: Processing	$1.80 /t	Grinding as required
Source: Loading	$1.90 /t	Use loader into hopper into trucks.
Transport: Standing	$2.50 /t	Source: UK data (>> mediterranean basin)
Transport: Fuel Out	$2.40 /t	c.150km
Transport: Fuel Return	$1.70 /t	c.150km
Site: Labour	$0.10 /t	General labour
Site: Unloading	$0.40 /t	General labour
Site: Spreading	$1.20 /t	Agricultural equipment + tractor

Site: Moving	$0.10 /t	Agricultural equipment + tractor
Site: Monitoring	$2.00 /ha	Local personnel
Site: Maintenance	$0.60 /t	Local personnel
Site: Land use	$10.00 /ha	Budget for title holders
Project management	10%	CO2-Zero & Partner staff
SG&A	10%	CO2-Zero & Partner other costs
Insurance	5%	Estimated
Total: Opex	$28.01 /t	

c. 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	Geochemical analysis	Understand mineral CDR capacity based on Mg-Fe relationship. Ability to exclude impurities that could be detrimental to the environment.	Q3, 2021	Independent laboratory reports.
2	Target site identification	Target site will set: · transportation costs; · environmental impact; · local climatic weathering conditions.	Q3, 2021	Contract with land title owners. Environmental permitting.
3	Certifying sequestration	Makes our CDR saleable.	Q1, 2023	CDR sales to third parties.

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	0	96,000 tonnes	No CDR without geochemical analysis.
2	0	96,000 tonnes	No CDR without a target site.
3	96,000 tonnes	96,000 tonnes	

d. 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	$34/tCO2	$34/tCO2	
2	$34/tCO2	$34/tCO2	
3	$34/tCO2	$34/tCO2	

e. 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?

Bill Gates, the ex-CEO of Microsoft.
We would ask him to use his public platform and contacts to introduce our olivine sequestration approach to financial institutions worldwide and to governments, NGOs in the less developed world.

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

Develop algorithms (with AI input) to predict and quantify CDR by olivine based upon:

- Grind size and grain form
- Mg-Fe ratios
- Weather conditions
- Presence of other elements, precipitation factors
- Target site biota.

PR for olivine CDR, to effectively address reservations about this CO_2 sequestration method.

7. Public Engagement and Environmental Justice (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 some mechanism 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. There are no right or wrong answers, and we recognize that, for early projects, this work may not yet exist or may be quite nascent.

a. Who are your external stakeholders, where are they, and how did you identify them?

External Stakeholder	Location	How identified
Local title holders in disused mines	mediterranean basin	Partner, CO2-Zero.
Local community who worked in now disused mines	mediterranean basin	Partner
Local and central government	mediterranean basin	Partner
CO2 offset buyers (BP, Microsoft, etc.)	World	CO2-Zero through media, corporate contacts

CO2 offset purchases by governments	Ireland, EU	Corporate, personal contacts
Global Climate Fund (GCF) and World Bank Climate Funds Management Unit	Developing world	Corporate meetings
Local NGOs and environmental groups	World	Corporate and personal contacts

b. If applicable, how have you engaged with these stakeholders? Has this work been performed in-house, with external consultants, or with independent advisors?

Stakeholder name	Location	How engaged
Local title holders in disused mines	mediterranean basin	Partner, CO2-Zero.
Local community who worked in now disused mines	mediterranean basin	Partner
Local and central government	mediterranean basin	Partner
CO2 offset buyers (BP, Microsoft, etc.)	UK	Virtual meeting(s)
CO2 offset purchases by governments	Ireland	Meetings with state agency (Bord na Móna)
Global Climate Fund (GCF) and World Bank Climate Funds Management Unit	Korea USA	Virtual meeting(s)
Local NGOs and environmental groups	World	None to date

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?

We have improved our communications, explaining:

- Geological weathering in simple terms, and the positive effect of “using nature to heal nature”.

- That our project will make a clear change to how companies manage their CO_2 emissions in the future.

One of the feedbacks from a potential customer: "*Is this going to be a real offsetting programme?*"

To explain that, upon successful deployment, our carbon offset business venture will be compliant and auditable.

