TOWARDS A WESTERN CANADIAN BATTERY VALUE CHAIN

Assessing Industrial Gaps and Opportunities for Economic Development

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Towards a Western Canadian Battery Value Chain: Assessing Industrial Gaps and Opportunities for Economic Development

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About us

BMAC

The Battery Metals Association of Canada (BMAC) is a national non-profit association of industry participants and champions from across all segments of the battery metals value chain. From mining to specialty chemical refining, manufacturing, end use and recycling, BMAC is focused on coordinating and connecting the segments of this value chain, ensuring Canada captures the economic potential of the sector and is able to attain its electrification targets. Together, our members collaborate to accelerate the development of the battery metals ecosystem in Canada.

The Transition Accelerator

The Transition Accelerator drives projects, partnerships, and strategies to ensure Canada is competitive in a carbon-neutral world. We're harnessing the global shift towards clean growth to secure permanent jobs, abundant energy, and strong regional economies across the country. We work with 300+ partner organizations to build out pathways to a prosperous low-carbon economy and avoid costly dead-ends along the way. By connecting systems-level thinking with real-world analysis, we're enabling a more affordable, competitive, and resilient future for all Canadians.

Energy Futures Lab

The Energy Futures Lab is an award-winning, Alberta-based not-for-profit that brings together a diverse network of innovators, influencers, and system actors from across Canada's energy landscape. Established in 2015, the Lab was created to address growing polarization around Canada's energy transition and respond to its most pressing challenges.

Through trusted leadership and creating non-partisan spaces for collaboration, the Lab convenes stakeholders and Rights and Title Holders to generate and test innovative, enduring solutions to complex, system-level issues. By empowering communities and change-makers to work across divides, the Lab fosters the conditions for meaningful progress toward a shared vision of a resilient and sustainable energy future.

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List of Abbreviations

AB – Alberta

AOSTRA – Alberta Oil Sands Technology and Research Authority

BC – British Columbia

BESS – Battery Energy Storage System

BMAC – Battery Metals Association of Canada

CAM – Cathode Active Material

CCUS – Carbon Capture, Utilization and Storage

CM – Critical Minerals

DLE – Direct Lithium Extraction

ESG – Environmental, Social, and Governance

EV – Electric Vehicle

E-waste – Electronic Waste

GHG – Greenhouse Gas

GIG – Greenview Industrial Gateway

ITC – Investment Tax Credit

LFP – Lithium Iron Phosphate (battery chemistry)

Li-ion – Lithium-ion Battery (battery chemistry encompassing LFP & NMC)

LNG – Liquefied Natural Gas

NAIT – Northern Alberta Institute of Technology

NMC – Nickel Manganese Cobalt (battery chemistry)

NW – Northwest (used contextually for regions)

NWT– Northwest Territories

PPA – Purified Phosphoric Acid

pCAM – Precursor Cathode Active Material

R&D – Research and Development

SAIT – Southern Alberta Institute of Technology

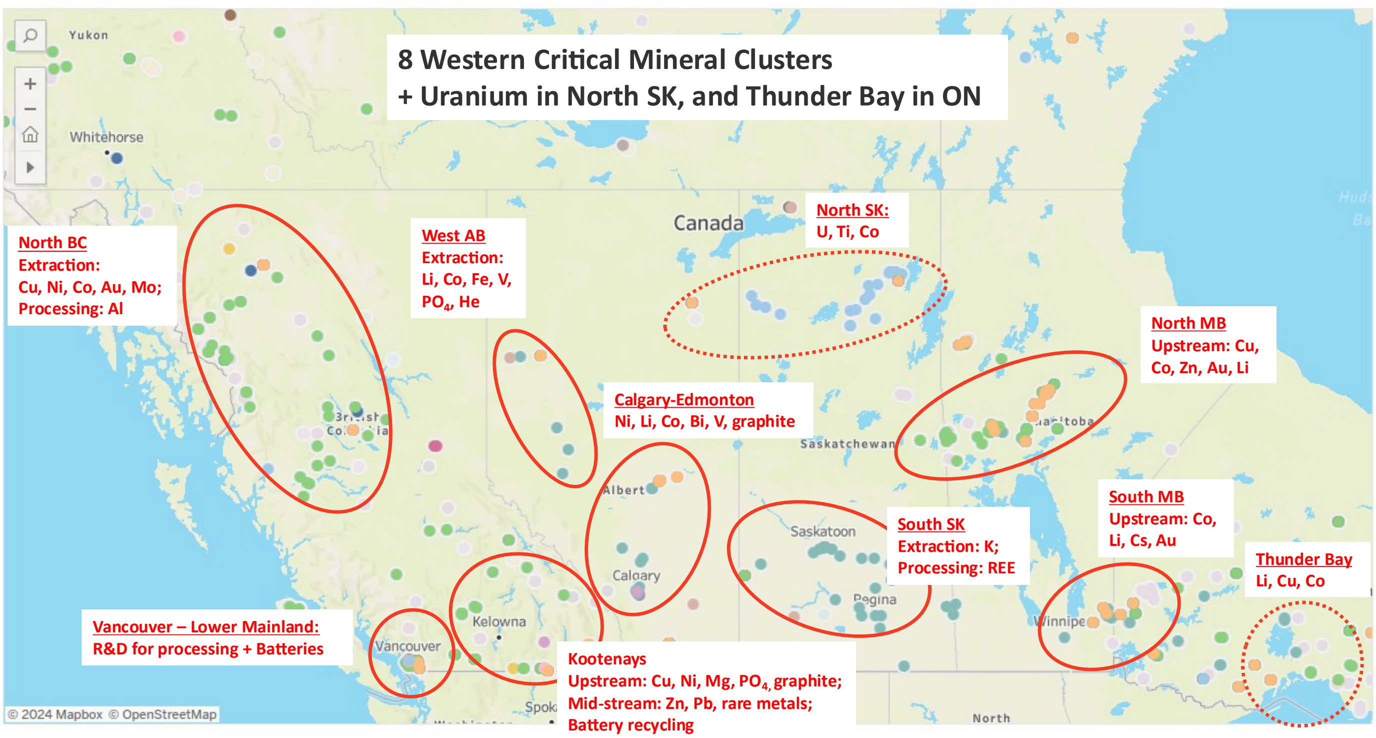
SK – Saskatchewan

SMR – Small Modular Reactor

Executive Summary

Western Canada holds significant potential to develop into a globally competitive value chain. This report, informed by extensive industry workshops and government consultations, identifies eight regional industrial clusters in British Columbia, Alberta, Saskatchewan, and Manitoba, and assesses opportunities and gaps across five of the eight identified to build a regionally grounded strategy unlocking the economic potential of Western Canada's critical minerals.

The Regional Industrial Clusters



- **Northern BC:** A remote yet mineral-rich region with strong potential for copper, nickel, gold, and silver, but lacking local processing capabilities. Strategic investments in nickel and copper metallurgy, infrastructure, and workforce training could unlock value-added opportunities and anchor a fully integrated mining cluster in Canada.
- **Vancouver & Lower Mainland**: A clean-tech innovation cluster with strengths in technology development for battery processing, recycling, and potential in manufacturing, backed by top talent and global connectivity. Strategic support for battery manufacturing, local supply chains, electricity access, and scale-up of innovators could solidify its role in Canada's battery value chain.

- **The Kootenays:** With a strong metallurgical base anchored by Teck's smelter, the Kootenays are emerging as a cluster for battery recycling, refurbishment, and niche manufacturing. Future growth depends on diversifying off-takers, upgrading infrastructure, advancing the extraction of different minerals, and boosting R&D in material recovery. Expanding into copper and nickel metallurgy is also a promising path.
- **Western Alberta:** This cluster holds strong potential for lithium extraction from brines, supported by oil and gas infrastructure and a skilled workforce. With additional resources, including iron, phosphate, and vanadium, as well as industrial assets such as the Greenview Industrial Gateway, the region is well-positioned for future midstream development. Unlocking this potential will require access to clean energy, supportive policies, and strong coordination with the Calgary–Edmonton Corridor.
- **Calgary-Edmonton Corridor:** The region is a nationally significant industrial powerhouse with deep strengths in oil, gas, and petrochemicals. Now, it's poised to lead in advanced battery materials. With access to critical feedstocks such as lithium-rich brines, vanadium-bearing fly ash, and synthetic graphite sources, the region is well-positioned to establish Canada's midstream capabilities. By expanding, refining, and focusing on the production of cathode and anode materials, the corridor can become a globally competitive hub for advanced battery materials and processing. Investing in clean energy and talent, as well as boosting industry collaboration, will be necessary.

An Interconnected Vision

Western Canada's battery ecosystem is evolving from a scattered set of industrial nodes into a strategically connected network of regional clusters. Each cluster, from resource-rich regions in the North to advanced material manufacturing clusters in Alberta and battery manufacturing centres in southern BC, has unique strengths that, when integrated, form a complete and resilient battery value chain. Material flows between clusters, from lithium and phosphate to nickel, cobalt, and copper, reveal a powerful opportunity: specialization by region combined with shared infrastructure and collaboration can generate greater collective value than isolated growth.

This interconnected vision takes shape in what we call the "give and go play", a material flow pattern that starts in Northern BC and the Territories, curves through Alberta's industrial heartland for cathode and anode material production, and folds back to Southern BC for battery assembly. Alongside this horizontal flow, the concept of "Bar Down" adds a vertical dimension: a flow of raw materials moving southward from the North, supported by an efficient transport infrastructure. In contrast, clean power and investment flow northward in return. A complementary west-east corridor linking BC's clean electricity with Alberta's industrial base can further boost the capital competitiveness of cleantech manufacturing. Together, these flows create a full-loop ecosystem centred on circularity, clean technology, and regional synergy.

To succeed, this strategy must be supported by effective coordination among governments, industry, academia and Indigenous communities. With thoughtful planning and strategic project origination, Western Canada can establish a globally competitive battery supply chain that is rooted in sustainability, regional diversity, and economic strength.

Give and Go: An Integrated Western Canadian Battery Value Chain

One illustration of this desirable future Western value chain is a coordinated movement, much like a "**give and go**" play, that flows strategically between regions to maximize value creation. This future network starts in the resource-rich North, moving through central processing in Alberta, and advances to the coastal South for final manufacturing, before circling back through recycling loops. Much like in hockey, where players pass the puck and then move into open space to receive it back, the 'give and go' in this context represents the dynamic, reciprocal flow of materials, expertise, and investment across interconnected regional clusters. This "give and go" is a metaphor and a strategic blueprint that summarizes value chain integration across mining, refining, advanced materials, and battery production in Western Canada.

The play starts in Northern British Columbia, the Territories, as well as the Kootenays, where world-class deposits of nickel, cobalt, copper, graphite, and phosphate will be mined, while at the same time, lithium brine will be extracted from Western and central Alberta. These raw materials are then transformed through metallurgical and chemical upgrading, potentially within the same clusters or sent down to the Calgary–Edmonton Corridor, a region with the potential to emerge as Western Canada's powerhouse for precursor, cathode active materials (CAM), anode production, and critical reagents. Alberta's industrial strength, existing industry and refineries, and innovation hubs make it a natural host for advanced material production.

The final leg of the give and go play brings these engineered, advanced battery materials back west to the Vancouver Lower Mainland, where proximity to international markets, ports, urban infrastructure, and a skilled workforce can support battery cell, module, and pack assembly. With end-of-life batteries flowing back through the system, particularly toward the Kootenays for recycling and refurbishment, the give and go becomes a closed loop, reinforcing circularity and supply chain resilience.

Each cluster specializes in what it does best, and when connected, the collective value created has the potential to exceed the sum of its parts. This metaphor of a give and go is a proposed vision of regional synergy and Canadian leadership in the global battery economy.

Going Bar Down: Building the Vertical Backbone of Western Canada Battery Supply Chain

In hockey, a "Bar Down" goal is a perfect shot that hits the crossbar and drops straight into the net. In Canada's battery value chain, the concept of "Bar Down" captures a similar idea: a clean, vertical flow of materials, from the North to the industrial South, targeted with precision and to support the goal of battery production.

