NetZero CCS Development Company Ltd

Carbon dioxide removal prepurchase application

Summer 2023

General Application

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

Public section

The content in this section (answers to questions 1(a) - (d)) will be made public on the [Frontier GitHub repository] after the conclusion of the 2023 summer purchase cycle. Include as much detail as possible but omit sensitive proprietary information.

Company or organization name

NETZERO CCS DEVELOPMENT COMPANY LIMITED ("NetZero")

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

Company is registered in Ireland. Subsidiaries in Oman, Zimbabwe, Indonesia, and USA.

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

T. Gerard Bennett ; Engr. Elijah Ugaddan

Brief company or organization description <20 words

CDR from 100B t of Olivine mineral. Technical, MRV. Projects in three regions. Six paths: Land, reef, OAE, CCS, DAC, Power.

1. Public summary of proposed project[1] to Frontier

a. **Description of the CDR approach:** Describe how the proposed technology removes CO_2 from the atmosphere, including how the carbon is stored for > 1,000 years. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar approach. If your project addresses any of the priority innovation areas identified in the RFP, tell us how. Please include figures and system schematics and be specific, but concise. Aim for 1000-1500 words.

We are building a natural cost-effective, high-volume supply of Magnesium Hydroxide for global OAE efforts to rebalance the oceans' pH after CO_2 absorption, and in so doing allow the oceans to absorb more CO_2 safely and responsibly.

The $Mg(OH)_2$ targeted in this project Pilot has several paths to CDR. OAE as discussed here. It is also intended for DAC with zero liquefaction and zero reinjection is being developed in parallel and $Mg(OH)_2$ is used in CCS as a one-time use permanent sorbent for industrial concentrated CO_2 emissions.

Our approach is unique in that we are using an abundant yet overlooked resource with virtually unlimited supply <u>if</u> we can show a suitable CDR sorbent can be extracted from high olivine content rock. We are not aware of any other effort to refine Dunite rock to $Mg(OH)_2$ or MgO.

- Our project delivers CDR capability at volume and with simplicity of deployment.
- Our pilot offers simple controls for MRV and environmental safety.
- Our FOAK can be lower than $80 per CDR by 2026.
- Our NOAK can be closer to $60 and will benefit from scale in global H electrolysis production efficiencies.
- Our CDR price can be compensated further by offtake products in high demand.

b. **Project objectives:** What are you trying to build? Discuss location(s) and scale. What is the current cost breakdown, and what needs to happen for your CDR solution to approach Frontier's $100/t and

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

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

The project site is Oman, although the pilot may be replicated in other jurisdictions where there is interest to share the research. Oman is chosen because of the immediate supply of very high Olivine content Dunite rock.

The pilot is 5,000t of olivine mineral input for 2,000t of $Mg(OH)_2$ and / or MgO production which in turn achieves approx. 2,250t of OAE mCDR.

The current cost breakdown is determined by the energy required for olivine refining. We have three options which the pilot is to review. The current cost breakdown for our PILOT and FOAK is as per table below:

(It differs from the Frontier TEA estimates)

		PILOT 5,000 input tons **3 processes** across three production processes		**1. electrolysis Mg(OH)2**		**2. calcination (MgO)**		**3. precipitation**	
	sector	rock to CDR ratio 45% volume output	**PILOT** no depreciation 5,000 tons mineral in cost total & per CDR	volume 1m tons mineral in	FOAK solar costs	volume 1m tons mineral	FOAK solar & gas costs	volume 1m tons mineral in	FOAK solar & gas cost
sector 1	1. rock supply	5,000 50 micron powder	$ 215,000	1,000,000 50 micron powder	$ 15,000,000	1,000,000 50 micron powder	$ 15,000,000	1,000,000 50 micron powder	$ 15,000,000
sector 2	conversion mineral to sorbant 2. Ore refinery	51.3% 2,567 Mg(OH)2 solution	$ 1,112,606	64% 640,000 Mg(OH)2 solution	$ 25,554,620	45% 450,000 Mg(OH)2 solution	$ 22,754,620	45% 450,000 MgO solution	$ 22,754,620
sector 3	3. Deploy OAE (CDR's)	87.5% 2,246 mCDR from OAE	$ 276,737	87.5% 560,000 mCDR from OAE	$ 3,310,000	87.5% 393,750 mCDR from OAE	$ 3,310,000	87.5% 393,750 mCDR from OAE	$ 3,310,000
sector 4	additional offtake silica sell @ $$ton 10	2,250	(22,500)	450,000	(4,500,000)	450,000	(4,500,000)	450,000	(4,500,000)
			$ 1,581,844 $ 704		$ 39,364,620 $ 70		$ 36,564,620 $ 93		$ 36,564,620 $ 93

3 options trialled

Expected FOAK

The pilot is non-commercial, and the pilot is not an optimal LCA. The pilot is for process decisions and preparation for high competitive FOAK 2025 /2026 pricing sub $100 and very low LCA of 1%.

