BRIEF FOR THE SENATE STANDING COMMITTEE ON FISHERIES AND OCEANS

# LOW-CARBON ALKALINITY PRODUCTION TO SCALE CANADIAN CDR

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## Executive Summary

Exterra Carbon Solutions offers a transformative approach to carbon dioxide removal (CDR) by producing low-carbon, high-purity magnesium and calcium oxides from legacy mine tailings. These oxides are critical feedstocks for scalable, durable, and verifiable carbon storage in applications like surface mineralization, Ocean Alkalinity Enhancement (OAE), and Enhanced Rock Weathering (ERW). By leveraging Canada's abundant mineral resources and renewable energy, Exterra addresses both the carbon storage gap and the industrial waste problem, positioning Canada as a global leader in climate solutions. Federal support is essential to scale these efforts, revitalize mining-impacted regions, and meet Canada's net-zero goals.

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## Introduction: The Need for Scalable Carbon Removal

Mineral carbonation is a natural geochemical process where carbon dioxide ($CO_2$) reacts with magnesium ($Mg^{2+}$) or calcium ($Ca^{2+}$) ions, forming solid carbonate minerals such as magnesite ($MgCO_3$) or calcite ($CaCO_3$). This reaction effectively removes $CO_2$ from the atmosphere and locks it into a stable, inert form. Mineral carbonation provides unmatched security and durability, with the Intergovernmental Panel on Climate Change (IPCC) emphasizing its permanence over millennia (IPCC, 2005).

### The Natural Process and Its Acceleration

Minerals as a carbon sink have the more than sufficient capacity to store all CO2 emissions generated by human activities to date (Lackner, 2003). Natural mineral carbonation occurs as a result of the weathering of the earth's surface. Passive mineral carbonation contributes significantly to the regulation of atmospheric carbon levels over geologic timescales (Hilley, G. E. & Porder, S., 2008). Annually, the natural weathering of silicate minerals on the earth's surface contributes to the removal of more than approximately 100 million tCO*2* from the atmosphere through passive mineral carbonation (Gaillardet, 1999).

The same reactions can be replicated in an engineered system. By altering the natural minerals the process can be accelerated from a 10,000-year timescale to a matter of hours. The key is making the calcium and magnesium readily available for the reaction which can be achieve by controlling temperature, pressure, surface area etc.

### Alkalinity: The Building Block for CDR

Alkalinity, primarily in the form of magnesium or calcium oxides (MgO or CaO), is the reactive agent essential for converting $CO_2$ into stable carbonates. These oxides bind with $CO_2$ to form bicarbonates (in rivers and oceans) and carbonate minerals. The availability of high-purity, low-carbon alkalinity is critical to ensuring the efficiency, scalability, and environmental safety of this process. Without sufficient alkalinity, the potential for mineral carbonation as a global-scale CDR method remains unrealized.

### Scaling Challenges and Opportunities

Scaling mineral carbonation requires significant mineral inputs. For every tonne of CO2 between 0.5 and 2 tonnes of pure Alkaline materials are required. To ensure a real carbon benefit, the production of the alkaline material must not generate more CO2 than it mineralizes, requiring new technology to replace emission intense traditional processing methods. In mineral waste, like mine tailings and steel slags, there is over 1 billion tonnes of CO2 mineralization capacity generated each year (Renforth, 2019). In addition to new materials, historic materials contain significant capacity. For example, historic Canadian Asbestos mines hold around 1 billion tonnes of Magnesium rich mine tailings, including;

1. **Eastern Townships, Quebec:** Located between Quebec City and Montreal, with a hydroelectric grid available nearby represent an ideal location to scale the extraction of low carbon oxides.
2. **Baie Verte, Newfoundland and Labrador:** Asbestos mine tailings located adjacent to the ocean, ideal for alkalinity production and OAE.
3. **Voisey's Bay Mine, Newfoundland and Labrador:** Nickel mining operations have left behind millions of tonnes of tailings rich in magnesium silicates, offering a localized source for alkalinity production.
4. **Cassiar Mine, British Columbia:** Asbestos mine tailings located near the Pacific for large-scale alkalinity projects.
5. **Clinton Creek Mine, Yukon:** Asbestos mine tailings rich in magnesium for alkalinity production for ERW in agricultural land.

Exterra's innovative process liberates divalent metals from waste materials while extracting valuable by-products, enabling the production of high-purity oxides with minimal emissions, unlocking the full potential of mineral carbonation for CDR and CCS.