This vertical structure originates in the resource-rich North, specifically in Yukon, Northern British Columbia, and the Northwest Territories, where mining operations are emerging to supply lithium, cobalt, nickel, copper, and rare earth elements. These critical materials must move downward through north-south transport infrastructure and trading corridors, connecting:

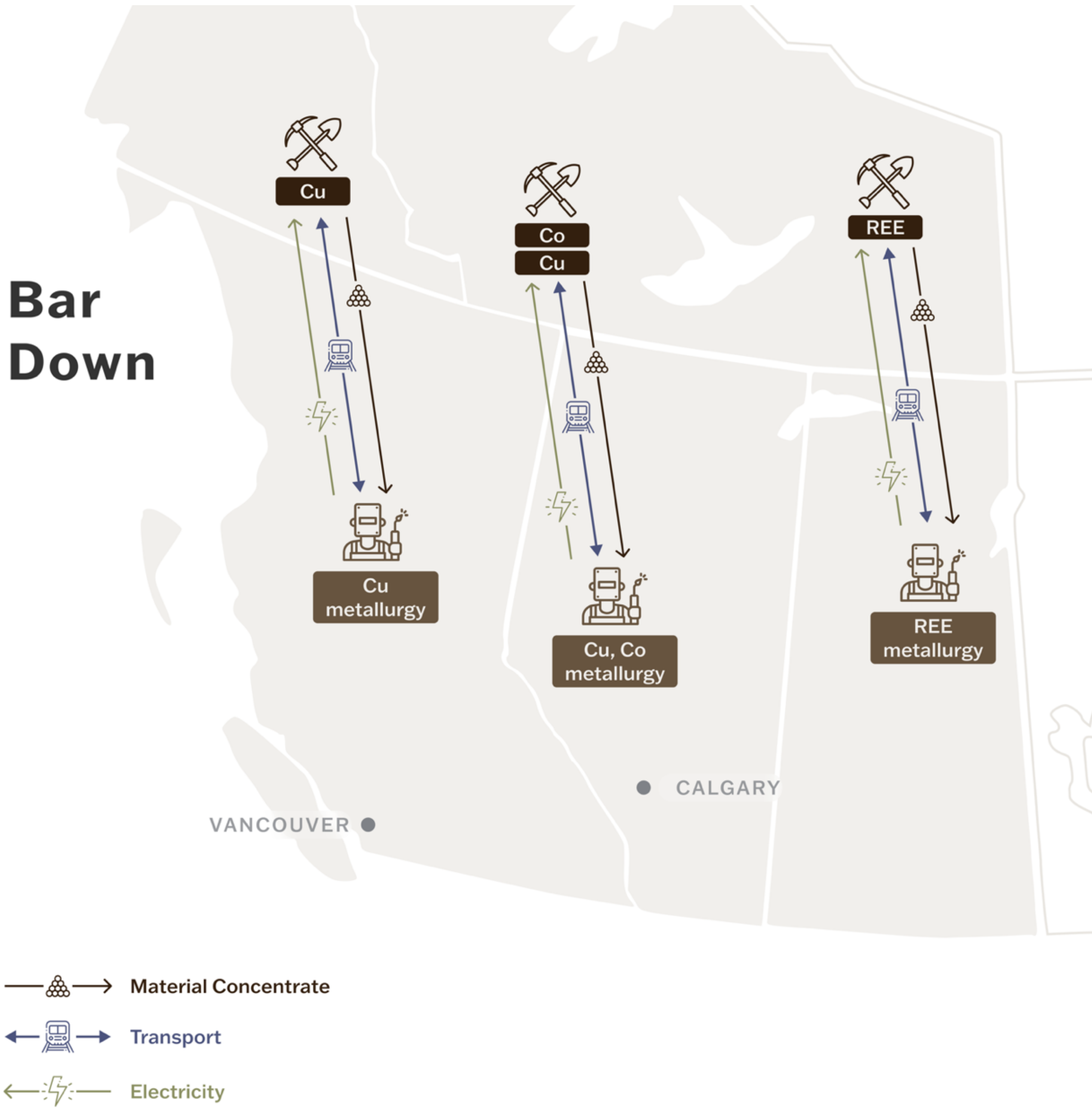
- Yukon to British Columbia
- Northern British Columbia to Southern British Columbia
- The Northwest Territories to Alberta
- The Northwest Territories to Saskatchewan

These routes represent the first leg of the give and go value chain, supplying raw materials to the current and future metallurgical processing hubs in Northern British Columbia, the Kootenays, or the Calgary–Edmonton Corridor, and beyond. Investment needs would include road and rail upgrades and expansion, as well as the creation of new infrastructure and transport corridors.

However, just as important is what goes back up: clean energy, grid capacity, and infrastructure investment must move northward, enabling remote regions to electrify their operations, power mining equipment, and create the conditions for full-cycle value creation. The necessary condition for this strategy to go forward is to prioritize supporting local economic development, benefiting the welfare and opportunities of local communities, and strengthening Indigenous reconciliation.

A complementary west-east corridor, integrating the clean hydroelectric grid of British Columbia to the more carbon-emitting Alberta, should also be considered to support the industrial development and capital attractiveness of cleantech in the Calgary-Edmonton Corridor.

This two-way corridor, with resources heading south and energy and infrastructure going north, would have a significant impact on economic development. It would form a resilient backbone for Canada's battery economy, connecting geography with strategy, and transforming regional isolation into national strength.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CALGARY
VANCOUVER
Material Concentrate
Transport
Electricity

The Need for a Western Canadian Battery Value Chain

Amid rising geopolitical and trade tensions, Canada should move beyond passive resource exports and proactively strengthen its trade position by processing its natural wealth domestically. The value proposition of more rapidly integrating the West and the North into this evolving national value chain is robust and compelling, with numerous benefits for Canada, including:

- **Enhancing Indigenous Economic Reconciliation:** All roads to an integrated value chain for critical minerals and batteries pass through Indigenous lands and it is imperative that the country leverage this generational opportunity to pursue economic reconciliation. The nation has the chance to situate the economic, environmental and social benefits of the evolving value chain and the interests of Indigenous communities at the core of this effort.
- **Increasing Economic Productivity:** A supercharged critical minerals and battery value chain in Western and Northern Canada can help the country get its economy back on the right track with projects that create long-term economic wealth for the country, with upstream mining and midstream processing sectors ripe with innovation potential and high-paying jobs.
- **Minimizing Social, Environmental and Climate Impacts:** In contrast to the emissions- and waste-intensive mining and processing taking place in other parts of the world, Canada can help raise climate and environmental standards for this global sector. By building a midstream processing sector the region can incentivize a demand-side draw for valuable post-consumer materials, versus having to export these recovered metals, chemicals, and black mass, and thereby enhance our national circular economy competitiveness.
- **Strengthening Supply Chain Security:** With an increasing over-concentration of critical mineral production and processing in a select few countries worldwide, Canada's supply chain and businesses are vulnerable to trade war action. This vulnerability allows foreign countries that do not share Canada's interests to potentially manipulate prices and the supply chain to achieve national goals that are contrary to ours. Onshoring this production and processing of the fundamental building blocks of our economy decreases this dependence on foreign actors.
- **Enhancing Sovereignty and Supporting Healthier Communities in the North:** Building-out Canada's northern transportation networks and wealth-generating economic capacity through triple-use infrastructure (i.e. community, industrial, and military) not only builds healthier northern communities, but also projects Canadian northern sovereignty at a time of increased great power competition in the Arctic.
- **Stimulating Industrial Innovation and Specialized Expertise:** Establishing a more integrated supply chain entails developing what could be considered

Western-world leading expertise in advanced metallurgical and chemical processing, fostering innovation in higher-tech applications, and likely leading the world in terms of emissions and waste reduction processes, technologies, and expertise in the chem-tech sector. Developing the region's midstream processing capacity can ultimately increase the technological capabilities of Canada's materials sector and develop specialized knowledge that can be exported to partner nations.

Developing and nurturing this integrated value chain requires a long-term perspective and government leadership in identifying, selecting, and appropriately supporting catalytic projects to move forward.

1 Introduction

1.1 Context, Aim and Scope of This Study

The present study builds upon and complements our critical mineral and metal for battery value chain strategy report, titled "From Rocks to Power: Strategies to Unlock Canada's Critical Minerals for Global Leadership in Energy Storage, EVs, and Beyond,"[1] which is based on the 2022 *Roadmap for Canada's Battery Value Chain*.[2] This body of work aims to align, support, and accelerate the critical mineral strategies released by the federal, provincial, and territorial governments of Canada with the industries in a systemic manner.

Most of the significant investments so far have focused on matching the IRA and have been primarily targeted at Québec and Ontario. Furthermore, those supported projects are mainly in the same segment of the EV battery value chain: Battery manufacturing gigafactories. Although recent investments have supported infrastructure funding for mining projects in the western provinces, the scale and focus still differ significantly compared to those in the eastern and central provinces. The whole country can and should benefit from investment in electric mobility and energy storage.

The strategy report aimed to develop plans that would establish a long-term position for Canada, grounded in regional strengths, and foster economic prosperity within a net-zero framework. Through various interviews and workshops organized in partnership with the industry expert network from the Battery Metals Association of Canada and beyond, we developed strategies for the battery and magnet value chains. These strategies, co-developed with the industry, were designed to be material-specific. The priorities outlined in this report establish a project pipeline and identify key priorities to support local economic development agencies and governments in their decision-making.

With clear strategies in hand, the next logical step was to study how to apply them in practice and integrate them within regional frameworks. Different provinces and industries face unique realities and varying potential economic development, which do not encompass the same commodities or value chain segments. Playing on each region's strengths, collaboration and coordination are necessary. As the Western provinces of Canada were not the primary focus of battery value chain investment, we sought to frame our study in this context to highlight their industrial potential.

The scope of the present report is to answer the following question:

> How could a full value chain approach unlock the economic potential of Western Canada's critical minerals?

1.2 Approach and Methodology

To answer this question, three examples of Canadian regional industrial clusters were first studied: The Sudbury nickel and copper mining cluster, the Hamilton steelmaking cluster, and the future Bécancour battery material cluster. Factors for success and various parameters from those clusters were identified to provide a solid analytical framework for this report. Together with the value chain analysis detailed in our previous strategy report, these tools helped categorize gaps and opportunities in the Western Canadian industrial clusters.

The identification of those regional industrial clusters was possible thanks to the commodity and value chain ecosystem maps developed by the Battery Metals Association of Canada (BMAC). Filtering for the high-impact critical minerals, and focusing on British Columbia, Alberta, Saskatchewan and Manitoba, areas with a high concentration of operational sites and projects were identified. In total, eight clusters were identified and subsequently analyzed in relation to commodity value chains and cluster success parameters.

A series of two workshops was organized through the BMAC network and hosted in partnership with the Transition Accelerator and the Energy Futures Lab (EFL). For the scope of the two workshops, as well as the outline of this report, we focused our efforts on five regional industrial clusters of the eight identified: Northern British Columbia, Vancouver Lower Mainland, the Kootenays, Western Alberta and the Calgary-Edmonton Corridor.

The first workshop brought together industrial and academic experts knowledgeable in battery value chains and familiar with the business ecosystems of the identified clusters. The experts reviewed maps showcasing operational and high-impact projects within clusters, and they evaluated the conditions of success of a region based on a series of questions and a preliminary analysis we had developed for each cluster. Future critical infrastructure and the connection to other regions and clusters were discussed. Based on the feedback from this session, as well as insights from additional one-on-one interviews with industry experts, a refined analysis was drafted for each of the five clusters, with a focus on actionable items, such as strategic investments required for each region.

The second workshop brought together representatives from federal and provincial governments, as well as local economic development agencies from across the five cluster regions. Participants also included government officials from neighbouring provinces, as well as Manitoba, Saskatchewan, and the three territories. Building on the outcomes of the first session, attendees refined the proposed strategic investments and contributed valuable insights on inter-cluster links and shared regional priorities.

A concept for a Western Canadian Battery Value Chain initiative was also introduced, envisioned as an independent and nimble initiative to strengthen project origination and streamline economic development across clusters. Its potential roles and added value were discussed in detail. This report reflects the combined input from both workshops, supplemented by targeted interviews and further analysis.

1.3 Summary of Findings

Western Canada holds significant potential to develop into a globally competitive battery value chain. This report, informed by extensive industry workshops and government consultations, assesses opportunities and gaps across five of the eight identified regional industrial clusters in British Columbia, Alberta, Saskatchewan, and Manitoba. The aim is to build a regionally grounded strategy that supports Canada's net-zero transition while maximizing local economic development.

- **Northern BC:** A remote yet mineral-rich region with strong potential for copper, nickel, gold, and silver, but lacking local processing capabilities. Strategic investments in nickel and copper metallurgy, infrastructure, and workforce training could unlock value-added opportunities and anchor a fully integrated mining cluster in Canada.
- **Vancouver & Lower Mainland:** A clean-tech innovation cluster with strengths in technology development for battery processing, recycling, and potential in manufacturing, backed by top talent and global connectivity. Strategic support for battery manufacturing, local supply chains, electricity access, and scale-up of innovators could solidify its role in Canada's battery value chain.
- **The Kootenays:** With a strong metallurgical base anchored by Teck's smelter, the Kootenays are emerging as a cluster for battery recycling, refurbishment, and niche manufacturing. Future growth depends on diversifying off-takers, upgrading infrastructure, advancing the extraction of different minerals, and boosting R&D in material recovery. Expanding into copper and nickel metallurgy is also a promising path.
- **Western Alberta:** this cluster holds strong potential for lithium extraction from brines, supported by oil and gas infrastructure and a skilled workforce. With additional resources, including iron, phosphate, and vanadium, as well as industrial assets such as the Greenview Industrial Gateway, the region is well-positioned for future midstream development. Unlocking this potential will require access to clean energy, supportive policies, and strong coordination with the Calgary–Edmonton Corridor.
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lithium-rich brines, vanadium-bearing fly ash, and synthetic graphite sources, the region is well-positioned to establish Canada's midstream capabilities. By expanding, refining, and focusing on the production of cathode and anode materials, the corridor can become a globally competitive hub for advanced battery materials and processing. Investing in clean energy and talent, as well as boosting industry collaboration, will be necessary.

Western Canada's battery ecosystem is evolving from a scattered set of industrial nodes into a strategically connected network of regional clusters. Each cluster, from resource-rich regions in the North to advanced material manufacturing clusters in Alberta and battery manufacturing centres in southern BC, has unique strengths that, when integrated, form a complete and resilient battery value chain. Material flows between clusters, from lithium and phosphate to nickel, cobalt, and copper, reveal a powerful opportunity: specialization by region combined with shared infrastructure and collaboration can generate greater collective value than isolated growth.

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To succeed, this strategy must be supported by effective coordination among governments, industry, academia and Indigenous communities. With thoughtful planning and strategic project origination, Western Canada can establish a globally competitive battery supply chain that is rooted in sustainability, regional diversity, and economic strength.

2 Assessing Battery Value Chain Opportunities in Western Canada

2.1 Identifying Regional Industrial Clusters

2.1.1 Regional Industrial Cluster

What do we mean by "Regional Industrial Cluster"?