Pilot Design

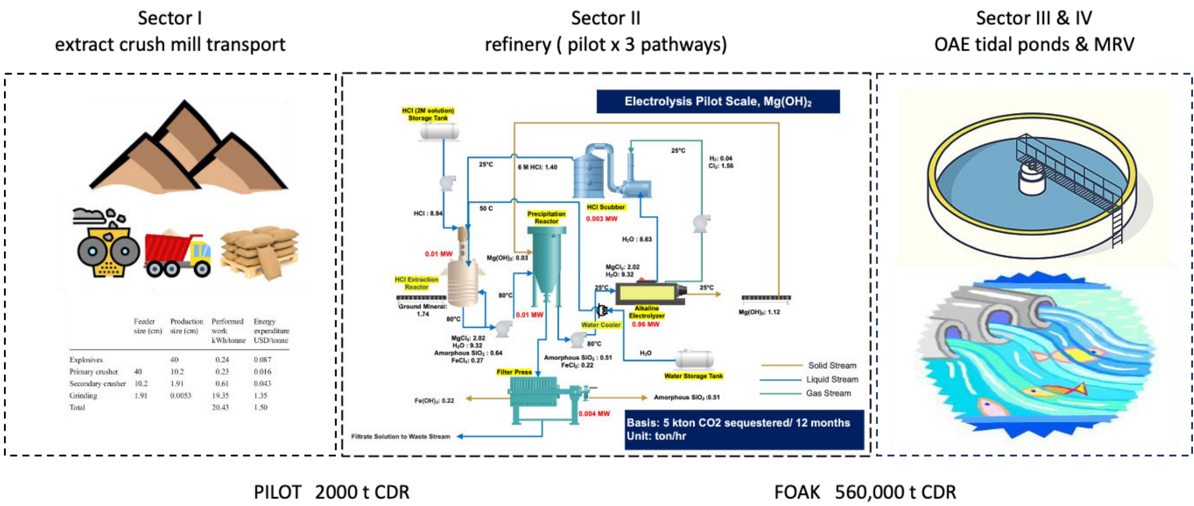
The pilot consists of four production sectors. Within sector III we evaluate three process pathways or options are compared.

Sector I - The extraction, crushing and milling of high olivine content Dunite rock to 50-micron powder

Sector II - The refining of the olive mineral to separate $Mg(OH)_2$ or MgO

Sector III - Deployment of the refined material to Sea water in controlled lagoons.

Sector IV - MRV data collection and packaging for verification and CDR registration



	Feeder size (cm)	Production size (cm)	Performed work kWh/tonne	Energy expenditure USD/tonne
Explosives		40	0.24	0.087
Primary crusher	40	10.2	0.23	0.016
Secondary crusher	10.2	1.91	0.61	0.043
Grinding	1.91	0.0053	19.35	1.35
Total			20.43	1.50

Sector I - Rock supply

To supply crushed and ground rock (50-micron powder) to the refinery process. To remove any contaminants prior to refining. The objective is to demonstrate a supply chain scalable to NOAK \$10 / t and to prepare for non-truck transport using water pipelines.

Sector II- Rock refinery

Once we have a milled 50-micron powder olivine material high in MgO SiO_2 content we pass it through a refining process to separate the MG into an active CDR sorbent MgO or $Mg(OH)_2$. There are three refining processes under review in this pilot.