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### The Role of Low-Carbon Alkalinity in Carbon Removal

Low-carbon alkalinity plays a foundational role in achieving scalable, effective, and environmentally sustainable carbon dioxide removal (CDR). It is the key reactive agent in multiple engineered and nature-based CDR ad CCS pathways, each leveraging the chemical properties of magnesium and calcium oxides (MgO and CaO) to capture and store atmospheric $CO_2$ as stable carbonates or bicarbonates. Below is an in-depth exploration of these pathways and why low-carbon alkalinity is critical to their success:

#### 1. Engineered Surface $CO_2$ Mineralization

- **Process:** High-purity MgO or CaO reacts with gaseous $CO_2$ at surface sites to form solid carbonates, such as magnesite or calcite. These reactions are rapid, measurable, and irreversible under natural conditions, ensuring durable storage.
- **Applications:** Ideal for pairing with industrial $CO_2$ emissions, flue gases, and direct air capture (DAC) systems.
- **Advantages:** Enables clear measurement, reporting, and verification (MRV) of carbon storage outcome and offers localized deployment, reducing the need for $CO_2$ transport.

**2. Ocean Alkalinity Enhancement (OAE)**

- **Process:** Alkalinity is introduced into ocean waters, where it reacts with dissolved $CO_2$ to form bicarbonates ($HCO_3^-$). This process not only sequesters $CO_2$ but also mitigates ocean acidification, providing vital support for marine ecosystems.
- **Role of Low-Carbon Alkalinity:** High-purity MgO or CaO ensures efficient bicarbonate formation without introducing harmful impurities into marine ecosystems. Low-carbon production methods minimize lifecycle emissions, maximizing the net carbon removal impact.

**3. River Alkalinity Enhancement (RAE)**

- **Process:** Alkalinity is added to freshwater river systems, leveraging natural water flows to transport bicarbonates downstream into larger water bodies, such as oceans, where they contribute to long-term $CO_2$ sequestration.
- **Role of Low-Carbon Alkalinity:** High reactivity of MgO and CaO ensures maximum bicarbonate conversion before dilution in water bodies. Offers a distributed solution for carbon removal, particularly in regions with extensive river networks.

**4. Enhanced Rock Weathering (ERW)**

- **Process:** Finely ground reactive minerals are applied to soils, where they react with atmospheric $CO_2$ and water to form stable carbonates. ERW enhances soil fertility and structure, benefiting agricultural productivity.
- **Role of Low-Carbon Alkalinity:** Using high-purity MgO or CaO accelerates carbonation rates, making ERW more effective. Suitable for large-scale deployment in agricultural and degraded lands.

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**Canada's Potential to Use Mineral Waste to Decarbonize**

Canada is uniquely positioned to lead the global effort in low-carbon alkalinity production due to its vast natural resources, advanced industrial infrastructure, and commitment to climate action. By leveraging existing mineral waste, renewable energy, and strategic geographic advantages, Canada can become a critical supplier of low-carbon, high-purity oxides for carbon dioxide removal (CDR) applications.

- **Multiple Leading Companies:** Arca Climate, Baie Minerals, Carbon Upcycling, Planetary Technologies, Blue Skies minerals.
- **Abundant Feedstock:** Canada generates millions of tonnes of mine tailings annually, with billions of tonnes in legacy stockpiles.
- **Renewable Energy Integration:** Hydroelectric power in provinces like Quebec and British Columbia minimizes emissions from oxide production, enabling highly carbon-negative CDR applications.

- **Strategic Locations**: Atlantic and Pacific Canada has significant alkalinity sources that are near the coast, supporting OAE and RAE deployments.

**Alignment with Canada's Climate and Economic Goals**

Canada's ambitious climate targets, including achieving net-zero emissions by 2050, create a strong policy environment for supporting low-carbon technologies like mineral carbonation. The government's focus on reducing industrial emissions and fostering a circular economy aligns directly with Exterra's solutions, which turn industrial waste into valuable inputs for CDR.

- **Circular Economy Benefits:** Reprocessing mine tailings into high-purity MgO and CaO eliminates environmental liabilities while creating economic opportunities. By-products such as nickel and silica support critical mineral supply chains for batteries and green construction.
- **Economic Revitalization:** Regions affected by the decline of mining, such as Val-des-Sources, benefit from job creation and land rehabilitation through projects like Exterra's Hub I.

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**Conclusion**

**Exterra's Contribution to Canada's Leadership**

Exterra Carbon Solutions is pioneering a transformative strategy to tackle Canada's climate and environmental challenges. By harnessing cutting-edge technology, renewable energy, and the country's mineral waste, Exterra is not only enhancing scalable carbon dioxide removal (CDR) but also generating economic opportunities and revitalizing regions affected by mining. The company's flagship project, Hub I, located in Quebec, exemplifies the potential to convert industrial waste into high-purity, low-carbon alkalinity, a crucial component for carbon removal processes.