To ensure our carbon sequestration projects can deliver the highest levels of environmental integrity, certification and verification will be carried out by internationally recognised organisations – such as Gold Standard - the most rigorous certification standard globally for carbon offset projects.

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?

We are already identifying similar projects in mediterranean basin and elsewhere.
There are no changes identified at this stage but we will implement lessons learned with Partner.

e. What environmental justice concerns apply to your project, if any? How do you intend to consider or address them?

Environmental issues: dust. Solution: hoppers

Olivine is heavy (sg = 3.4) and will quickly fall to the ground. Over time, it infiltrates the ground, and counter-acts acidic soils.

We do not expect chrome and nickel problems with our olivine source.

Our project will not have disproportionate impact on marginalised social groups or critical ecosystems.

No potential conflicts will occur with regards to control and access to olivine as a natural resource as people do not depend on these resources. We will be using a side product of mining operations.

Adjacent land-owners will be informed about the use and purpose.

Social/environmental costs from the project's operations will be minimal as our activities will be located on an abandoned mine, a site already degraded and exploited.

11. Legal and Regulatory Compliance (Criteria #7)

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

Our Partner is an existing operator of an olivine quarry and are very familiar with the regulatory framework in mediterranean basin.

Local legal advice has been obtained on the general terms of our partnership with them, which is through a company owned by both of us.

b. What permits or other forms of formal permission do you require, if any? 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.

Partner advise that we need:

- Co-operation from landowners and owners of the target site (disused mineworks)
- Environmental permit (from Forestry Dept.) – possibly.

If disused mines are used and if the owners' licences are still valid, then permission from the central government is not required.

c.

mediterranean basin has a long mining and quarrying tradition, with a set of regulations and customs developed over a long time.

As olivine is a natural mineral, already quarried in the country, we are not overly concerned about our small-scale initial project of 80,000 tonnes. Our reception has been friendly and positive.

Larger projects taking up hundreds of km2 is another matter, which we can approach with the knowledge and example of the first one.

12. 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)	30,000 tonnes
Delivery window (at what point should Stripe consider your contract complete?)	3 years
Price ($/metric tonne CO_2)	US$75/tonne.

Application Supplement: Surface Mineralization

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

Source Material and Physical Footprint (Criteria #1 and #8)

1. What source material are you using, and how do you procure it?

Olivine, procured from existing mine and quarry sources.

2. Describe the ecological impacts of obtaining your source material. Is there an existing industry that co-produces the minerals required?

Zero ecological impact as the technogenic deposit already exists.

3. Do you process that source mineral in any way (e.g grinding to increase surface area)? What inputs does this processing require (e.g. water, energy)? You should have already included their associated carbon intensities in your LCA in Section 6.)

Yes, the olivine technogenic deposit has an average grind size of 300 microns but we will grind this to 100 microns as much more net carbon is captured that way (see section 4(d) and 6 above).

Source	kgCO2/t	kgCO2/d	Ratio @120tpd
Site Ops	26.69	3,304	2.80%

- Crushing 120tpd to 100 microns requires power 17.44 kWh/t x 120tpd = 2,093 kWh/day.
- This is derived from conventional diesel, biofuel, or electrical power. We have assumed a worst case of conventional diesel emitting 500gCO2/kWh = 1.0 tCO2 per day.
- No water is required at the source site.

4. Please fill out the table below regarding your project's physical footprint. If you don't know (e.g. you procure your source material from a mining company who doesn't communicate their physical footprint), indicate that in the square.

	Land area (km^2) in 2021	Competing/existing project area use (if applicable)

Source material mining	Already mined, spread out in three piles on c. 15 hectares.	N/A
Source material processing	< 1 hectare	N/A
Deployment	2400 hectares	Ex-mining area

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

	Projected # of km^2 enabling 100Mt/yr	**Projected competing project area use (if applicable)**
Source material mining	15,000 ha	Quarrying
Source material processing	1,000 hectares	None
Deployment	4,000 km2	Recover 1mm deep every 5 years

5. If you weren't proceeding with this project, what's the alternative use(s) of your source material? What factors would determine this outcome?