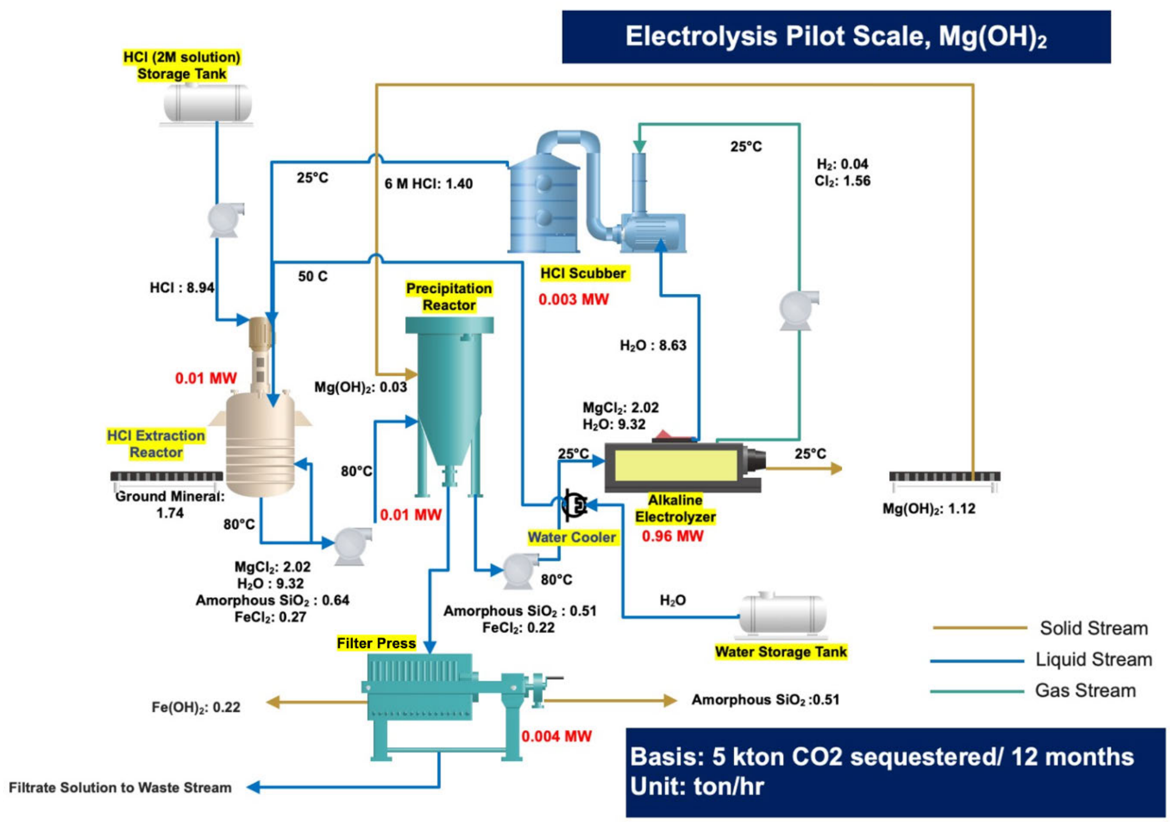
- A two-stage precipitation followed by alkaline electrolysis to generate a solution of $Mg(OH)_2$ ready for OAE (preferred).
- A two-stage precipitation followed by calcination to generate a solution of MgO ready for OAE (immediate TRL 9).
- A three-stage triple-precipitation to generate a solution of $Mg(OH)_2$ ready for OAE (low cost) .

Each of these trials shares certain preparatory components. Each of the three process options has separate challenges, capex costs, conversion ratios from source olivine mineral, ease of operation, etc. The pilot will help to select the optimal process based on energy usage, minimal CO_2 emissions and lowest CDR cost. Our current preference is Electrolysis.

Interestingly, if electrolysis remains the preferred option for FOAK and NOAK, it places us on a parallel trajectory to Hydrogen development. Significant cost reductions can be expected for electrolysis. Potentially a 50% cost reduction.

Below is the process design for the Electrolysis option.

Figure 1. Process Flow Diagram of the Electrolysis process to produce $Mg(OH)_2$. Our system is modular so replacing only the electrolyzer with a calciner or $Mg(OH)_2$ precipitation tank can facilitate our refining processes.



FOAK and NOAK refinery energy source and LCA reduction

Today electrolysis seems the most promising process. Electrolysis has a high energy input requirement (3.2 Gj per t). To use electrolysis in FOAK or NOAK we will require paired solar installed capacity to ensure our $Mg(OH)_2$ output has a 1% LCA from the refining process (approx. 1% for the full CDR process).

Likewise, the transport of our sand / powder materials will transition from a pilot using diesel trucks to a sludge pipeline which significantly reduce the CO_2 emissions, acts as a pumped hydro energy store for the solar capacity and is a comparable or lower cost to road transport.