> An industrial cluster is a regional grouping of similar or related companies, for example, companies in the same industry or in the same value chain. Companies with common competitive strengths and needs usually cluster together due to the benefits of being located near each other.

Well-known Canadian examples of industrial clusters include the oil and gas industry in the Calgary-Edmonton corridor, Montreal's aerospace cluster, and Toronto's financial service cluster.

As we aim to support the development of the battery value chain in western Canada, we must rely on the strengths of the existing industrial clusters and analyze the gaps and challenges that need to be tackled.

As such, it can be useful to understand how industrial clusters appeared, developed, and organized along the battery, critical minerals and metals value chains. Such historical examples in different regions of Canada can help shine a light on how to proceed for economic development in western Canada.

The following section will highlight three different clusters and how they emerged: the **Greater Sudbury cluster** in ON, which developed from upstream mining of copper and nickel to midstream; the **Hamilton cluster** in ON, which specializes in midstream and downstream steelmaking and milling; and the Bécancour cluster in QC, which focuses on midstream and downstream segments of the metallurgy of several metals and the production of valuable chemical reagents.

2.1.2 Canadian Examples

2.1.2.1 Sudbury: The Historical Canadian Upstream and Midstream Cluster for Nickel and Copper

The unique geology of the Sudbury Basin, formed by an ancient impact, endowed the region with rich deposits of nickel, copper, PGMs, and cobalt. Although these resources were known and utilized by First Nations, major mining development began in 1883 with the construction of the Canadian Pacific Railway. Sudbury's first copper mine, the Copper Cliff mine, owned by the Canadian Copper Company (an American company), established its smelter in 1888, later adding a Bessemer converter. The smelted matte was then sent to New Jersey for further refining.

Exporting nickel ore and matte to the U.S. was duty-free, but refined nickel was not, limiting Canadian refining. Provincial and federal governments attempted to impose a nickel matte export duty to encourage domestic refining, but threats of shutdown by the Canadian Copper Company blocked the policy. Eventually, the Canadian Copper Company joined with other American firms to form the International Nickel Company, or Inco.

In 1904, Mond Nickel began producing pure nickel in Europe from Sudbury's Victoria Mine ores, shipping nickel to the UK for refining and European sales. This technology differed from New Jersey's refining methods.[3] Mond Nickel also built a smelter in the Sudbury area in Coniston,[4] and both Mond and Inco developed hydroelectric plants in the region as wood for steam power dwindled.[5,6] Rising military demand during WWI led Inco to establish a nickel refinery in Port Colborne, Ontario, in 1918.[7]

The 1928 merger of Mond Nickel and Inco created a Canadian corporation just ahead of U.S. anti-trust scrutiny. In parallel, Falconbridge emerged as a new player, building its own mine, smelter, and company town and establishing nickel refining operations in Norway.

Despite the Great Depression's brief impact on nickel prices, Sudbury's mining sector rebounded and thrived, supplying 90% of the world's nickel through the 1940s. By the 1950s, technological advancements enabled sulfur dioxide and high-grade iron ore recovery. Sulfuric acid production opened new markets, supplying lead batteries, detergents, and pulp and paper. Falconbridge continued expanding to support the U.S. market and developed nickel laterite projects in Indonesia, New Caledonia, and Australia. The 1970s brought environmental reforms, reducing sulfur dioxide emissions and modernizing operations with more efficient smelters, including the renowned Inco Superstack.

Today, while Sudbury no longer dominates the global nickel market—outpaced by Indonesia and China—Glencore (Falconbridge's successor) and Vale Canada (Inco's successor) maintain active mining and smelting operations. Sudbury's success is further supported by advanced education and research facilities, including Laurentian University, Cambrian College, and Collège Boréal, which provide specialized industry training. Research hubs like NORCAT, the Centre for Excellence in Mining Innovation (CEMI), and the Mining Innovation Rehabilitation and Applied Research Corporation continue to advance mining technology and innovation in the region, ensuring Sudbury's role as a leader in mining expertise.

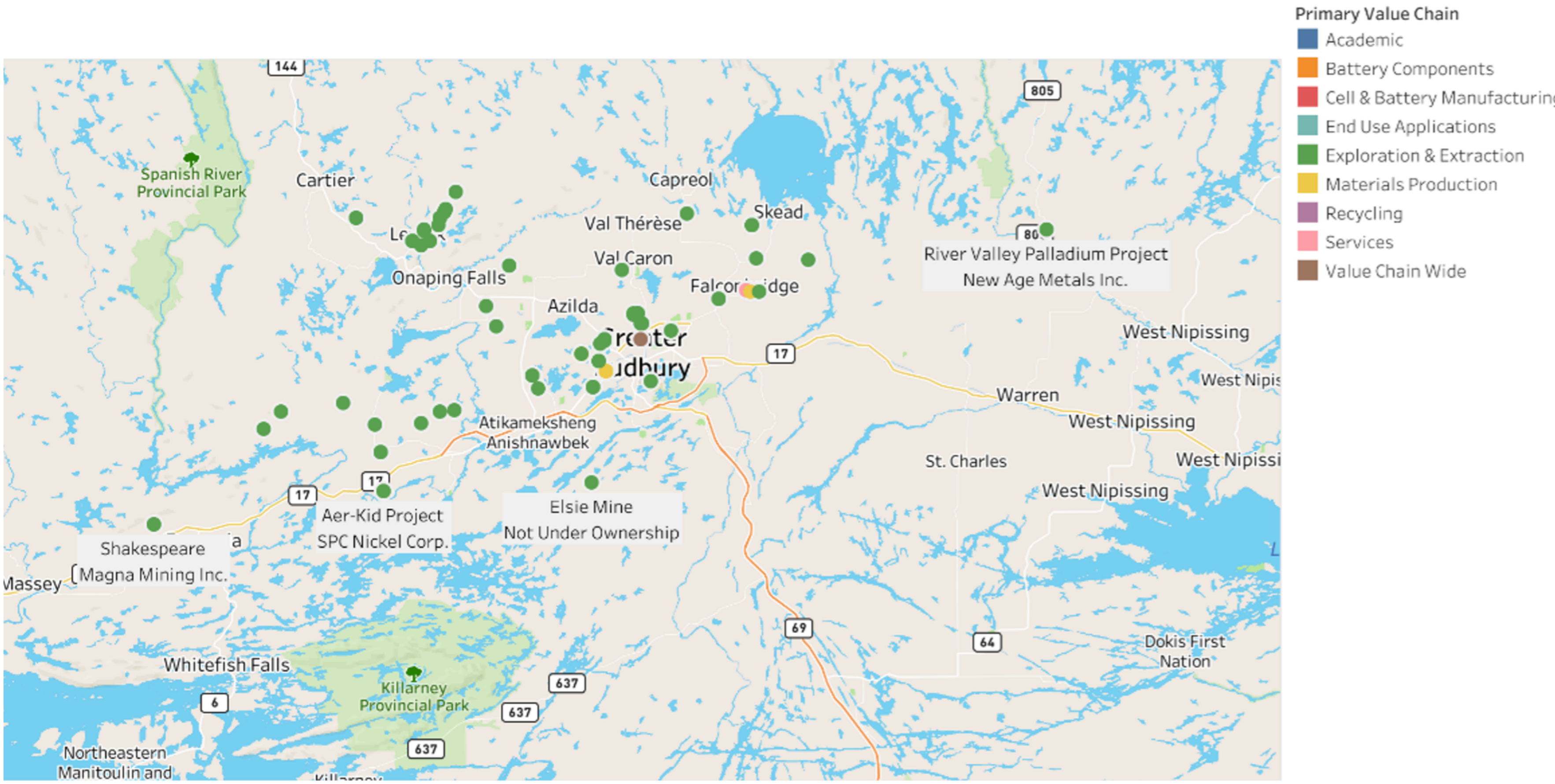


Figure 2.1.1 BMAC Value Chain Map of the Greater Sudbury Area: Accounting for Nearly 50 Sites Across the Battery Metals Value Chain in the Region

2.1.2.2 Hamilton: The Steel Cluster

Hamilton, Ontario, has a rich history as a steelmaking cluster anchored by industry giants like ArcelorMittal Dofasco and Stelco. This industrial cluster exemplifies the midstream segment of the iron and steel value chain, which saw rapid growth in the early 20th century due to Hamilton's strategic location and resources. Key advantages included access to affordable hydropower, proximity to major construction and auto manufacturing markets, and nearby sources of iron ore from Northern Ontario, Quebec, and the Appalachians.[8] Hamilton's position on Lake Ontario provided navigation routes and access to U.S. coal and markets via the Erie Canal. The Toronto, Hamilton, Buffalo Railway development and the Canadian Pacific Railroad further connected Hamilton to iron trade centres in New York.[9]

Local policies also supported industrial growth, such as tax exemptions offered by the city for plant development by the Hamilton Steel and Iron Company in 1899–1900. In 1912, the Hamilton City Council agreed to provide essential services like water, sewer, and roads to the new Dominion Steel Casting plant, reinforcing its commitment to nurturing its steel industry.[10]

Local research institutions have a long history of supporting innovation in the steel sector.[11] McMaster University's engineering department and the Steel Research Centre have provided local firms with valuable talent and research collaboration opportunities since the 1960s. Similarly, NRCan's CanmetMATERIALS, located in McMaster University Innovation Park since 2010, is the largest research centre in Canada dedicated to fabricating, processing and evaluating metals and materials.

2.1.2.3 Bécancour

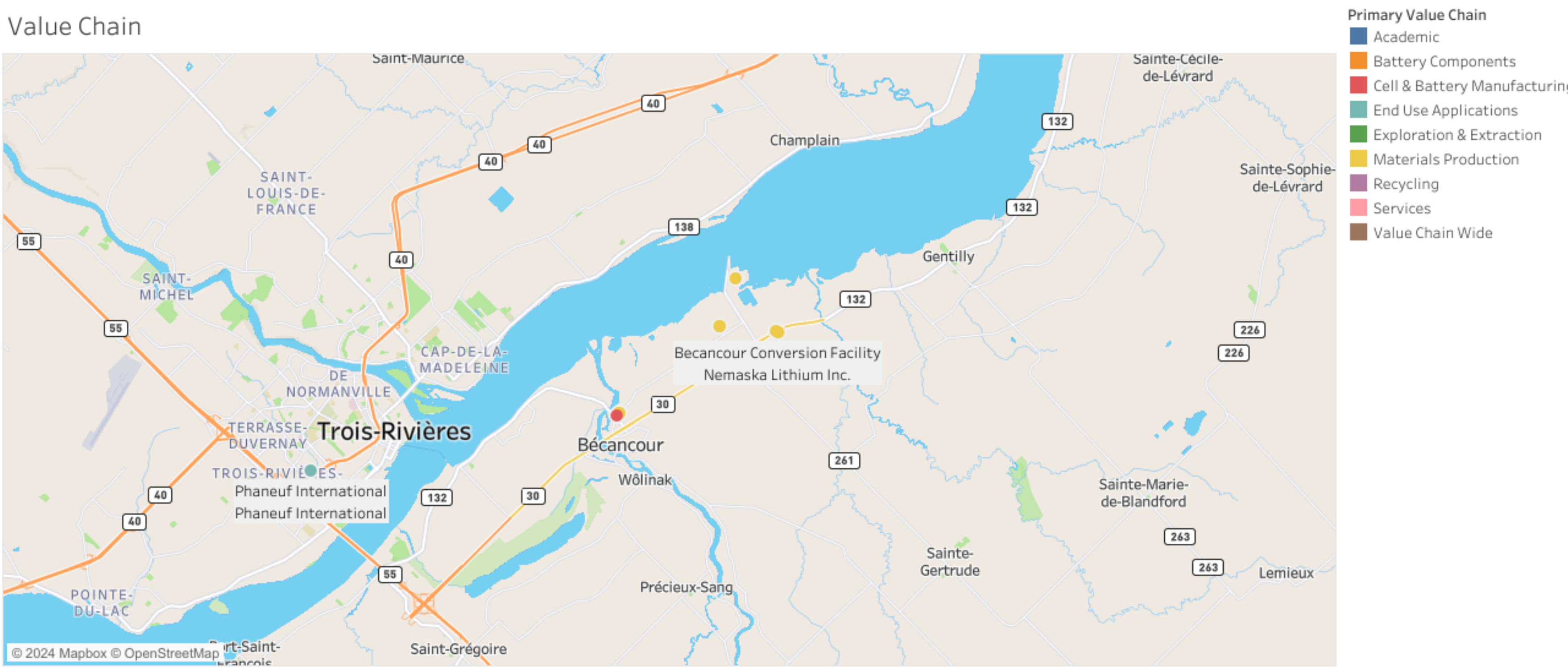


Figure 2.1.2 BMAC Value Chain Map of the Bécancour Area

The Bécancour cluster is a 70 square km industrial park part of the 'Vallée de la Transition Énergétique' (VTÉ), an innovation area comprising Trois-Rivières and Shawinigan on top of Bécancour. The innovation areas, or 'Zones d'innovation', are four different Québec-government fostered areas in the province that aim to increase the transition from idea to market, attract private and foreign investment, and promote clean, sustainable growth. In particular, the VTÉ has a board that gathers local industries, universities, and government officials as observers. The VTÉ also benefits from the participation and collaboration of several Québec universities, research institutes and industrial research centres.

Bécancour is a deep-water port accessible year-round and has access to the Midwest, the Great Lakes through rivers and waterways, and the Atlantic Ocean. The cluster also has access to highways and railway transport. It is located across from the city of Trois-Rivières and between the two bigger cities of Montréal and Québec City.