- **Hub I Project in Val-des-Sources, Quebec:** Processes serpentine tailings to produce high-purity MgO with minimal emissions. Capable of scaling to support million tonne-level annual $CO_2$ removal, making it the world's largest surface carbonation hub.
- **Technology Innovation:** Exterra's proprietary technology liberate alkaline metals from waste, enabling full carbonation potential while minimizing energy use. The process is highly adaptable to various types of feedstocks found across the globe.
- **Economic and Environmental Co-Benefits:** Tailings reprocessing reduces environmental risks, such as heavy metal leaching, while creating high-value by-products. Collaboration with local communities ensures social acceptance and shared economic benefits.
- **A New Industry:** Being a leader can create opportunities for the Canadian economy. What if our solution could create jobs from coast to coast? The circular economy can be a new job-creating industry.

## A Call to Action

Canada stands at a pivotal moment in its climate journey. Supporting Exterra Carbon Solutions is not just an investment in technology but a commitment to building a sustainable future. With the right policies, funding, and collaboration, Canada can lead the world in deploying scalable, effective carbon removal solutions.

Exterra invites policymakers to:

- **Champion Innovation:** Recognize the importance of low-carbon alkalinity in achieving climate goals and commit to funding transformative projects.
- **Partner for Impact:** Collaborate with Exterra to expand operations, maximize resource utilization, and create a globally recognized Canadian leadership model in carbon management.
- **Act Now:** Exterra's solutions are ready to deploy, offering immediate benefits for emissions reduction, resource recovery, and economic growth.

**Invest in the Future:** Secure a sustainable future by investing in Exterra's and other Canadian companies innovative mine tailings reprocessing projects, which enable long-term environmental benefits and economic returns. By supporting these initiatives, stakeholders can play a pivotal role in shaping a resilient and low-carbon economy.

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## References

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EXTERRA carbon solutions

# REACHING NET-ZERO USING MINERAL WASTE

An opportunity to support Canada's climate targets and sustainable critical mineral production by reprocessing mineral waste. The extraction of low-carbon oxide metal minerals (calcium or magnesium), also known as alkalinity, have broad applicability to $CO_2$ reduction and removal.

## Highlights

*Permanent $CO_2$ storage using mineral waste*

### Location

Historical mineral waste sites near hard-to-abate industrial emissions, biogenic $CO_2$ sources, agricultural land or ocean discharge points

### Mineral waste feedstock

Mafic and ultramafic mine tailings
Alkaline industrial residues

### Project $CO_2$ storage capacity

Phase I: Up to 500,000 $tCO_2$ per year
Phase II: Potential to scale to +1$MtCO_2$

### $CO_2$ storage potential

Up to 0.5Gt $CO_2$ available today in Québec
3Gt $CO_2$ per year from new waste (global)

### Investment

Phase I plant: ~C$600 million

## Low-Carbon Oxides from Waste (LOW™)

*100% electric process with integrated reagent recycling for low footprint*

Tailings generated by mining containing magnesium or calcium are sourced from historical piles

The Low-carbon Oxide from Waste (LOW) circuit extracts reactive oxides and byproducts from mineral waste with a low-carbon footprint

Valuable byproducts such as silica, nickel and cobalt, are sold as green commodities supporting local supply chains

The process produces magnesium or calcium oxides (MgO or CaO), a stable alkaline mineral that easily binds with $CO_2$

$CO_2$ from the air or emission sources reacts with the oxide, forming a stable, inert and irreversible carbonate (or a bi-carbonate if oxide is used for OAE)

The carbonates are safely disposed of as backfill material or used for green construction materials

## Exterra Carbon Solution's Hub I Project

Hub I will be Quebec's only $CO_2$ storage & circular economy hub and the world's largest low-carbon alkalinity production project, positioning Canada as a global leader in the industry.

**100M tonnes** of mine tailings
**40M $tCO_2$** storage capacity
**250k tonnes** of nickel equiv.
**40M tonnes** of silica (SCM)


*Rendering of Hub I for illustrative purposes only*

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### Community Support

Once the heart of global asbestos production, Southern Quebec supplied half the world's demand. When health concerns led to its ban, the region faced economic decline.

Today, as it seeks revitalization, Exterra's approach has garnered significant community support, reflecting Southern Quebec's drive for a brighter, sustainable future.

Thetford · MRC des Appalaches · MRC des Sources · Val-des-Sources

### Environmental Benefits

**Water**
Immobilization of metals (Mg, Ca) in carbonates reducing contamination risks

**Land Rehabilitation**
Economic tailings site remediation, crucial for mining-affected landscapes

**Asbestos destruction**
100% asbestos fiber destruction removing health risks of waste piles

**Circular Economy**
Hub I also extracts byproducts from waste such as nickel and silica

## Low-Carbon Oxides (Alkalinity) and $CO_2$

Mineral carbonation, also known as carbon mineralization, is a natural process that can be accelerated in engineered environments to sequester carbon dioxide ($CO_2$) captured from industrial facilities or directly from the air or oceans. This is achieved by reacting $CO_2$ with alkaline materials rich in calcium and magnesium, such as certain minerals and industrial by-products. Through this process, $CO_2$ is transformed into stable carbonate minerals, effectively and safely locking it away from the atmosphere for millennia.