Refinery Offtake Products

The refinery process has several commercial offtake commodities, most notably, Amorphous Silica (SiO_2). We have several pilot objectives regarding these offtake products. We are targeting olivine with >90% $MgOSiO_2$. Any decrease in Silica output is likely to accompany an increase in $Mg(OH)_2$ output. Amorphous Silica revenue estimates range from $30 to $300 / t, but will be impacted by distance to market and silica specification. There may be a possibility to generate hydrogenated silica.

1. Confirm the expected ratio of 45% source olivine to amorphous silica.
2. Confirm the specification of our offtake silica.
3. Match our offtake silica to target forward buyers of silica.
4. Ditto for $Fe(OH)_2$ and H recovery.
5. Determine the $$ support offtake sales can provide to CDR costs, although our strategy at present is to use these offtake revenues as reserves against Government taxes, or other costs that may affect the project.

Sector III - alkination deployment

The refinery will deliver volumes of $Mg(OH)_2$ and/or MgO in solution ready for OAE deployment.

We will use control lagoons for safety. Lagoons are cheap and easy to create. Modeled on shrimp cultivation or water treatment lagoons, they provide our pilot with a controlled environment. The first lagoon is for storage of the concentrated solution of $Mg(OH)_2$ or MgO. We will conduct daily volume trials with $Mg(OH)_2$ solution released to a second isolated tidal sea water lagoon. We will only release trial water volumes back to the sea after structured environmental checks.

The objectives of OAE deployment trials are:

1. To determine dilution ratio $Mg(OH)_2$ to sea water prior to release, to observe and measure effect.
2. To determine the same dilution ratio for MgO to sea water, to observe and measure its effect.
3. To measure the dissolution rate for $Mg(OH)_2$ and MgO in ocean ambient temperatures.

4. To consider controlled $Mg(OH)_2$ and MgO dissolution acceleration using sea water at elevated temperatures and pressure prior to re-release to ocean.
5. To determine carbon curve(s) for both $Mg(OH)_2$ and MgO under selected conditions and time.
6. To decide which is the better CDR deploy agent $Mg(OH)_2$ or MgO, from a CDR and refinery combined perspective.
7. Using an array of multiple sensor tests to determine the best indicators of alkalinity change in the control lagoons.
8. To develop, publish and peer review to ICVCM standards our OAE methodology (for anyone to use).
9. To observe any environmental impacts.

Sector IV MRV data and CDR registration.

Our MRV and sensor team will be preparing the pilot data to create an OAE CDR methodology supported by these trials with clear measurement techniques. We will be peer reviewing and seeking ICVMC accreditation of the methodology as well as combining with any of the expected 3rd party methodologies from Vesta Puro and others.

Pilot and project LCA

This pilot is not commercial nor LCA optimized. The pilot is trialing three separate refinery options and using standard energy supplies of grid and elements diesel. FOAK will be dedicated to renewable energy sources to deliver LCA close to 1%. These dedicated energy installations are assumed in our FOAK calculations.

The Pilot LCA is not attractive, but unavoidable for such a test.

The FOAK LCA is very attractive at 1% for the entire process of electrolysis with water sludge pipelines. This is achieved through dedicated solar capacity, energy storage and removal of road transport.

c. **Risks:** What are the biggest risks and how will you mitigate those? Include technical, project execution, measurement, reporting and verification (MRV), ecosystem, financial, and any other risks. Aim for 500-1000 words.

The biggest risks our project faces are: A. The performance of electrolysis; calcination and triple precipitation. B. The supply of electrolysis equipment for rollout as we follow the same demand as H production. C. The energy costs of our refining process to produce $Mg(OH)_2$. D. Unintended environmental impacts as yet undetected. E. Resale value for silica allows us significant flexibility to adapt to risks above.

d. **Proposed offer to Frontier:** Please list proposed CDR volume, delivery timeline and price below. If you are selected for a Frontier prepurchase, this table will form the basis of contract discussions.

Proposed CDR over the project lifetime (tons) *(should be net volume after taking into account the uncertainty discount proposed in 5c)*	This pilot: 2,000 t CDRs
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	January 2024 – September 2026, 2026.
Levelized Price (\$/ton CO_2)* *(This is the price per ton of your offer to us for the tonnage described above)*	\$250 per CDR for pilot. \$95 for first 1 million CDRs pre-2030

** This does not need to exactly match the cost calculated for "This Project" in the TEA spreadsheet (e.g., it's expected to include a margin and reflect reductions from co-product revenue if applicable).*