Historically, Bécancour was designated as a new steelmaking centre for Sidbec (a former province-owned steelmaking company) by Quebec's premier, Jean Lesage, in the 1960s, but the project finally took place elsewhere, in Contrecoeur. Following this cancellation, the province bought the Bécancour land and decided to develop the industrial park and port while the nearby Laviolette bridge joining Bécancour and Trois-Rivières became operational. Several industrial projects were cut short, such as Norsk Hydro's magnesium facility, which was dismantled in 2008, or Hydro-Quebec's Gentilly-2 nearby nuclear power station, which was shut down in 2012.[12] Nowadays, the cluster notably hosts an aluminum smelter owned by Alcoa and Rio Tinto Alcan.

More recently, the provincial and local governments have worked to attract industries linked to the energy transition to the Bécancour area. Several plants in the critical minerals and battery value chain are projected in the cluster, among which:

- An NMC cathode active material plant operated by Ultium CAM, a General Motors and POSCO joint venture.[13]
- A battery-grade nickel sulfate plant by Vale, supplying the previous CAM plant, is located on the neighbouring lot. Nickel will be provided from Vale's operations in Sudbury and in Long Harbour.[14,15]
- Another NMC cathode active material plant joint venture by Ford, SK On and EcoProBM.[16] However, Ford recently backed off of the JV.
- A battery-grade lithium hydroxide plant from Nemaska Lithium, supplied by lithium concentrates from the Whabouchi hard-rock lithium mine. Supply agreements to the Ford CAM plant have also been signed.[17,18]
- Nouveau Monde Graphite (NMG) projects to open an anode active material plant in Bécancour, supplied by its natural graphite mine in Matawinie. An offtake agreement has been signed between GM and NMG.[19,19,20]
- A battery-grade cobalt sulfate plant by Electra battery Materials.[21]
- A battery-grade manganese sulfate plant by Euro Manganese using electrolytic manganese supply either by MMC's operations in South Africa or Euro Manganese's project to produce manganese from mine tailings in Czechia.[22]

The 'Société du parc industriel et portuaire de Bécancour' (SPIPB) accounts for 15 industrial and 16 service companies in the cluster. Some chemical companies notably produce reagents for cathode and anode active material manufacturing. Olin notably produces sodium hypochlorite, caustic soda, chlorine, hydrogen and hydrochloric acid, Arkema produces hydrogen peroxides and Air Liquide produces liquid and gaseous hydrogen and is projected to produce oxygen, nitrogen and argon.[23]

Energy-wise, the cluster is located at the convergence of 3 electrical distribution networks, with access from 3 different hydroelectric sources: the Churchill Falls, the James Bay, and the Saint-Maurice River system. Additionally, TC Énergie co-produces locally 550 MW of electricity and steam from natural gas. In addition to being served by a high-capacity natural gas network, the industrial park also has access to both drinking and industrial-grade water. It has its own sewage and industrial wastewater treatment plant.

2.1.2.4 Lessons Learned from the Canadian Clusters Examples

Several lessons can be learned from studying these two historical clusters in Ontario and the new one in development in Québec. A few elements appear as common factors for the development of a successful industrial cluster: the access to inexpensive energy at scale, specifically from low carbon sources; the connection to innovation networks such as academia and industrial R&D centres; the local transport infrastructure, its capacity and maintenance, and its connection to other regions with the ability to transport chemicals, reagents and products easily; access to a specialized workforce with the suitable expertise and in sufficient numbers; and the business agreements and contracts between suppliers and off-takers, as well as their diversification in terms of companies and countries of origin or destination. Together with the in-depth value chain analysis previously carried out in our strategy report,[1] these considerations and criteria were investigated under the name of 'cluster success analysis'. See **section 2.2.2** for more information.

2.1.3 Methodology and BMAC Ecosystem Map

The Battery Metals Association of Canada released ecosystem maps in October 2024,[24] gathering openly available data on companies, active sites and planned projects in the critical mineral space in Canada. Two map versions were released, one focusing on the value chain and one focusing on the various commodities or minerals of interest. These tools are especially valuable as they gather data about companies and sites from various segments of the battery value chain, including Exploration & Extraction, Materials Production, Cell & Battery Manufacturing, Battery Components, Academia, Recycling, and Services. Around 67 minerals, metals, materials and commodities are also accounted for, including Canada's federally recognized 34 critical minerals.

Using specifically the commodities map, regions with a higher concentration of active sites and projects in western Canada were identified. For this identification exercise, the following minerals, metals and commodities were filtered for:

- Copper, graphite, iron, lithium, nickel, phosphate, rare earth elements and vanadium, as they were the focus of our previously published critical minerals strategy report.[1]

- Aluminum: not only is aluminum part of the federal critical minerals list, but it is also essential for transportation, construction, machinery, and defence. The Kitimat aluminum smelter in BC and its surroundings is a prime example of a small mid-stream cluster with energy and transport infrastructure.
- I Cobalt is essential for the cathode materials of NMC-type Li-ion batteries, and it can also be present in nickel, copper or gold-rich deposits.
- Helium is very rare on Earth, and Alberta can be competitive thanks to its existing oil and gas industry. Canada as a whole holds the fifth rank in terms of helium resources globally.
- Potash is strategic for fertilizers, and it is already part of a cluster in southern Saskatchewan along the Prairie Evaporite Formation. With 11 active mines, Canada is already the global leader in potash production in front of Russia and Belarus.
- Uranium, similarly to potash, is already widely extracted in the Northern Saskatchewan cluster, the Athabasca basin. Depending on the mineralogy, uranium deposits can be linked to vanadium or rare earth elements.
- For this work, western Canada specifically included the provinces of British Columbia, Alberta, Saskatchewan and Manitoba.

Those additions to the original eight critical minerals, metals and materials included in our strategy work serve to show the already existing industrial clusters (aluminum in BC, uranium and potash in SK) and highlight potential future venues (helium and cobalt). We also hypothesize that those industrial clusters have a workforce with transferable skills and that the existing industrial infrastructure, such as energy and transportation, can be re-used. The same goes for innovation infrastructure and networks like R&D centres and academia.

2.1.4 Results

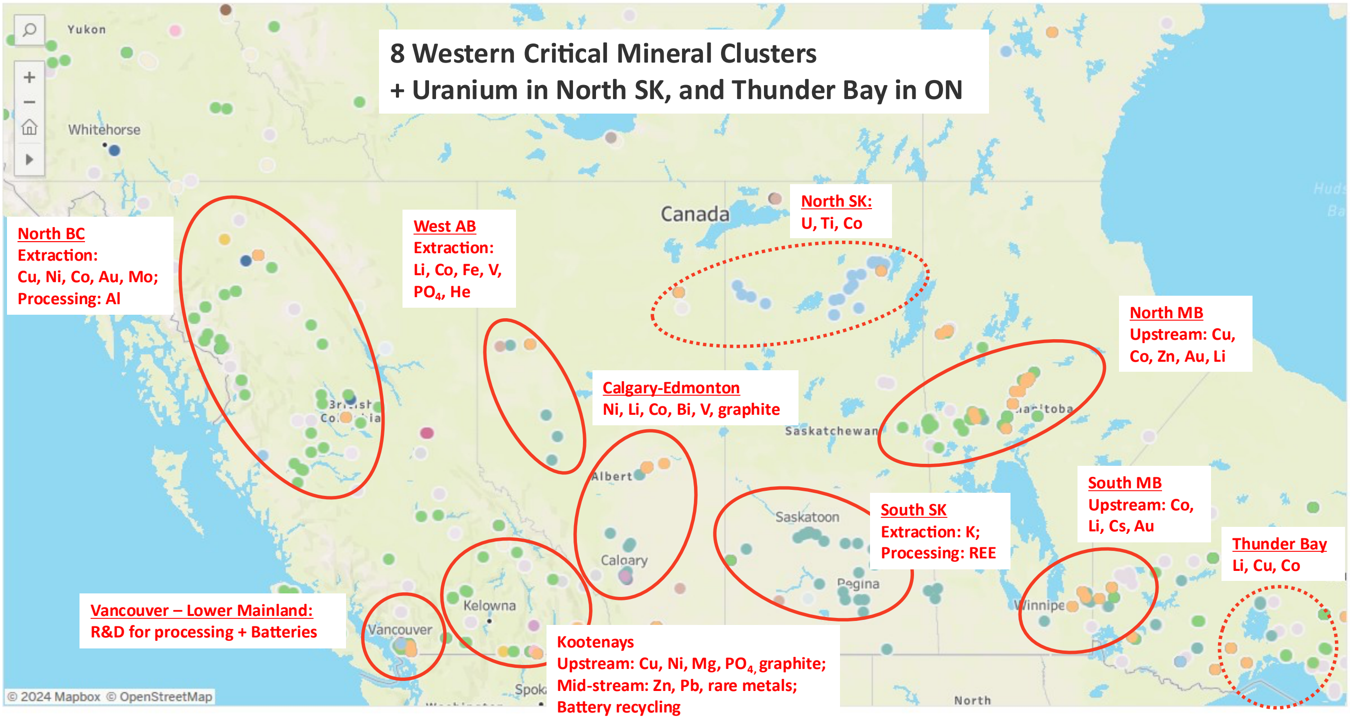


Figure 2.1.3 The Eight Western Regional Industrial Clusters Identified According to the BMAC Commodity Map

Eight regional industrial clusters were identified in western Canada, including the provinces of British Columbia, Alberta, Saskatchewan and Manitoba.

- **Northern BC:** also known as the gold triangle or the copper corridor, this northern BC area was regrouped with central BC to highlight the important mineral resources opportunities in the region. Due to the region's remoteness, the lack of infrastructure for energy or transport remains challenging. Currently, the cluster is focused on upstream extraction with copper and gold mines, while midstream metallurgy is carried out at Kitimat's aluminum smelter.
- **Vancouver - Lower Mainland:** This region regroups the Lower Mainland, the Vancouver area, and the eastern part of Vancouver Island. This cluster focuses on innovation, with multiple universities and R&D centers, as well as numerous technology and process provider companies. Various battery manufacturing projects are also planned in this cluster. As such, this cluster might focus on downstream production in the future on top of innovation.
- **Kootenays:** This cluster comprises of the Kootenays region, as well as the area around Kelowna, Trail and all the way to the Elk Valley. This region is driven by the historical implantation of the zinc lead smelter in Trail operated by Teck, with various smaller metal making and recycling operations around. Many mining

opportunities as well as some active mines are also present in this region, notably for copper, gold, coal, but also for magnesium, nickel, phosphate and graphite. In summary this cluster is already essentially focused on midstream metallurgy, but it has potential to push forward circularity and develop more upstream extraction.

- **Western Alberta:** This region comprises the area around Grande Prairie and Peace River. Compared to the other clusters, this one is relatively new as it has no active industrial site along the critical mineral value chain yet. However, it holds lithium brine resources, but also some in iron, vanadium and phosphate. The future potential for upstream extraction for this cluster is fairly clear, with the possibility for midstream processing.
- **Calgary-Edmonton Corridor:** the Calgary-Edmonton corridor is already an industrial cluster essential to the Canadian oil and gas industry. With a history of industrial development, innovation, and good infrastructure, this region already has experience in processing, notably for nickel with the Fort Saskatchewan Sherritt facility. More midstream processing plants are planned in the region, while some lithium extraction sites are also projected.
- **Southern Saskatchewan:** The cluster comprises the region between Saskatoon, Regina and Moose Jaw, and is vital for the current potash extraction along the Prairie Evaporite Formation, where four companies operate 11 potash mines. Further potash and lithium projects also exist in the cluster, while the recently opened SRC Rare Earth Processing Facility specializes in rare earth refining. This cluster focuses then on both upstream mining and midstream metallurgy and refining.
- **Northern Manitoba:** along the Flin-Flon – Snow Lake greenstone belt, including the Thompson area and a small part of northeastern Saskatchewan. Copper, zinc, gold, silver and nickel are the main commodities extracted in the region, while lithium spodumene deposits exist. This cluster is oriented towards upstream extraction but was historically a midstream metallurgy centre with the Flin Flon copper-zinc smelter (closed in 2010), the Flin Flon zinc hydrometallurgical plant (closed in 2022), and the Thompson nickel smelter (closed in 2018).
- **Southern Manitoba:** The region encompasses the Winnipeg, Selkirk and Southeastern Manitoba, notably along the Bird River greenstone belt and the Cat Lake – Winnipeg River pegmatite field. The cluster can be extended to the various mining projects located in western Ontario. The active mine of the region remains the Tanco mine (Cesium, tantalum and lithium), but several projected extraction projects for lithium, cobalt, copper, nickel and PGEs are promising. This cluster is predominantly oriented toward extraction.

We acknowledge that there are at least two more mining clusters close to the regions examined:

Firstly, the **Athabasca Basin** in Northern Saskatchewan is a strong uranium cluster, with two operating mines (McArthur River and Cigar Lake), one planned to restart this year (McClean Lake) and two mills (Key Lake and McClean Lake).[25–27] This specific region made Canada the second largest uranium producer globally in 2022 according to NRCan.

Secondly, the **Thunder Bay area** in western Ontario has also seen the development of many mining projects, notably for lithium spodumene mining and processing and extraction projects for copper, cobalt, nickel, gold, and PGEs.

While the western Ontario region is close to the southern Manitoba cluster, it is still outside of the chosen boundaries, explaining why it is not featured in this study. The northern Saskatchewan cluster focuses solely on uranium, which is used as a fuel rather than a critical mineral for the battery value chain. This study also discarded it as its value chain is very specific and separated. Moreover, the ecosystem map did not show enough non-uranium critical mineral projects to be considered as a cluster for this study. However, it can be recognized that uranium mining and processing can possibly have synergies with the critical mineral industry, notably for extracting vanadium from carnotite and the phosphate or REE industries.

