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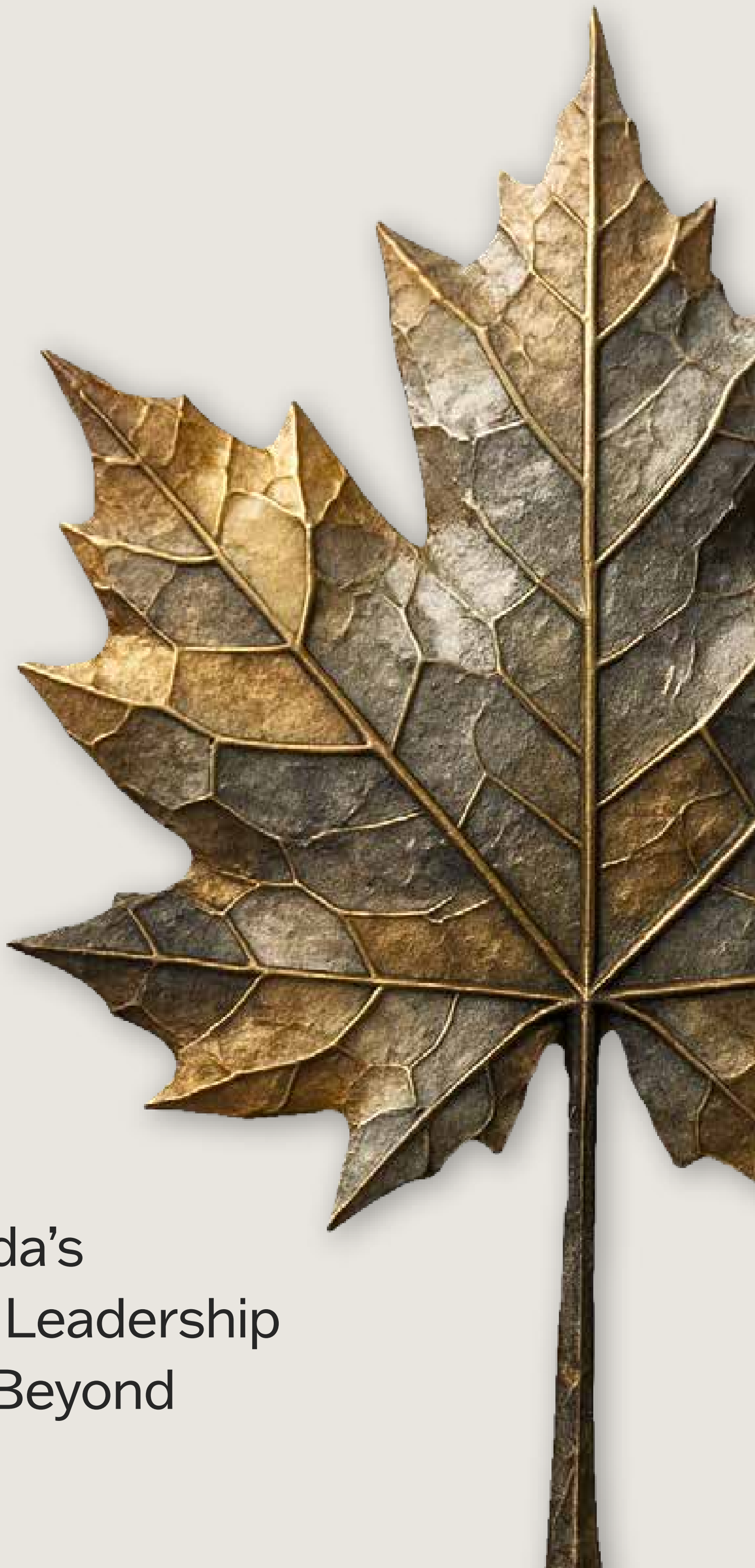

FROM ROCKS TO POWER

Strategies to Unlock Canada's Critical Minerals for Global Leadership in Energy Storage, EVs, & Beyond

Executive Summary

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Executive Summary

The Canadian federal government defines critical minerals as minerals with a threatened supply chain while still having a reasonable chance of being produced in Canada. They also need to be either essential to Canada's economic or national security, be required for a transition to a low-carbon and digital economy, or position Canada as a sustainable and strategic partner within global supply chains. The first iteration of the Government of Canada's critical mineral list was proposed in 2021 and subsequently updated in 2024. Both federal and several provincial governments published lists of critical minerals within the framework of a strategy and suite of policies to boost their development.[1–6]

This report aims to lay the analytical groundwork for mineral-specific strategies to secure Canada's place in the global value chain for electric vehicles. Although the current list by the federal government accounts for 34 minerals, only eight critical minerals and materials were selected for the present study: Copper, graphite, iron, lithium, nickel, phosphate, rare earths (counted as one, although it is a subset of seventeen different elements), and vanadium. This selection allows a deeper dive into specific and strategic minerals we believe are essential for the EV value chain in Canada. Indeed, those selected critical minerals all have integral roles in the EV supply chain, whether for battery materials, motors and magnets, electricity and current transmission or energy storage in a broader sense.