A substantial portion of the Earth's crust consists of carbonate minerals like limestone, underscoring the viability and stability of this natural carbon storage method. Each year, more than 100 million tonnes of atmospheric $CO_2$ are naturally sequestered through mineral carbonation via natural weathering processes.

## How Metal Oxides (Alkalinity) Can Be Used For Decarbonization

### INDUSTRIAL $CO_2$

Biogas & Hard-to-Abate

Every tonne of captured carbon requires **durable storage** to have a beneficial impact. Not every region of the world has a geology that is favorable to store $CO_2$. In fact, **over 50% of global industrial $CO_2$** emissions occur outside of regions suitable for underground carbon storage, and technology such as **$CO_2$ mineralization is critical to addressing hard-to-abate emissions**.

### ATMOSPHERIC $CO_2$

River Alkalinity Enhancement
*("RAE")*

Ocean Alkalinity Enhancement
*("OAE")*

Enhanced Weathering
*("EW")*

ERW, OAE and RAE require between **1 and 5 tonnes of alkalinity per tonne of CDR.** Lowering the carbon footprint of alkalinity increases the net carbon removal impact.

### DIRECT AIR CAPTURE $CO_2$

Some direct air capture technologies use alkaline materials to **mineralize atmospheric $CO_2$ directly.** By using low-carbon alkalinity instead of high-emission alkalinity, the systems' **energy consumption can be reduced significantly** by removing the alkalinity regeneration step and the **efficiency of capture** can be **increased** by removing sorbent cycling decay.

## Durable

Carbon mineralization offers the **safest** and most **permanent** form of carbon storage because it traps $CO_2$ into the crystal structure of minerals, a **practically irreversible** process under natural conditions.

In fact, the IPPC states "*the fraction of carbon dioxide stored through mineral carbonation that is retained after 1,000 years is virtually certain to be 100%.*"

Traditional $CO_2$ storage methods are not necessarily permanent – physical leakage from storage reservoirs is possible via (1) gradual and long-term release or (2) sudden release of $CO_2$ caused by disruption of the reservoir.

## Auditable

$CO_2$-bearing minerals can be seen, touched, and weighed enabling simplified and transparent carbon accounting.

Exterra's MRV uses simple, off-the-shelf technology and we have developed standards for measuring the carbon impacts with multiple Voluntary Carbon Market bodies including:

VERRA | puro • earth | ISOMETRIC

Additionally, there are already established OAE & EW methodologies enabling credit generation today:

- **Isometric:** Ocean Alkalinity Enhancement from Coastal Outfalls
- **Puro.Earth:** Enhanced Rock Weathering

## Scalable

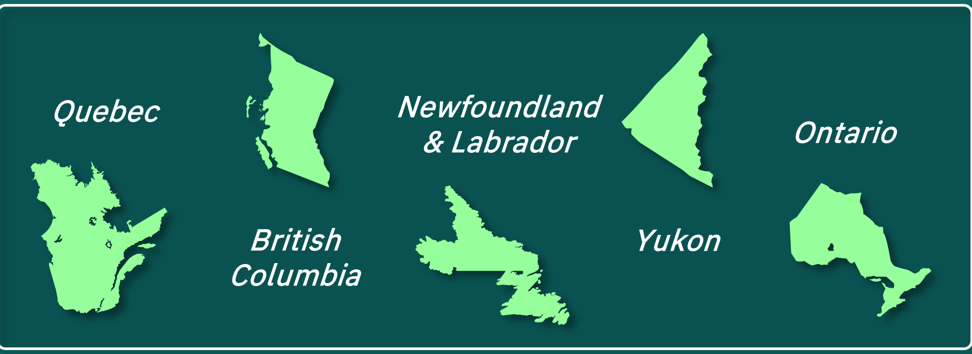
Suitable mineral waste is abundant, and most technologies are electrified supporting the development of clean energy infrastructure. Furthermore, there are many types of mines that have huge, untapped capacity for low-carbon alkalinity extraction.

## Co-Benefits

Repurposing mineral waste to produce low-carbon oxides (alkalinity) can provide numerous co-benefits:

- Environmental risks from waste are reduced
- Projects can have a negative land footprint
- Extracted byproducts contribute to the circular economy

## Provinces with Sources of Mineral Waste




## A Strong Canadian Cleantech Ecosystem

| ERW | RAE / OAE | MINERALIZATION |
|---|---|---|
| Canadian Wollastonite | CarbonRun | BAIE Minerals Inc. |
| ARCA | Planetary | carbon upcycling |

*and more....*