We also acknowledge that the **territories** will have an essential role to play in developing these clusters. Due to the remoteness of the northern territories, it is generally admitted that they will focus on the earliest stage of the value chain, such as mining and milling, and the resulting critical mineral concentrate will have to move south for shipping or further domestic processing. Challenges such as access to a skilled workforce, clean electricity, or sufficient transport infrastructure are common issues for Yukon, Northwest Territories, and Nunavut. As such, initiatives to link the highlighted eight regional industrial clusters to the territories to develop synergies and share mutual advantages should be supported. A few examples illustrating this concept are the Yukon-BC grid connect project,[28] or the Fortune Minerals planned mine in the NWT, which will produce concentrates that will be further processed in a projected plant in the Edmonton region.[29]

Given the constraints of the analytical exercise, this study focuses on the first five clusters presented, which cover British Columbia and Alberta.

2.2 Assessment

2.2.1 Value Chain Analysis

The present value chain analysis analyzes the flow of materials through each value chain segment, from primary extraction to the manufacturing of finished product, commodity by commodity or material by material. As supply chains are not always linear, and because of the need to push for an optimized handling of materials through recycling or second life, circularity was also analyzed as a separate step.

In this report, we are mostly interested in value chains directly related to batteries, energy storage, EV or but also in value chains that are adjacent to those:

- The battery value chain, specifically:
    - For Li-ion:
        - NMC Cathode Active Material
        - LFP Cathode Active Material
        - Graphite Anode Active Material
        - Electrolyte
    - The Vanadium Redox Flow Battery Value Chain
- Rare Earth-based permanent magnet Value Chain
- The Copper Wire Value Chain

To simplify our value chain analysis, we consider five segments: Extraction, Processing, Advanced Material Production, Battery Manufacturing and Circularity. Throughout the report, extraction will be considered upstream, battery manufacturing will be downstream, and processing and advanced material production will be considered midstream. The following sections will describe each value chain segment to define what they entail clearly. Those value chains were previously analyzed in detail in our earlier report.[1]

For each segment and commodity of the value chain, the sites were differentiated according to several categories:

- **Operational Sites:** Mines and plants that are already in operation at the time of the elaboration of this report.
- **Advanced Projects:** Mines and plants that are not yet in activity at the time of the elaboration of this report, but which are already advanced in terms of development, with publicly available data which is accessible, such as technical studies and recent press releases.
- **Future Cluster Value:** According to the feedback collected for this study from industry, government, and civil society, as well as our own analysis, those are proposals of projects that could unlock ecosystemic economic development in a cluster.

2.2.1.1 Extraction

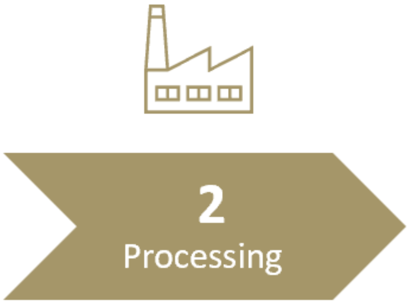
The extraction stage refers to the earliest segment of the value chain, which is extracting primary raw materials from the ground. We consider this segment to be upstream. This mostly refers to mines, either underground or open-pit, but can also comprise of quarries (sometimes the terminology used for phosphate) or direct extraction through pumping, such as is the case for the first step of Direct Lithium Extraction (DLE) operations. Solution mining is also a technology used for potash extraction.

In many cases, the mined material is also treated through mineral processing through physical means on site, yielding concentrates that are much more convenient and economical to transport than raw ores. Those physical processes are known as beneficiation, and can consist of various steps of comminution (crushing, milling), sizing, concentration (froth flotation, gravity concentration, magnetic separation, etc.). The materials left over after the physical processes are called the mine tailings. All those processes are included in the proposed extraction stage as they often occur at the same sites.

In the case of vanadium, the primary extraction mostly refers to either carnotite (uranium ores) or titanomagnetite (iron-titanium ores). Still, one potential important source of secondary vanadium for Canada can be found from petroleum sources, especially from Alberta heavy oil from tar sands. This source will also be considered to be part of the extraction segment. Being a gas, helium differs from other elements, the extraction stage refers to the drilling and bringing it to the surface along with natural gas.

Canada has shown a strong expertise in this segment for copper, iron, cobalt and nickel. Canada has recently started mining lithium spodumene in Québec, with some marginal operations in Manitoba. Natural graphite is also mined in Québec. Finally, there is potential to develop lithium brine DLE in Alberta and Saskatchewan, Phosphate in BC and Québec, and Rare Earth mining in the NWT, BC and Québec, among others regions. Vanadium, as mentioned above, can be a good prospect from Alberta oil sands or from Québec titanomagnetite deposits. Uranium and potash have a strong mining industry in Saskatchewan. Only Saskatchewan currently produces helium, but Alberta shows promising potential.

2.2.1.2 Processing



The processing stage refers to the transformation of raw materials and concentrates through physicochemical processes and metallurgical operations after the extraction step. These can occur through heavy industry operations such as smelting and refining non-ferrous and ferrous metals, such as steelwork. We consider this segment to be midstream.

Regarding flowsheet or specific operations, the processing stage considered in this report includes very diverse steps as all the studied commodities, metals, and critical minerals of interest have very different processing routes. For copper, cobalt, and nickel, this include smelting or hydrometallurgical processes, solution extraction (SX), electrowinning (EW), and electrorefining. Precipitation, such as copper cementation, is also part of the processing stage. The production of copper, nickel or cobalt salts, such as nickel sulfate, is also part of the processing stage. For iron and steel, this includes smelting through a furnace (BF or EAF), further reduction through blast-oxygen furnaces (BOF) or direct reduction iron (DRI) processes, alternatives such as molten oxide electrolysis, and finally, secondary metallurgy and casting. For lithium, this includes the processing steps to obtain either lithium carbonate or lithium hydroxide, either from lithium brine sources or from hard-rock lithium such as spodumene or petalite. For phosphate, this includes processing phosphate rock concentrates through the thermal or wet process to merchant grade phosphoric acid and upgrading it to purified phosphoric acid. For rare earth elements, this includes cracking, leaching, separation to individual rare earth salts, calcination and reduction to metals during metalmaking. For helium, this includes its separation from natural gas through distillation. For aluminum, this means the conversion of bauxite to alumina through the Bayer process and its transformation to aluminum in a smelter through the Hall-Héroult process. For vanadium, this includes all the processes to reach sodium vanadate and vanadium pentoxide, from carnotite, titanomagnetite or petroleum-based fly ash and catalyst. For graphite, this can include all the processing stages delivering non-energy storage products, such as micronized graphite, but not the spherical graphite or the coated spherical purified graphite, as those will be counted in the advanced material production segment.

Canada already has historical expertise in copper, nickel and cobalt metallurgy as well as in steelwork. Lithium processing plants are planned in Québec and Ontario for spodumene feedstock, while most DLE projects in Alberta and Saskatchewan incorporate a processing step after brine extraction. Phosphate processing plants are planned in Québec and in Ontario. REE processing is already being spearheaded by the SRC in Saskatchewan but also by several companies in Ontario. Bauxite is processed to alumina and then aluminum in British Columbia and in Québec. Uranium is milled in Saskatchewan to produce yellowcake, which is then refined in Ontario.

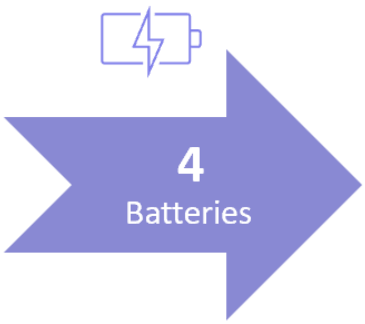
2.2.1.3 Advanced Material

This segment refers to producing specialty chemicals and materials with high added value, such as cathode active materials and their precursors and anode active materials or electrolytes.

For NMC Cathode, this includes steps such as the chemical transformation of battery-grade sulfate or other salts from nickel, cobalt, and manganese to NMC pCAM and the subsequent integration of lithium (often hydroxide), calcination, washing, to NMC Cathode Active Material production. For the LFP Cathode, this includes different pathways, such as solid-state or solution chemistry, to synthesize the $LiFePO_4$ active material, purified phosphoric acid, iron salts or metallic iron, and lithium salts. Subsequent carbon coating of the active material is also part of this segment. Graphite anode is the material of choice for most Li-ion battery chemistries. The present segment includes the steps to produce battery-grade graphite or coated spherical purified graphite CSPG, whether from natural sources or synthetic ones. This includes processes such as spheronization, purification, and coating. For vanadium redox flow batteries, this includes all the steps to convert intermediate vanadium chemicals, such as vanadium pentoxide, to different vanadium electrolyte solutions. Outside of the battery value chain, this can refer to the alloying and magnet manufacturing for the rare earth permanent magnet value chain.

Globally, this mid-stream segment of the value chain is dominated by Asian actors, and most particularly China. Canada still lags behind in this segment, but several companies are interested in developing domestic capacity, notably in Québec, while one project was paused in Ontario.[30]

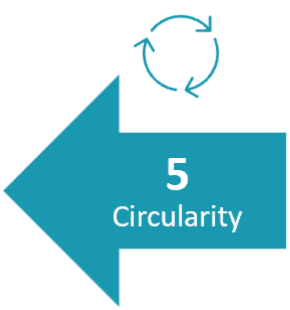
2.2.1.4 Battery Manufacturing



The battery manufacturing segment refers to the battery cell and pack manufacturing process, which includes manufacturing electrodes, the cell assembly, cell formation and finishing, and finally, the pack assembly. This segment is considered to be downstream. It can refer to regular Li-ion batteries as well as alternative chemistries and technologies such as vanadium redox flow batteries or solid-state batteries.

Previously, more than ten companies announced plans to build battery plants or gigafactories in Canada, but several were paused or delayed. Only a handful of companies operate battery manufacturing plants in Canada, notably in Québec, Ontario and British Columbia.

2.2.1.5 Circularity



Finally, circularity is the last segment of our value chain analysis. This segment is broad and often linked to the processing and advanced material manufacturing segments.

One key section of this segment is recycling: reprocessing materials from end-of-life products or waste streams to make either end-products or intermediates of the value chain. For example, used NMC batteries are shredded and generate black mass, and from this black mass can be extracted nickel salts, manganese, cobalt, or lithium chemicals, and sometimes even graphite. Those chemicals can be re-used for the fabrication of new batteries. This example links the end-of-life product of the battery manufacturing segment to the processing or advanced manufacturing segment. Re-processing waste such as mine tailings, slags or by-products to extract useful elements is another example of recycling.

Another key section of circularity is second life. If the battery performance is still suitable, used EV batteries can be repurposed for stationary energy storage products. Second life thus extends the life span of batteries and avoids unnecessary processing or recycling when the battery is functional enough to be repurposed.

Several companies operating in Canada already push forward circularity: Lead-acid and Li-ion batteries are recycled in British Columbia, and a few Canadian companies specialize in black mass recycling and in rare earth element extraction from e-waste.

2.2.2 Cluster Success Analysis

2.2.2.1 According to Criteria

In addition to the value chain analysis, which focuses on material flow along the upstream, midstream, and downstream segments, as well as circularity, the 'cluster success' analysis dives into the parameters that are key to the success of a regional industrial cluster.

Those parameters were broken down into five different buckets:

- Active Ecosystem
- Innovation & Research
- Skilled Workforce
- Abundant Green Energy
- Transport Infrastructure

Of course, additional parameters can play a role in the potential success of an industrial cluster. For instance, access to materials and reagents can be a significant factor. The policy and regulatory environment, as well as investment attractiveness, are essential features for the economic development of a cluster. Still, they're bound to depend on the jurisdiction with a much larger scale, such as a provincial or federal regulation.

Each finding and feedback from the industry, government and other stakeholders that came out of the workshops, interviews and our analysis were sorted into different categories for this analysis:

- **Assets:** These features can be considered strengths of a specific regional industrial cluster. Examples include the local availability of inexpensive hydropower, deep connections and collaboration with research institutions, the presence of a tidewater port, diversified suppliers and clients, *etc.*
- **Challenges:** These features can be seen as an industrial cluster's weaknesses and gaps. For instance, they can include the lack of appropriate transport infrastructure, a carbon-intensive electric grid, difficult access to a skilled workforce due to an area's remoteness, or dependency on only one off-taker.
- **Strategic Investment:** This category refers to proposed value-added initiatives or projects that could unlock the cluster's economic development potential. Examples include road upgrading, transmission line extension, and training programs with local colleges*, etc.*

2.2.2.2 Active Ecosystem

The active ecosystem category mostly refers to the supplier and offtaker agreements of the companies operating or planning to operate in the cluster.

These agreements can be located inside the cluster, in the province, Canada, or foreign countries, and involve different risk levels. Additionally, depending on the competitiveness of the specific markets, the lack of diversification for off-take or supply agreements can be a higher risk for some companies. This category is especially essential as it can delay or pause industrial projects.

2.2.2.3 Innovation & Research

The innovation and research category refers to either the cluster's direct research and development capacity or its links and collaborations with research institutions. This includes both academic and industrial research as well as optimization. In the battery value chain, where most processing steps, technology providers, and the number of patents and intellectual property are concentrated in Asia, investing in innovative and different processes can be strategic and lead to beneficial disruptions. Thus, a cluster with high-quality research can become more competitive globally. For more information on how innovation can affect the battery industry, please refer to the Canadian Battery Innovation Roadmap released by Accelerate in 2024.[31]

2.2.2.4 Skilled Workforce

The skilled workforce category refers to how trained labour is accessible within a specific cluster. Regional attractivity, demographics, local industrial history and the presence of training centres, colleges, polytechnic institutes, and universities can affect this category.

