The future of net-zero mining is here

Image: © RHJ | iStock

Dr. Estibalitz (Esti) Ukar discusses how Canada Nickel Company, in partnership with the University of Texas at Austin and the U.S. Department of Energy, is re-engineering its workflow to integrate CO_2 capture into its business model, potentially shaping the future of responsible mineral development

To meet growing demand for **critical minerals and net-zero targets,** mining must make carbon management a core part of operations. Read here how **Canada Nickel Company,** in collaboration with the University of Texas at Austin and the U.S. Department of Energy, is re engineering its workflow to embed CO_2 capture directly into its business model, and what this could mean for the future of responsible mineral development.

Carbon capture as a value proposition, not a cost

Nickel sits at the heart of the energy transition, with rapidly rising demand driven by electric vehicle batteries, grid-scale energy storage, and other clean energy technologies. Yet traditional nickel production has been associated with high greenhouse gas emissions and high costs, particularly in laterite operations and energy-intensive processing routes. Rather than treating carbon capture as a downstream remediation option, Canada Nickel has placed it at the center of project design, using carbon mineralization to improve environmental and economic outcomes.

The Crawford deposit, Canada Nickel's flagship project, is hosted in ultramafic rocks rich in magnesium and iron, containing minerals such as brucite, olivine, and serpentine that rapidly react with CO_2 to form solid carbonate minerals, permanently sequestering carbon through carbon mineralization.

This process also softens the rock, making it easier and less energy- intensive to mine. By integrating carbon mineralization from the outset, Canada Nickel aims not only to reduce emissions, but to create a mining operation that is inherently carbon- neutral – or even carbon-negative – while using natural rock reactions to lower mining

ts and generate additional revenue through carbon capture.

Reinventing mining: Embedding CO_2 capture from day one

Mining is a front-loaded business: early decisions lock in costs, environmental impacts, and social license outcomes for decades. Canada Nickel embeds carbon capture and permanent CO_2 storage from the start, making them core value drivers rather than an afterthought.

The Crawford nickel processing plant is expected to produce over 48,000 tonnes of nickel annually at its peak, making it the largest in North America. A complementary stainless-steel and alloy facility will process nickel-chromium concentrate, producing over 1 million tonnes of alloy annually, including 500,000 tonnes of 304-grade stainless steel, and is set to become Canada's largest stainless-steel production site.

All carbon emissions from both plants are planned to be captured and permanently stored in Crawford rocks, positioning Canada Nickel as a global pioneer in the net-zero metals sector.

Technology: Carbon mineralization in practice

Canada Nickel's carbon-negative strategy pursues two complementary approaches to carbon mineralization. Ex-situ tailings carbonation captures CO_2 in waste material after processing, turning what is normally a long-term liability into an ongoing carbon asset. In-situ mineralization targets the ore body itself, enabling CO_2 storage before and during mining.

1. Ex-situ carbon mineralization: Capturing CO_2 during processing

Ex-situ carbon mineralization occurs above ground and is fully integrated into the mineral processing workflow at the Crawford Project. Through patent-pending In-Process Tailings (IPT) Carbonation technology, a concentrated CO_2 stream is injected into freshly generated tailings while they are still in the processing circuit, rather than after final deposition. Conditioning the tailings for six to 36 hours converts CO_2 into stable carbonate minerals, permanently storing carbon.

Because mineralization occurs during active processing, reaction rates are faster, costs are lower, and monitoring is simpler than with passive approaches. Test results indicate IPT Carbonation can achieve net-zero carbon capture on industrial timescales, potentially storing up to 1.5 million tonnes of CO_2 per year at peak production, and is expected to capture and store more than 34 tonnes of CO_2 per tonne of nickel produced via ex-situ carbonation over the project life.

Following carbonation, tailings are deposited into the tailings management facility, where residual reactive minerals continue to absorb atmospheric CO_2, providing additional long-term sequestration. This ex-situ approach not only offsets operational emissions but also creates value through high- quality carbon credits, which can generate revenue or be applied to meet climate commitments.

2. In-situ carbon mineralization: Storing CO_2 underground

In-situ carbon mineralization involves injecting CO_2-rich fluids into magnesium-bearing ultramafic rocks prior to mining. The CO_2 reacts with minerals such as brucite and olivine to form stable carbonates, expanding and fracturing the rock in a process called reaction-driven cracking. These reactions naturally break the rock into smaller, weaker pieces and replace hard silicates with softer carbonates, creating a preconditioned mass that is easier and less energy-intensive to process. The approach reduces blasting and grinding requirements, permanently stores CO_2, and can generate carbon credit revenue. In-situ carbonation also integrates seamlessly with subsequent ex-situ carbonation stages, and after mining, the site can continue to serve as a long-term CO_2 sink, creating lasting economic and environmental value.

Led by the University of Texas at Austin and funded by the U.S. Department of Energy, Canada Nickel launched an in-situ carbon mineralization pilot at Crawford in late 2025. The pilot injected CO_2-enriched water into a 400-metre-deep well before mining, demonstrating how CO_2 capture can be implemented from day one and in stages over the mine's life.

After nearly two years of laboratory work and site preparation, the field test was successful: approximately 12 tonnes of CO_2 remained dissolved at depth, with no upward migration of gas bubbles, surface leakage, or induced

micity. Extensive monitoring – including groundwater sampling, seismic sensors, gas detection, and satellite-based analysis – continues to track subsurface reactions, which are expected to mineralize most of the CO_2 within six months.

Ongoing monitoring of the Crawford pilot will continue to validate reaction rates, long-term CO_2 storage, and operational benefits. These results will help refine in-situ mineralization techniques and demonstrate the economic and environmental value of integrating carbon capture directly into mining operations.

Implications for the global mining sector

The Crawford in-situ carbon sequestration pilot is the first of its kind and a clear demonstration of Canada Nickel's commitment to innovation and a new vision for mining. Its outcomes will be closely watched – not only for technical results but for what they represent: a glimpse of a mining industry designed for a net-zero future and a model of collaboration between industry, academia, and government.

Crawford, along with 25 similar deposits identified in the Timmins area and established sites such as Sudbury and Kidd Mine, could serve as a template for mineral-rich regions worldwide. By integrating mining, processing, and large-scale carbon storage, CO_2 from regional industrial sources could be permanently sequestered in ultramafic rocks in the area, creating a net-zero industrial cluster where mining contributes to the climate solution not merely as a supplier of metals, but as an active participant in carbon management.