One of the main contributions of this report is to collect and synthesize industry knowledge specific to each of the eight minerals. This adds a much-needed level of specificity to current policy discussions, which tend to speak of 'critical minerals' as a monolith. This report illuminates mineral-specific market dynamics, material flowsheets, and Canadian strengths in the various supply chains by convening industry experts in a series of workshops. The longer-term contribution of this exercise is catalyzing the creation of a coalition of industry actors, from upstream and downstream in each of these supply chains, who are pursuing the common goal of capitalizing on Canada's critical mineral opportunity.

This report follows from *A Roadmap for Canada's Battery Value Chain*, published in June 2022 by the Transition Accelerator with the Battery Metals Association of Canada, Accelerate, and the Energy Futures Lab.[7] That report synthesized insights from workshops with industry actors to lay out clear timetables and targets for electric vehicle, battery, and metals production and an action plan designed to achieve them. The report laid out a strategy to achieve the roadmap's overall target of Canada capturing 10% of North American supply chains, meaning Canada must produce 1,300,000 electric vehicles by 2030 as well as the raw materials, processed metals, and batteries for 100 gigawatt hours (GWh) of battery capacity.

The report translated this overall goal into specific targets for four specific battery metal strategies as a starting point: lithium, nickel, graphite, and rare earth. A priority flagged for future research was expanding this metal-specific analysis to other critical minerals essential for Canada's battery value chain. This report undertakes this task by articulating detailed strategies for eight critical minerals.

The Eight Critical Minerals and Materials Investigated in This Report

Copper is necessary for all electrification efforts linked to the energy transition, whether it is for producing, transporting, or using electricity: it is in electrical wires, generators, transformers, inverters, electrical motors, *etc.* For EVs, it is used in wiring, in the electric motor, and as a current collector in the battery. It is also essential for the charging infrastructure.

Graphite is essential for anode material across Li-ion battery technologies. Although it can be doped with silicon to enhance its properties, it is mainly used for its ability to reversibly store lithium-ion in a stable manner, while being relatively low-cost and abundant.

Lithium is essential as a small, light, and efficient energy carrier in all lithium battery technologies. The storage and release of lithium ions allow for the storage and usage of electrical current in an optimized manner. It is specifically used as a material for cathode and electrolyte.

Although **iron** is abundant and primarily used for steels and alloys, our attention focused on the iron precursors used for lithium-iron-phosphate (LFP) battery cathodes. These can include pure iron powders or iron sulfate. High-purity iron ore was added to the federal critical minerals list in 2021.

Nickel is primarily used for stainless steel, but it is also a vital part of the nickel-manganese-cobalt (NMC) battery cathodes, a type of high-performance and long-range Li-ion battery. Although it can be substituted for LFP batteries, nickel-based batteries are expected to remain a significant part of the battery mix in the years to come, especially in North America. The trend has also seen an increase in the nickel ratio of NMC batteries.

Phosphate is mainly used for the fertilizer industry. However, phosphate and, ultimately, its transformation to battery-grade purified phosphoric acid supply can be the bottleneck for LFP battery cathode fabrication. Thus, it is essential for the lithium-iron-phosphate battery industry, a technology that allows for cheaper, safer and better cycling energy storage than LFP, at the cost of lower performances. Phosphorus in general was added to the federal critical mineral list in 2024.

Rare Earths are typically used as high-performance permanent magnets, which can be found in wind turbine generators or electric motors. Rare-earth magnets are considered strategic materials as they are difficult to replace without a significant loss of performance.

Although **vanadium** alloys can be used for specialty steels in the car industry, vanadium is not used in EV batteries per se, but vanadium flow batteries have shown the potential to be long-lasting stationary energy storage solutions. Several opportunities exist in Canada, from titanomagnetite to oil sands and carnotite deposits.