Several urban clusters have already developed fairly efficient approaches to skilled workforce accessibility, while others are too remote to compete without challenges. Specific commodity value chain segments or processes also require specific skills that can be lacking, regionally or country-level.

In some cases, skills can be transferable: the pulp and paper industry workforce could be well suited for hydrometallurgical operations, or the skills used in the oil and gas industry can be an asset for some direct lithium extraction operations.

However, training for the battery and critical minerals value chain industries will generally require a long-term investment on a pan-Canadian level.

2.2.2.5 Abundant Green Energy

The abundant green energy category is a necessary feature for an industrial cluster linked to the battery and the critical minerals value chains. Heavy industry, such as mining, processing, and advanced material manufacturing, is energy-intensive and requires inexpensive sources of energy, such as electricity, heat, *etc.* As the need for decarbonization pushes the development of the battery industry, investors in this space often require that projects operate with green or low-carbon energy.

Some regions, such as British Columbia and Manitoba, already have a largely decarbonized electricity grid, while Alberta, Saskatchewan, and the territories rely on fossil fuels.

In addition to a grid's GHG intensity, the question of scale and capacity for available energy is also important. Energy is a particularly influential lever that governments, crown corporations and utilities have to unlock the economic potential of chosen clusters.

2.2.2.6 Transport Infrastructure

Finally, the transport infrastructure category is required for all types of industry dealing with consequent material flows. The mobility of raw materials, intermediates, and products necessitates a complex logistic approach and sufficient infrastructure such as roads, highways, railways, train stations, ports, dry ports, *etc.*

Remote regions may not have sufficient transport infrastructure to enable the economic development, while more industrialized regions can leverage their infrastructure to boost local development strategies.

Transport infrastructure, akin to energy, is another important tool that governments and crown corporations have to encourage local economic development.

3 Northern BC

3.1 Summary

Value Chain Segment	1 Extraction	2 Processing	3 Advanced Material	4 Batteries	5 Circularity
Operational Sites	Cu, Au, Ag, Mo	Al (Rio)	/	/	/
Advanced Projects	Ni, Co, PGEs, Pb, Zn, Nb, REEs, Te	/	/	/	/
Future Cluster Value	/	Cu & Ni metallurgy	/	/	Black Mass recycling for Ni, $NiSO_4$ production

Cluster Assessment	Skilled Workforce	Abundant Green Energy	Transport Infrastructure	Active Ecosystem	Innovation & Research
Now	Remoteness: Challenging	Hydro. Remoteness: Challenging, Competition	Difficult road maintenance	Concentrates sent to Asia	/
Gaps	Training Centers, Partnerships	NWT extension/ expansion	Port expansion, better road and infrastructures	Develop domestic midstream: in cluster or outside	/

Figure 3.1.1 Summary of the Northern BC Cluster Assessment

Unlocking the Potential of the Copper Corridor: A Call for Building Infrastructure and Metallurgy Investment for Copper and Nickel

The Copper Corridor, also called the Golden Triangle, is a cluster encompassing both northern and central regions from British Columbia. It's a powerhouse of mineral wealth, currently specializing in the extraction of copper, gold, and silver, with promising opportunities for nickel. Yet, a critical gap remains—midstream metallurgy. The region's mountainous terrain and isolation exacerbate challenges in infrastructure, energy, access to skilled labour, and logistics. Currently, most concentrates are shipped to Asia, missing key opportunities for local value creation and processing. A strategic cluster approach—focused on shared transport networks, utilities, processing and byproduct management—could transform the region into a fully integrated mining and metallurgical cluster, boosting economic resilience and strategic Canadian value chains.

An attractive future development for this cluster is to strengthen the value chains of copper and nickel, both on the extraction side and in the metallurgical processing side, to add value and grow Canadian supply chains.

Indeed, nickel is crucial for stainless steel and nickel-rich electric vehicle (EV) batteries, which require nickel sulfate for the cathode. Nickel demand is also increasing as cobalt use declines. Canada produces only 4–5% of the global supply, primarily from sulfide ores, while the dominant laterite production—often with higher environmental costs—is growing abroad, notably in Indonesia. BC has a unique opportunity to build an integrated, lower-impact nickel value chain by advancing the extraction and processing of sulfide and awaruite in the province to nickel sulfate, while linked to future domestic cathode and battery manufacturing.

Copper is essential for most clean energy technologies—from EVs and batteries to wind, solar, and grid infrastructure—due to its superior conductivity. Demand is expected to outpace supply significantly over the next decade, driven by the energy transition and declining ore grades. Copper is refined through energy-intensive metallurgical processes, with global supply dominated by Chile, Peru, China, the DRC and the U.S., while China dominates global refining. More than half of Canadian extraction comes from BC, with additional operations in Ontario, and a smelter in Québec. BC is in a very good position to grow its copper metallurgy operation and integrate it to copper mills and wiring to sustain the energy transition and widescale electrification.

Key points for future cluster value:

- Pursue the development of copper, nickel and cobalt mines while acknowledging that gold or molybdenum can enhance economics and that opportunities exist for REE and antimony.
- Developing metallurgical facilities to process copper or nickel could unlock value-added potential to the cluster and bolster Canadian strategic value chains. Prospective locations include Kitimat, Prince Rupert or Prince George. Further scoping studies and analysis should be carried out.
- Support training programs and partnerships between industry and colleges and institutes to develop mining and processing skills
- Expand the Northwest Transmission Line and last-mile connections to support mining projects
- Upgrade highways, build new roads for project access, and consider expanding port capacities to meet increased shipping demand.

3.2 Value Chain Analysis

3.2.1 Extraction

3.2.1.1 Operational Sites

The current mining operations primarily focus on precious metals, such as gold and silver, but also include the mining of copper and molybdenum within the cluster (**Table 3.1**). The operating coal mines were not included in this list.

Table 3.2.1 List of Operational Extraction Sites in Northern BC

Site	Operator	Commodity
Blackwater	Artemis Gold	gold, silver
Brucejack	Newmont	gold, silver
Gibraltar	Taseko Mines	copper, molybdenum
Mount Milligan	Centerra Gold	copper, gold, silver
Mount Polley	Imperial Metals	copper, gold
Premier Gold	Ascot Resources	gold, silver *(paused)*
Red Chris	Newmont & Imperial Metals	gold, copper

3.2.1.2 Advanced Projects

Table 3.2.2 List of Advanced Projects for Extraction Sites in Northern BC (non-exhaustive)

Project	Operator	Commodity
Baptiste	FPX Nickel	nickel, copper, cobalt
Berg	Surge Copper	copper, molybdenum, gold, silver
Turnagain	GigaMetals	nickel, copper, cobalt, molybdenum, PGM
Galore Creek	Newmont & Teck	copper, gold, silver
KSM	Seabridge Gold	gold, copper
Kutcho	Kutcho Copper	copper, molybdenum, gold, silver
Schaft Creek	Teck & Copper Fox Metals	copper, molybdenum, gold, silver
Yellowhead	Taseko Mines	copper, gold, silver
Wicheeda	Defense Metals	REE

3.2.1.3 Future Cluster Value

- Pursuing nickel copper and cobalt projects
- **Additional Minerals:** In addition to the traditionally extracted gold, silver, copper, coal, and nickel projects, Northern BC also hosts significant resources of cobalt, zinc, antimony, molybdenum, and rare earth elements.
    - **Au & Mo as Valuable Byproducts for Copper:** Molybdenum can be present in copper concentrates, generating additional revenue. Additionally, gold extraction alone should not be prioritized for strengthening a Canadian battery or critical mineral value chain; however, gold as a byproduct can increase the economic value of copper extraction sites.
    - **Antimony:** The US DoD is interested in antimony, as their country had an 85% net import reliance in 2024 for antimony metal and oxide.

3.2.2 Processing

3.2.2.1 Operational Sites

Besides the Kitimat plant, no other metallurgical or processing plant is operating or is in an advanced project stage in this cluster.

Table 3.2.3 List of Operational Processing Sites in Northern BC

Site	Operator	Commodity
Kitimat Aluminum Smelter	Rio Tinto	bauxite to alumina & aluminum

3.2.2.2 Future Cluster Value

- Building Midstream Metallurgical Facilities: Copper & Nickel:
    - A processing facility would need:
        - Access to a significant amount of cheap and clean power
        - A port would facilitate access for materials transit
        - Proper solid waste management: smelter slag or leach residues
    - Possible Locations:
        - **Kitimat:** A tidewater port location, with a skilled workforce. There is already an aluminum smelter, but there is little synergy beyond infrastructure. Kitimat might be more receptive to such a project

than Prince Rupert. However, the location near a shallow sound is not great for effluent management.

    - **Prince Rupert:** Another tidewater port location. It should be less challenging in terms of available space, labour, or effluent disposal than Kitimat.
    - **Prince George:** An inland location. It has a sulfuric acid plant which could be used for other industries since paper mills shut down. The pulp and paper workforce has skills which are transferable to metal processing. This could be a good option for the hydrometallurgy of awaruite from the Decar nickel district.[32] However, effluent management can be an issue for inland facilities, and moving concentrates around northern BC could be expensive.

- Nickel: three options, a smelter, a hydrometallurgical facility, or both
  - A smelter is suitable for converting nickel sulfide concentrates to nickel matte.
  - A hydrometallurgical facility can leach awaruite from the Decar region to battery-grade nickel sulfate. Additionally, leaching nickel matte can also produce nickel sulfate.
  - A large metallurgical plant utilizing both pyrometallurgical and hydrometallurgical processes to accommodate various feedstocks, including nickel sulfide concentrates from northern BC, awaruite from central BC, and mixed precipitates from overseas. Synergies with the production and utilization of sulfuric acid could be implemented.[1]
- Copper Smelter
  - Currently, enough copper concentrate is produced in BC to justify the construction of a copper smelter. Of course, those concentrates have contractual obligations to export, but additional copper streams will come from future copper projects. However, the current economics of copper smelters is impeded by very low treatment and refining charges (TC/RCs).[33] An integrated smelter or a joint venture could be a solution. If not, smaller hydrometallurgical facilities for copper leaching and precipitation/cementation or electrorefining could be an alternative.[1]

3.2.3 Advanced Material

3.2.3.1 Future Cluster Value

- Producing Nickel Sulfate at the Future Nickel Metallurgical Plant:
    - A future nickel metallurgical plant could be designed to produce nickel sulfate or even precursors to the cathode active material (pCAM) for NMC batteries. Nickel sulfate can be produced by leaching nickel matte from nickel sulfide concentrates if the facility is a smelter, or it can be easily produced from a hydrometallurgical facility leaching awaruite concentrates.[1]

3.2.4 Batteries

Battery manufacturing is not a priority for this cluster in terms of development. The Lower Mainland would offer better opportunities.

3.2.5 Circularity

3.2.5.1 Future Cluster Value

- Integrate Recycling at the Future Nickel Metallurgical Plant:
    - **Black Mass Leaching and Recycling:** Incorporating processes for leaching and recycling black mass —the mixture of materials recovered from end-of-life batteries —should be gradually implemented. While economically and technically challenging, starting these processes now will position the metallurgical complex as a leader in sustainable resource management. In addition to nickel, manganese, cobalt, and lithium, and potentially graphite could also be recycled.[1]

3.3 Cluster Success Analysis

3.3.1 Skilled workforce

3.3.1.1 Assets

- **Transferable Skills:** Pulp and paper industry workers possess relevant skills for prospective metallurgical processing projects, including handling slurries, acids, bases, and pressure equipment. This is particularly the case for the Prince George area.

- **Kitimat:** The Rio Tinto aluminum smelter workforce already has the skills and a very good understanding of metallurgical industrial processing.

3.3.1.2 Challenges

- **Attracting Talent:** Recruiting and retaining skilled labour in remote areas, especially for midstream processing, remains difficult. This will be a lasting challenge for this cluster.

3.3.1.3 Strategic Investments & Opportunities

- **Educational Programs & Partnerships:** Existing training programs and centres are already available in other mining clusters, such as Sudbury. Projects, such as partnerships between mining companies and colleges (like the British Columbia Institute of Technology or BCIT) to develop training programs and establish a mining centre of excellence, should be supported. Similar programs could be extended to the processing and metallurgy segments.

3.3.2 Abundant Green Energy

3.3.2.1 Assets

- **Clean Electricity:** BC's energy mix is predominantly clean, with hydroelectricity accounting for 88% of total electricity generation.
- **Electrification Needs:** Foresight Canada is currently leading a mining power demand project, with BC Hydro participating in identifying electrification requirements for mining and processing.
- **Transmission Planning:** Backbone transmission lines are already being planned through the province, but they are not necessarily financed for implementation. Additionally, the generation capacity remains uncertain. BC Hydro is conducting extensive planning and studying the impact on local communities. Reinforcing this planning capacity and helping implementation should be supported.

3.3.2.2 Challenges

- **Power Supply Challenges**: The North Coast has limited generation supply and transmission capacity, with last-mile connectivity being a significant issue.
- **Competition for Power:** High demand from LNG facilities and other industrial projects increases competition for limited power resources. Processing facilities require a lot of power. For instance, Rio Tinto powers its own plant for Kitimat, the Kemano Generating Station.

3.3.2.3 Strategic Investments & Opportunities

- **Transmission Line:** A northward extension of the Northwest Transmission Line and/or capacity expansion is required, along with power lines for the last mile to connect to various projects. NRCan has recently contributed $25M for a 'BC Hydro Transmission Line for Northwest B.C. Mines' project through the Critical Mineral Infrastructure Fund (CMIF).[34]

3.3.3 Transport Infrastructure

3.3.3.1 Assets

- **Ports Access:** Northern BC has several tidewater ports suitable for shipping materials in and out, including the ports of Stewart, Prince Rupert, and Kitimat. Port expansion might be required.