This is an existing olivine waste pile which is not of a purity or in a form that appeals to the refractory buyers. Price determines this outcome.

Measurement and Verification (Criteria #4 and #5)

6. We are aware that the current state of the field may include unknowns about the kinetics of your material. Describe how these unknowns create uncertainties regarding your carbon removal and material, and what you wish you knew.

Technogenic deposit will have significant variations.

- Iron-Magnesium relationship – we do know how the extent of the surface effect, if any.

- How weather in western mediterranean basin may effect sequestration.
- Potential biota that could slow or speed up sequestration.

The major factors influencing olivine dissolution rates are pH, temperature, mineral saturation. However, the manifold parameters, such as runoff, soil CO_2, soil respiration, root-soil interactions, etc, exert a strong influence on the weathering rate.

We will be monitoring the soil chemistry at regular time intervals. The terrestrial enhanced weathering will be assessed for a broad range of variables to establish a model that can accurately predict the rate of chemical weathering.

7. If your materials are deployed extensively, what measurement approaches will be used to monitor weathering rates across different environments? What modelling approaches will be used, and what data do these models require?

Regular, systematic measurement of chemical composition of the olivine distribution will be aided by having multiple (c.100 each 1m2 in area) shallow boxes containing olivine. These “trays” make it easier to measure the carbon sequestrated in the same place year after year and will be inspected weekly and immediately after high winds or heavy rain.

Modelling approaches will be based on samples removed from the trays every quarter or as is otherwise needed for independent external auditing.

Data required will the changing carbon levels and the magnesite testing.

Olivine outside the trays will be measured at multiple locations, especially where it piles up due to local hydrology, wind and at ditches, cliffs and clefts. We will place a range of olivine rock sizes (500 microns to 50cm) at the dispersal site as a control.

Human and Ecosystem Impacts, Toxicity Risk (Criteria #7)

8. What are the estimated environmental release rates of heavy metals (e.g. Cr, Ni, Pb, Hg)? Dust aerosol hazards? P loading to streams? How will this be monitored?

Environmental issues: dust mitigation measures.

1. Olivine is heavy (sg = 3.4) and will quickly fall to the ground. Dust concentrations will be measured and compared with limits given in the Turkish Air Pollution Control Regulation, 2004.
2. Using agricultural spreaders to apply the olivine: spreading will be performed when it is not windy.

3. To suppress the dust the material will be damped. Before transportation we are going to sprinkle water on the material and cover it, so it is not blown away.
4. Constant environmental monitoring. Biochemical analysis will be implemented to measure effects of olivine on the biochemistry of the soil.
5. The advantage of using olivine powder on a post mining area is that it slowly mixes into the soil like a fertilizer, counteracting soil acidity and providing important elements for plant growth such as Mg, K and Fe).

9. If minerals are deployed in farmland, what are the estimated effects on crop yields, what's this estimation based on, and how will actual effects be monitored?

We are deploying onto disused mining areas, where no crops are grown. Data from many academic studies show that dunite improves the ground.

Projects such as Carbdown in Germany and Greece are investigating the purposeful ploughing-under of 8 cm of olivine into the soil, with one of the benefits being less fertilizer use by the farmer. Source: carbdown.de

10. How will you monitor potential impacts on organisms in your deployment environment? (E.g. Health of humans working in agricultural contexts, health of intertidal species, etc. depending on the context of deployment)

We will be taking stream samples and examining the biochemistry of local plants and insects

We will gather data at project start, during dispersal and then in the subsequent time to check for levels of iron, nickel, chrome and other elements.

A 1mm layer is not substantial and will have negligible impact on the chemistry of local biosphere.

11. If you detect negative impacts, at what point would you choose to abort the project and how?

Deployment happens during the first 3 years during which time intensive site monitoring will check for Cr, Ni and other trace elements.
If a significant negative impact (or potential impact) is detected we would immediately liaise with scientific advisors and advise local government and relevant authorities. We would then decide (with them) what to do with their input.