Although **cobalt** and **manganese** constitute an important part of NMC battery cathodes, this report does not cover them. Canada is already a major global cobalt player: it is ranked 7th worldwide for cobalt mining, and 4th for cobalt refining, with 4 domestic cobalt refineries. Global manganese output mainly comes from South Africa, Gabon and Australia, and Canada's production has historically been small. Manganese mining occurred in Nova Scotia and New Brunswick in the previous centuries, while more recent small-scale operations occurred in British Columbia. Natural Resources Canada does not show any manganese production in 2023 or 2022. For both metals, the trend is to decrease their ratio while increasing the use of nickel in NMC cathodes.

Table 1.1.1 Summary of Canada's global rank in reserve, extraction and processing for the selected critical minerals, as well as a comparison between the 2022 extraction and the mandated benchmark target to reach in 2030

Critical Mineral	**Copper**	**Graphite**	**Iron**	**Lithium**	**Nickel**	**Phosphate**	**REE**	**Vanadium**
Role / Canada	Current	NMC + LFP Anode	LFP cathode	NMC+LFP cathode, electrolyte	NMC cathode	LFP cathode	Permanent Magnets	Flow battery
Global Reserve Rank[a]	13th	9th	7th	6th	7th	*18th	10th	/
Global Extraction Rank[a]	12th	7th	7th	7th	6th	None	None	None
Global Processing Rank[a]	16th	None	15th (steel)	None	4th	None	None	1 refinery
2022 Extraction in tonnes[a,b] (% world)	520,000 (2.4%)	13,000 (0.8%)	41,400,000 (2.7%)	520 (0.4%)	143,000 (4.4%)	0	0	0
2030 Target (tonnes)[b,c]	75,000	223,000 (raw graphite)	38,000	11,000	37,000	80,000 (85% PPA)	/	/

*Data from the 2016 *Yearly Mineral Commodity Summary of the* U.S. Geological Survey.
[a]Data mostly from the: U.S. Geological Survey, *Yearly Mineral Commodity Summary*, 2024; and also from NRCan, 2024; IEA, 2024.
[b]Unless specified, in tonnes per annum and in the elemental form.
[c]Original and updated targets from: A Roadmap for Canada's Battery Value Chain. Transition Accelerator, Battery Metals Association of Canada, Accelerate, Energy Futures Lab. The target is to build an EV supply chain replicating Canada's 10% share of North American automotive manufacturing. The numbers represent the additional capacity of the selected critical minerals to bring online by 2030 in tonnes per annum.

Summary of Findings

Building Canada's Leadership in Copper Metallurgy and Expanding Copper Mining

Copper is a cornerstone material for the transition to EVs and the broader clean energy economy. To ensure Canada captures its share of the North American EV market—10% as a baseline, with a potential leadership target of 35% by 2030—Canada must address declining copper processing capacity and maximize its resource potential. While British Columbia (BC) holds significant untapped copper reserves, the country lacks the metallurgical infrastructure to process these resources at scale.

- **Accelerate Near-Term Copper Production:** Advance life extensions and expansions of current copper mining operations while supporting the implementation of mining projects in development, especially in BC, and expand concentrate production.
- **Boost the Midstream Segment by Building a New Metallurgical Plant:** There is already enough copper concentrate produced in British Columbia to justify the operation of a new copper smelter, provided that we ignore the selling agreements already in place to sell Canadian copper concentrates to Asian smelters. Building a new pyrometallurgical plant in BC, taking feed from the existing mines, projected ones, and scrap would advance the Canadian copper supply chain. If the social mandate does not allow it, supporting R&D and optimizing viable hydrometallurgical operations of copper sulfide should be pursued. Scaling existing operations, such as the Horne smelter and Montreal copper refinery, should also be supported.

Positioning Canada as a North American Leader in Graphite Anodes

Canada has the resources and industrial capacity to become the primary North American supplier of coated spherical purified graphite (CSPG) for EV battery anodes. By advancing natural graphite mining, establishing processing hubs, and diversifying into synthetic graphite, Canada can secure its role in the critical minerals supply chain while driving economic growth and innovation. A bullish scenario can be considered. This strategy focuses on:

- **Expanding Natural Graphite Mining:** Prioritize mining and shaping/milling projects in Québec and British Columbia, leveraging the provinces' rich deposits and industrial infrastructure. The projects in Québec are more advanced and should be supported and reinforced, while the ones in BC need a boost to develop more rapidly.
- **Developing Coating Hubs and Anode Material Plants:** Establish coating and anode production hubs in Québec and British Columbia, supported by partnerships with international companies that possess the expertise and intellectual property for anode manufacturing technology.