3.3.3.2 Challenges

- **Challenging Transport:** Transport in Northern BC is complex by road or rail due to the area's remoteness. There are only a few transportation roads, some of which have poor maintenance.

3.3.3.3 Strategic Investments & Opportunities

- **Highways and Roads:** Upgrading highways for safer traffic and improved maintenance is necessary, as well as constructing new roads to facilitate access to various projects.
- **Port Expansion:** The Port of Stewart may require expansion if shipping along the coast increases.
- **Alignment of Interests for Infrastructure Funding:** Local Indigenous groups, communities, and Industries have aligned to advocate for road expansion, which could benefit both the regional economy and improve safety. Joint advocacy helped the BC and federal governments fund necessary highway upgrades.[35]

3.3.4 Active Ecosystem

3.3.4.1 Challenges

- **Export-Oriented Mining Industry:** All mineral products from the region are likely shipped to Asia; for example, copper concentrates are sent to smelters in China, the Philippines, and South Korea for metallurgy.

4 Vancouver Lower Mainland

4.1 Summary

Value Chain Segment	1 Extraction	2 Processing	3 Advanced Material	4 Batteries	5 Circularity
Operational Sites	/	NESI (Li) Saltworks (Li) Mangrove (Li) Go2Lithium (Li)	/	Invinity (VRFB)	Recyclico Battery X Materials
Advanced Projects	/	/	/	Malahat (LFP) Molicel (NMC cells/packs)	/
Future Cluster Value	/	/	PCAM/ CAM if waste managed	Support & secure off-takers	Integrate recycling to pCAM/CAM

Cluster Assessment	Skilled Workforce	Abundant Green Energy	Transport Infrastructure	Active Ecosystem	Innovation & Research
Now	Good Training, Affordability?	Hydro. Competition, Timelines	Harbours, rail, roads	Depends on CAM/Cells from Asia	UBC, SFU, NanoOne, Teck
Gaps	/	More Power, Prioritization	/	Develop midstream supply. Secure off-takers	Li DLE AOSTRA, Scale up

Figure 4.1.1 Summary of the Vancouver – Lower Mainland Cluster Assessment

Southern BC: A Strategic Base for Battery Manufacturing and Clean Tech Innovation in Processing and Recycling

The southern BC cluster encompasses the Vancouver area, the Lower Mainland and Victoria. This cluster is a growing clean-tech hub, not for its mineral wealth, but for its strength in midstream, downstream and recycling innovation. The region boasts a strong talent pipeline, thanks to its top academic and research institutions, and is well-connected globally through its extensive ports, rail, and highway infrastructure. While hydroelectric power is available, the growing industrial demand and long approval timelines present obstacles. Several battery manufacturing projects are in development; however, at least one was paused due to market uncertainty and a lack of off-takers. Most rely on imported materials—such as cells and cathodes—from Asia, highlighting the need to strengthen local supply chains.

Key points for future cluster value:

- Support battery cell manufacturing in the Lower Mainland by addressing short-term market challenges and securing reliable off-takers to unlock long-term potential.
- Expand electricity supply for clean manufacturing, critical minerals, and battery projects. Ensure paused but approved BC Hydro projects retain grid access and coordinate utility engagement across stakeholders.
- Support the domestic supply chain and encourage innovators who fill gaps in the value chain. Champion Indigenous-led cleantech projects as a pillar of economic reconciliation and supply chain resilience.
- Invest in scaling Canadian cleantech firms, develop homegrown intellectual property, and integrate circularity requirements.
- Establish a Direct Lithium Extraction research and demonstration centre, modelled after AOSTRA, to lead in lithium brine processing and foster national collaboration across institutions and provinces.

4.2 Value Chain Analysis

4.2.1 Extraction

No extraction of critical minerals is currently active in this cluster. Vancouver Island has previously hosted the Island Copper Mine, which is now inactive; the Myra Falls copper, lead, and zinc mine, which is currently on indefinite pause; and the North Island copper and gold mining project, which has recently released a preliminary economic analysis.[36]

4.2.2 Processing

4.2.2.1 Operational Technology-Providing Processing Companies

There are many companies in the critical mineral processing space within this cluster, often serving as technology providers with expertise and intellectual property (IP) in innovative chemical processes or equipment design and manufacturing rather than large-scale processing plants.

Table 4.2.1 List of Operational Technology-Providing Processing Companies in the Vancouver Lower Mainland cluster (non-exhaustive)

Company	Technology	Product
Go2Lithium	Direct Lithium Extraction	LiCl
Mangrove Lithium	Lithium refining systems	$LiCl/Li_2SO_4$ to $Li_2CO_3/LiOH$
Noram Electrolysis Systems	Electrolyzer systems	$LiCl/Li_2SO_4$ to LiOH
Saltworks Technologies	Crystallization, Filtration systems, Reactors	LiCl to $Li_2CO_3/LiOH$
NanoTerraTech	Biomass to graphite conversion	biographite

4.2.2.2 Advanced Projects

Mangrove Lithium announced in late January 2025 the planning and construction of an electrochemical lithium refining facility in Delta, BC. [37]

Table 4.2.2 List of Advanced Projects for Processing Sites in the Vancouver Lower Mainland Cluster (Non-exhaustive)

Project	Operator	Commodity
Delta Lithium Conversion Plant	Mangrove Lithium	lithium

4.2.3 Advanced Materials

There is currently no industrial-scale advanced material manufacturing site in the Vancouver/Lower Mainland cluster. However, NanoOne, a Canadian company specializing in cathode active material, does have an R&D centre called the 'Innovation Hub' in Burnaby.

4.2.4 Batteries

4.2.4.1 Operational Sites

There is currently a 200 MWh vanadium flow battery plant operated by Invinity in Vancouver. They have notably provided batteries for the Chappice Lake solar PV and storage plant, developed by Elemental Energy in Alberta.[38] VRB Energy, another vanadium flow battery manufacturer, previously had its headquarters and offices in Vancouver but has since relocated its headquarters to Tempe, Arizona. Their current production capacity is based in China, with plans to open two additional factories in China and one in Arizona.[39]

Table 4.2.3 List of Operational Battery Manufacturing Sites in the Vancouver Lower Mainland Cluster (Non-exhaustive)

Site	Operator	Product
200 MWh Manufacturing Facility	Invinity	vanadium Redox Flow Battery
Office	VRB Energy	vanadium Redox Flow Battery

4.2.4.2 Advanced Projects

Molicel/E-One Moli Energy, a Taiwanese Li-ion battery manufacturer, has an R&D centre and sales office in Maple Ridge, BC, while batteries are produced in Taiwan. A $1.05 billion lithium-ion battery cell factory was planned to expand operations in Maple Ridge, but the project was suspended in late 2024.[40] The Malahat Nation has partnered with the BESS company Energy Plug to plan a battery assembly factory producing LFP-based energy storage systems on Vancouver Island.[41]

Table 4.2.4 List of Advanced Projects for Battery Manufacturing Sites in the Vancouver Lower Mainland Cluster (Non-exhaustive)

Site	Operator	Product
Maple Ridge Li-ion battery factory (suspended)	Molicel	Li-ion (NMC) batteries
1 GWh Malahat Nation Battery Assembly Factory	Malahat Nation + Energy Plug	LFP-based BESS

4.2.4.3 Future Cluster Value

- **Battery Manufacturing Support:** Despite paused projects, battery cell manufacturing is possible and should be supported in the Lower Mainland. The primary challenge is to develop the market and to find off-takers. The market's future indeed looks promising, but it requires support to navigate the current cycle and address short-term challenges.

4.2.5 Circularity

Several companies have already invested in the battery circularity space in this cluster, mostly as technology providers. Recyclico notably produces lithium carbonate or hydroxide and pCAM for NMC battery cathode from black mass; they also designed modular plants for shipping to allow on-site battery recycling. Battery X also focuses on black mass recycling to lithium, manganese, cobalt, nickel chemicals, and, notably, graphite. They are also developing urban mining opportunities and have designed a battery diagnostic system. pH7 Technologies extracts critical minerals from e-waste and spent catalyst thanks to solvometallurgical and electrochemical processes.

Table 4.2.5 List of Operational Technology-Providing Circularity Companies in the Vancouver Lower Mainland Cluster (Non-exhaustive)

Company	Technology	Product
Recyclico	Black Mass Recycling/Modular Plant Design	lithium carbonate or hydroxide, pCAM
Battery X	Black Mass Recycling /Urban Mining/Battery Diagnostics	graphite, lithium, manganese, cobalt, nickel
pH7 Technologies	Spent catalyst and E-waste recycling	platinum, palladium, rhodium, iridium, gold, silver, copper, tin, nickel

4.3 Cluster Success Analysis

4.3.1 Skilled workforce

4.3.1.1 Assets

- **Skilled Workers:** Southern BC/Lower Mainland already has a skilled workforce suitable for manufacturing, and there is less competition for manufacturing jobs in this cluster.
- **Academia and Training Centres:** The abundance of universities, colleges, and technical institutes offers an advantage for this cluster in terms of training and innovation.
- **Attractiveness:** The cluster is recognized as an attractive region due to its strong innovation-driven economy, access to high-quality education and research, and a high quality of life.

4.3.1.2 Challenges

- **Affordability:** Innovators in the Lower Mainland are facing challenges such as rising rents and the difficulty of attracting employees who live nearby due to long commutes. Affordability remains a significant barrier: securing housing for staff has become increasingly difficult, leading companies to relocate their facilities farther from the region's core and academic hubs.

4.3.2 Abundant Green Energy

4.3.2.1 Assets

- **Clean Electricity:** BC's energy mix is predominantly clean, with hydroelectricity accounting for 89% of total electricity generation.[42] BC Hydro supplies 95% of British Columbia, but Fortis is another major utility.
- **Electrification Needs Survey:** Foresight Canada is leading a mining power demand project, with BC Hydro participating in identifying electrification requirements for mining and processing.

4.3.2.2 Challenges

- **Competition for Power:** High demand from LNG, oil, and gas facilities, as well as other industrial projects, explains the increased competition for limited power resources. Large-scale projects from those sectors can mobilize quickly and limit access from others.

- **Electricity is Not Available on a Large Scale:** BC remains a net electricity importer, which affects economic opportunities, as seen in the case of prospective data centre projects that have been lost. Power is not available at the gigawatt scale.
- **Timeline Length:** The timeline for accessing electricity in projects is quite lengthy; however, if the project's visibility and usefulness have garnered the government's attention, it can be beneficial.

4.3.2.3 Strategic Investment & Opportunities:

- **More Power & Project Prioritization:** There is a growing need for large-scale electricity supply, and priority should be given to clean manufacturing and the critical minerals and battery value chain. Stakeholders must align and engage utility champions to ensure these power needs are met for projects. Projects already approved by BC Hydro should retain their grid access, even if temporarily paused.

4.3.3 Transport Infrastructure

4.3.3.1 Assets

- **Ports Access:** The Lower Mainland/Southern BC is home to several ports, including the main large harbour of Vancouver, as well as Port Alberni, the Port of Nanaimo, the Port of Victoria, and the Roberts Bank Port. Both containers and bulk capacity exist.
- **Railway and Road Access:** This cluster features a robust road and rail infrastructure, providing direct access to ports, a border crossing with the United States, and inland connections.
- **Reliable International Connections:** proximity to U.S. markets, as well as good access to Pan-Pacific trading partners and Europe.

4.3.4 Active Ecosystem

4.3.4.1 Challenges

- **Dependence on Asian Mid- and Downstream Capacity:** The advanced materials feedstocks for several battery manufacturing and recycling projects and operations, such as cathodes and anodes, or scrap materials like black mass, are all sourced from Asia.
- **Need for More Competitive Manufacturing:** There is a need for increased capacity in materials manufacturing and recycling, as well as cost-effective economic and regulatory frameworks to make these industries more viable.

- **Competition with China is Challenging** particularly in the areas of pCAM, CAM, and battery manufacturing. Competition is tough in terms of cost, labour, technology, capital, and rapid deployment. There is also the question of waste management, as it would be difficult to develop NMC/LFP pCAM and cathode manufacturing through traditional processes (the ones used in China) in this jurisdiction and cluster.
- **Off-Taker Uncertainty:** One important factor contributing to the cause of the Molicel battery factory project was off-taker uncertainty, as well as the slowdown in the general electrification market.

4.3.4.2 Strategic Investments & Opportunities:

- **Ex-China Opportunities:** Shifting regulations, like the EU Battery Passport, and increasing demand for transparency and supply chain traceability are creating new global standards.[43] Combined with the growing frustration among some foreign governments and companies with Chinese suppliers, this might open a strategic window for Canada to position itself as a reliable and trusted alternative.
- **Indigenous Reconciliation Through Cleantech:** Indigenous-led projects, such as the Malahat Battery Gigafactory, should be supported as they drive economic reconciliation by advancing Canadian supply chains in clean technologies.
- **Support North American and Domestic Value Chains:** Canadian projects that secure raw or refined material off-take from domestic sources should be prioritized, along with innovators filling in key gaps in the domestic value chain. While Canada alone may not be able to sustain large-scale battery off-take, tapping into broader North American and strategically diversified global markets is essential for long-term viability and resilience, depending on tariff and geopolitical circumstances.
- **Embed Circularity and Refurbishment for Batteries by Design:** Government incentives for battery manufacturing should require details on circularity, material recycling, or second-use by design for project application.