- **Advance Synthetic Graphite in Alberta:** Build a synthetic graphite processing facility in Alberta's Industrial Heartland, utilizing existing petrochemical infrastructure.
- **Explore Alternative Graphite Sources:** bioresources such as the pyrolysis of forestry industry wood waste can be converted into graphite, and natural gas can be transformed into hydrogen and graphite through a pre-combustion carbon capture system. Such alternatives should be supported through R&D and scaled locally.

Canada Should Scale Innovative and Cleaner Processes to Incorporate its Iron Products into EV Cathodes

Canada already has significant operations in high-purity iron ore mining and steelmaking, and the mandated benchmark quantity of supplementary iron necessary for LFP cathode manufacturing is likely not a bottleneck. However, iron sulfate is traditionally the chemical intermediate necessary to produce precursors to LFP cathodes. Canada can encourage iron sulfate production from steel mills, but above all, it should support the commercial viability and scaling of new pCAM and CAM processes using iron powder or iron oxide to bypass iron sulfate and avoid controversial sodium sulfate waste issues.

- **Produce Iron Sulfate from Existing Steel Mills:** The pickling step in steel mills necessitates the treatment of steel with sulfuric acid; this is an opportunity to produce iron sulfate as a byproduct to sell for pCAM/CAM LFP cathode makers.
- **Leverage Canada's Iron Products and Support Clean Cathode Manufacturing Processes:** NanoOne has developed cleaner processes to use iron powder or iron oxide with other precursors to produce CAM in one pot and avoid sulfate salt issues. These initiatives should be supported to ensure commercial viability and scaling, as they can boost competitiveness and increase social mandate against Chinese CAM processes. Rio Tinto's RTIT plant in Quebec already produces pure iron powder as a by-product of its titanium operation.

Advancing Lithium Spodumene and Brine in Canada

To secure 10–12.5% of the North American EV market, Canada must capitalize on its abundant lithium resources and establish a robust, integrated supply chain. With increasing global competition and new lithium projects emerging worldwide, Canada should not aim for a bolder scenario but can distinguish itself by focusing on both natural and direct lithium extraction (DLE), sustainable processing, and advanced manufacturing capabilities.

- **Direct Lithium Extraction (DLE) in Western Canada:** Prioritize lithium brine extraction in Saskatchewan and Alberta, integrating these operations with a dedicated DLE research hub to advance innovation, de-risk and scale DLE operations, modelled on the Alberta Oil Sands Technology and Research Authority (AOSTRA). Building a Cathode Active Material (CAM) and Precursor Cathode Active Material (pCAM) facility in Alberta or British Columbia would further enhance the region's role in the battery value chain.

- **Spodumene Mining and Processing in Québec and Ontario**: Ramp up spodumene extraction to take advantage of rich and large deposits and existing projects. Strengthen the Bécancour lithium hydroxide processing hub in Québec to convert spodumene into battery-grade materials. Support one lithium hydroxide plant project in the Thunder Bay area to take feed from the Western Ontario spodumene projects. Establish a spodumene processing research centre to drive technological efficiency and sustainability.

Canada Should Spearhead Nickel Production and Processing for EV Batteries in North America

Canada has the opportunity to become a leading supplier of nickel for the North American electric vehicle market. With significantly larger nickel resources than the U.S., Canada should aim for a leadership scenario, capturing up to 35% of the 2030 market share, well above the 10% baseline goal. Achieving this target requires scaling up domestic mining and processing capacity while building integrated supply chains for battery-grade nickel products.

- **Expand Nickel Mining and Processing**: Strengthen existing nickel mining operations and processing capacity by expanding and modernizing capacities in Newfoundland and Labrador, Québec, Ontario, and Alberta. Advance 3–4 large-scale mining projects to produce 35–40 ktpa of elemental nickel each, ensuring a steady supply of battery-grade materials.
- **Develop Long-Term Processing Capacity in British Columbia:** Establish a large nickel metallurgical facility in BC capable of producing nickel sulfate ($NiSO_4$), nickel metal, or precursor cathode active materials (pCAM). Integrate black mass recycling to support future battery circularity, complementing feedstock from imported laterite precipitates and domestic sulfide ores.
- **Leverage Imported Feedstocks in the Short Term:** Use imported mixed hydroxide precipitates (MHP), mixed sulfide precipitates (MSP), or matte as interim feedstocks to scale up domestic processing capabilities to nickel sulfate or pCAM.

Leveraging Canada's Igneous Phosphate Deposits to Lead Purified Phosphoric Acid Production and LFP Batteries

Canada can potentially play a pivotal role in the North American transition to lithium iron phosphate (LFP) battery production by scaling up domestic supply chains for battery-grade phosphoric acid (PPA). PPA production capacity is thought to be a global bottleneck for LFP cathode material production. However, Canada's rare igneous deposits make it particularly suitable for developing PPA. This scenario requires developing new phosphate extraction projects and phosphoric acid processing capacity.

- **Accelerate Phosphate Mining Development:** Launch 3–4 phosphate mining projects across Québec, British Columbia, and Ontario. Prioritize igneous phosphate deposits for cathode material (battery-grade PPA) due to their suitability for high-purity processing while reserving sedimentary deposits primarily for fertilizer use in the short term (MGA).
- **Build Purified Phosphoric Acid Processing Hubs:** Establish two processing hubs to produce merchant-grade phosphoric Acid (MGA) and Purified Phosphoric Acid (PPA). The one in Québec should focus on converting local igneous deposits into PPA for pCAM and CAM applications. The one in Western provinces (Alberta or BC) should handle regional feedstocks for fertilizer use and support a potential Western Canada's LFP supply chain.

Building Canada's Rare Earth Element (REE) Supply Chain and Magnet Manufacturing Capacity

To establish a leadership position in the growing market for rare earth elements (REEs), Canada should focus on developing a centralized processing and magnet manufacturing hub, which could be built around the SRC's initiatives in Saskatchewan. This strategy ensures alignment with global supply chain demands while leveraging Canada's resource base and technological expertise. A phased approach is critical, balancing immediate actions with long-term development, and a high level of coordination will be needed to establish this nascent domestic supply chain from the start.

- **Short-Term Reinforcement of Midstream REE Processing:** Import monazite concentrates and other REE-rich waste materials to maximize the production of individual rare earth oxides (REOs). Leverage existing Canadian facilities, such as the Saskatchewan Research Council (SRC) processing facility and Canadian IP, such as Ucore's technology, to refine REOs and establish a robust processing foundation.
- **Establish Magnet Manufacturing**: Use domestically processed REOs to build metalmaking, magnet manufacturing and magnetic powder production facilities. Build partnerships with material manufacturers, EV motor producers, and OEMs to secure off-take agreements and ensure a reliable, customer-driven supply chain.
- **Develop Mining Capacities in the Medium Term:** Ramp up mining capacities by opening 3–4 REE mines, including projects in the Northwest Territories, BC, Saskatchewan and Québec to provide a consistent supply of high-grade REE concentrates. Maximize economic viability by selling value-added co-products alongside REEs. Ensure the centralized processing facility in Saskatchewan can handle feedstock from domestic mines, reducing dependency on international sources and strengthening the Canadian supply chain.

Unlocking Canada's Potential in Vanadium Recovery and Energy Storage Solutions

Canada has a unique opportunity to establish itself as a global hub for vanadium recovery, processing, and vanadium redox flow battery (VRFB) production. By leveraging existing industrial assets and its proximity to petroleum-based vanadium sources in Alberta, Canada can create a competitive vanadium value chain. This initiative supports the transition to clean energy and strengthens Canada's critical minerals sector.

- **Build Midstream Processing and Manufacturing Capacity:** In the short term, Canada should build vanadium processing and VRFB production capacities in Alberta. Establish a vanadium processing and recovery plant in the Alberta Industrial Heartland or Fort McMurray, and leverage proximity to the oil sands industry for a steady vanadium supply from petroleum residues.
- **Boost Vanadium Recovery from Secondary Sources:** Promote recovery from fly ash from coal and oil-fired power plants in Alberta, Saskatchewan, and the Maritimes. Ensure steady feedstock for the processing facility while reducing industrial waste.
- **Leverage Existing VRFB Assets:** Expand and integrate the capabilities of facilities like Invinity's Vancouver operation, VRB Energy's expertise and Vanadium Corp to jumpstart electrolyte and VRFB manufacturing and domestic deployment, with export opportunities.
- **Expand Primary Vanadium Supply in the Long Term:** Develop vanadium co-production and collaborate with iron, uranium, and aluminum mining operations in resource-rich provinces (BC, SK, QC, NL) to recover vanadium as a co-product. Support the titanomagnetite vanadium mine projects in Quebec. Establish supply chain linkages between vanadium mining, processing, and battery manufacturing to strengthen Canada's critical mineral resilience and value-added production capabilities.