4.3.5 Innovation & Research

4.3.5.1 Assets

- **Innovative Companies in the Midstream and Recycling:** As listed in the Value Chain Analysis section **(Section 4.2)**, numerous innovative companies are present in the processing, advanced materials, and circularity sectors, particularly serving as technology providers. This is a testament to the presence of numerous academic institutes, a skilled workforce, and the overall attractiveness and innovation capacity of this cluster.

- **Industrial R&D Centres**: Cathode active material company NanoOne has an innovation hub in Burnaby, while Teck operates the CESL Technology Centre in Richmond, which conducts research on the hydrometallurgy and processing of copper, nickel, and gold. Kemetco in Richmond is a private contract science and operations company providing research in extractive metallurgy, processing, and battery development. Finally, BC Research is a cleantech and processing technology incubator that focuses notably on electrochemistry, mineral processing, and water treatment. The NORAM electrolysis systems (NESI) demonstration facility is hosted at BC Research's pilot bay facility.
- **Global Green Credits Hub:** Simon Fraser University is already a global hub for green credits. Those are essential to developing ESG-differentiated technologies and green premiums. This positions Canadian value chains to stand out globally by embedding sustainability as a source of added value and competitive advantage.

4.3.5.2 Strategic Investments & Opportunities

- **Develop a Lithium Processing Research Centre Similar to AOSTRA:** Direct Lithium Extraction (DLE) offers a major opportunity to create a dedicated research and demonstration fund—modelled after Alberta's AOSTRA—to accelerate innovation. Establishing a DLE research centre would advance lithium brine processing technologies and position Canada as a leader in next-generation battery materials. This could be achieved by coordinating research resources among UBC, SFU, BC Research, Kemetco, and other partners. Links to institutions and companies in Alberta and Saskatchewan would be necessary.
- **Specifically Support Scale-up and Innovation Ecosystem:** Targeted support for scaling Canadian battery and cleantech companies is crucial to help them bridge the development, pilot, and commercialization stages—avoiding the so-called 'valley of death.' The goal is to develop homegrown IP and build globally competitive champions, following the path of companies like Ballard or, previously, Molicel.

5 Kootenays

5.1 Summary

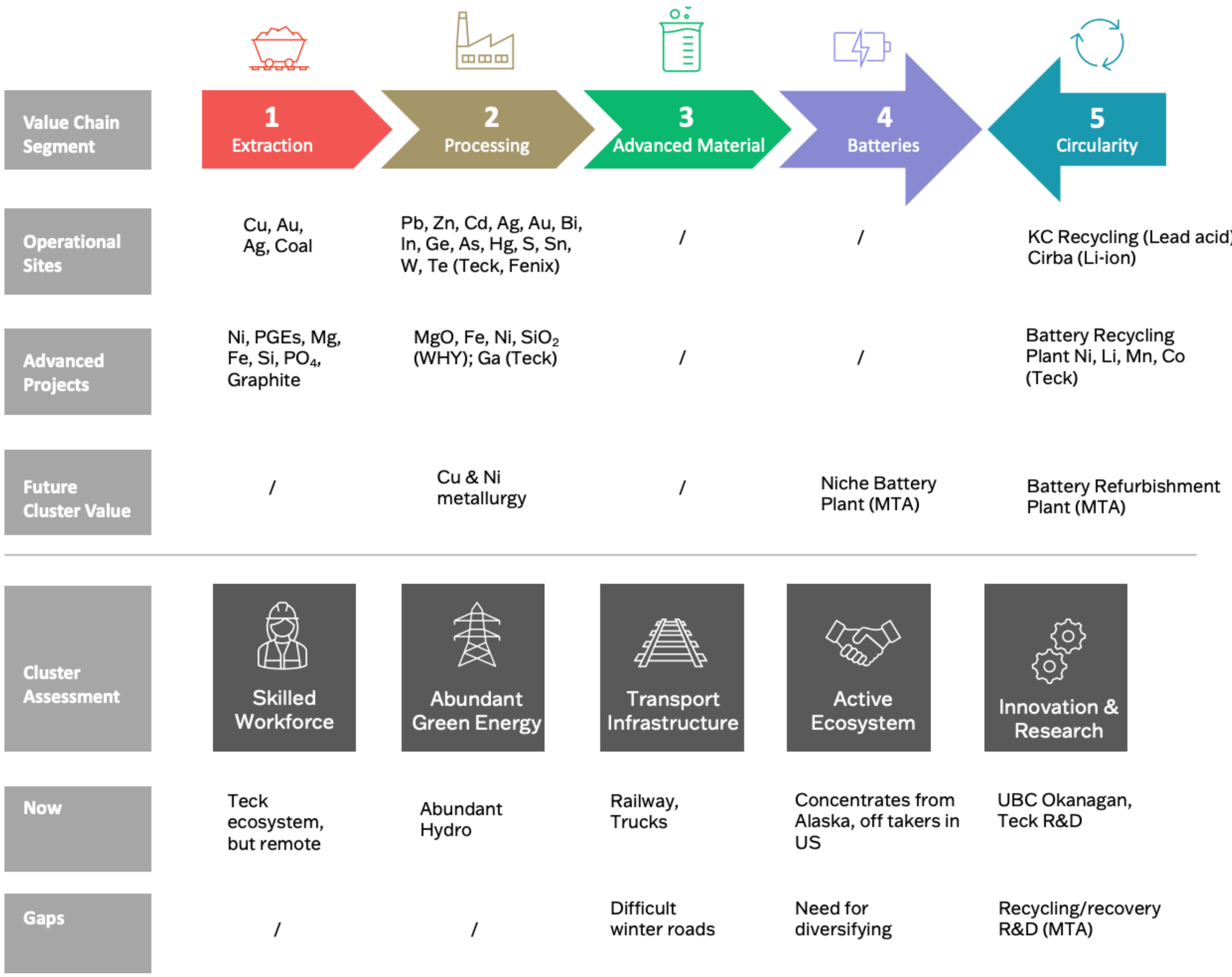


Figure 5.1.1 Summary of the Kootenays Cluster Assessment

Kootenays: A Legacy Metallurgical Cluster Evolving into a Battery Recycling Powerhouse

The Kootenays region—encompassing Trail, Nelson, Elk Valley, and Kelowna—has a rich history of metallurgy, anchored by Teck's long-standing zinc and lead smelter and complemented by emerging players such as Fenix Advanced Materials. It's also gaining traction in battery recycling, with KC Recycling and Cirba Solutions already operational, and Teck exploring the development of an EV battery recycling facility. Rich in critical minerals such as copper, phosphate, graphite, and magnesium, the region benefits from reliable hydroelectric power and solid transport infrastructure. While the cluster's industrial base is well-established, stakeholders see a need to diversify off-takers and production. Battery recycling is viewed as the key future growth opportunity to unlock the region's next phase of value creation. Metal Tech Alley's 2024 battery hub feasibility study recommended focusing on battery refurbishment, second-life niche battery manufacturing, and material recovery research.

Key points for future cluster value:

Develop Battery Recycling and Refurbishment Facilities: Support the development of a potential hydrometallurgical battery recycling plant by leveraging existing infrastructure and sulfuric acid supply. Pursue additional facilities for battery or electrode refurbishment to boost circularity.

Diversify Markets and Infrastructure: Broaden the region's industrial base by strengthening new producers and attracting new off-takers. Upgrading road and rail capacity to support future growth and access new markets might be necessary.

In this regard, advance the extraction of critical minerals from various value chains to support diversification, including phosphate, graphite, and magnesium.

Support Niche Battery Manufacturing: Establish a facility focused on non-Li-ion chemistries and components, particularly for handling heavy metals and plastics.

Boost R&D for advanced materials research and recycling processes to enhance circularity and critical mineral recovery, as recommended by Metal Tech Alley.

Alternatively to the locations proposed in the Northern BC cluster, the Kootenays region could host a copper metallurgical plant, as it historically did, or a nickel one to produce metal and nickel sulfate.

5.2 Value Chain Analysis

5.2.1 Extraction

5.2.1.1 Operational Sites

This cluster is rich in various mineral resources, and copper, gold, silver, and molybdenum are currently being extracted. The Highland Valley Copper and the Copper Mountain Mine are among the largest copper mining operations in Canada. Teck recently sold its four Elk Valley Resources steelmaking coal mines (Line Creek, Greenhills, Fording River, and Elkview) to Glencore.

Table 5.2.1 List of Operational Extraction Sites in the Kootenays

Site	Operator	Commodity
Copper Mountain	Hudbay & Mitsubishi	copper, gold, silver
Highland Valley Copper	Teck	copper, molybdenum
New Afton Mine	New Gold	gold, copper
Mount Brussilof	Baymag	magnesium

5.2.1.2 Advanced Projects

There are several extraction projects in this cluster, focusing on magnesium, graphite, and phosphate. West High Yield is currently planning magnesium mines in the Record Ridge area, next to Trail. The company Eagle Graphite was previously developing the Black Crystal mining project for natural graphite production, but the project was stalled. Finally, Canadian phosphate, previously registered as Fertoz, is seeking to develop several sedimentary phosphate deposits in the Fernie area.

Table 5.2.2 List of Advanced Projects for Extraction Sites in the Kootenays (Non-exhaustive)

Site	Operator	Commodity
Record Ridge & Midnight	West High Yield	magnesium
Black Crystal (stalled)	Eagle Graphite	natural graphite
Wapiti & Fernie	Canadian Phosphate (Fertoz)	sedimentary phosphate

5.2.2 Processing

5.2.2.1 Operational Sites

Metal smelting operations have been active in this region since the late 19th century, and the integrated lead-zinc smelter operated by Teck is now the primary metallurgical facility of the cluster. In addition to lead and zinc, the plant produces cadmium, silver, gold, bismuth, antimony, indium, arsenic, mercury, and sulfur products. It is also the only Canadian producer of germanium dioxide, making Canada the second-largest source of U.S. imports of germanium dioxide, after Belgium.[44] Fenix Advanced Materials is a smaller company also based in Trail, which specializes in refining byproducts from the smelter and producing high-purity rare metals.

Table 5.2.3 List of Operational Processing Sites in the Kootenays

Site	Operator	Commodity
Trail Smelter	Teck	zinc, lead and many byproducts
Fenix Facility	Fenix Advanced Materials	cadmium, indium, antimony, tin, tellurium

5.2.2.2 Advanced Project

West High Yield is projected to develop a magnesia plant in combination with its Record Ridge magnesium mine projects. The facility will produce high-purity MgO and $Mg(OH)_2$ products, as well as nickel and silica.

5.2.2.3 Future Cluster Value

- **Nickel and Copper Metallurgy:** While low treatment charges make copper smelter development challenging, the volume of copper concentrate produced in BC has sparked interest. Nickel processing may present a more viable path—producing nickel metal or sulfate through Teck or other players could create significant value for the cluster. The Kootenays region could be another alternative to the Northern BC locations mentioned in **Section 3.2.2.2.** Please refer to this section or the strategy report for more details.[1]

5.2.3 Advanced Material

There is no plan to develop advanced material plants from primary materials in the cluster. The development of a prospective EV Battery Recycling Facility would produce metal salts such as nickel sulfate or cobalt sulfate, which could be reused for pCAM and CAM manufacturing.

5.2.4 Batteries

5.2.4.1 Future Cluster Value

General Li-ion battery manufacturing has not been identified as a priority for this cluster in terms of development. The Lower Mainland would offer better opportunities. However, Metal Tech Alley gave recommendations to establish a plant in its 2024 feasibility study:

- **Niche Battery Manufacturing Facility** for chemistries different than Li-ion. It would focus on handling heavy metals and plastics, and on producing either parts or full batteries.

5.2.5 Circularity

5.2.5.1 Operational Sites

Cirba Solution currently recycles alkaline, primary lithium and Li-ion batteries, and it also produces black mass. KC Recycling also operates in this cluster, recycling lead-acid batteries to produce lead and plastic pellets.

Table 5.2.4 List of Operational Circularity Companies in the Kootenays Cluster (Non-exhaustive)

Company	Technology	Product
Cirba Solution	Li-ion battery recycling	black mass
KC Recycling	Lead-acid battery recycling	lead, plastic pellets

5.2.5.2 Advanced Projects

- **EV Battery Recycling Facility:** Teck is interested in developing a hydrometallurgical plant for battery recycling near their smelter. Sulfuric acid produced by the smelter could be the main input for leaching black mass from NMC batteries. Nickel, manganese, cobalt and lithium could be extracted and processed into salts. A different player further down the value chain could make pCAM and CAM from those products for new batteries.

5.2.5.3 Future Cluster Value

- **Metal Tech Alley's Recommendations:** Metal Tech Alley's 2024 Battery Hub Feasibility Study recommended the development of three facilities, amongst which:
  - **Battery Refurbishment Facility**: Battery or electrode refurbishment and remanufacture.

5.3 Cluster Success Analysis

5.3.1 Skilled Workforce

5.3.1.1 Assets

- **Teck's Ecosystem:** Teck, thanks to its Trail smelter operations, has built an ecosystem that attracts and supports a skilled workforce. Other companies feed off Teck's influence in the cluster.
- **Colleges and Universities:** Selkirk College and the University of British Columbia Okanagan are examples of institutions that provide relevant training in this area, suitable for a wide variety of roles, including operators, technicians, engineers, and research-level positions.

5.3.1.2 Challenges

- **Competition with Teck for Talent:** It can be challenging for smaller startups and companies to compete with Teck for top talent and retain their best employees.
- Lack of proximity to large population and manufacturing centres

5.3.2 Abundant Green Energy

5.3.2.1 Assets

- **Clean Electricity:** BC's energy mix is predominantly clean, with hydroelectricity accounting for 89% of total electricity generation.[42]
- **Several Grid Systems and an Abundance of Electricity:** the Trail area receives power from three different grid systems.
- **Numerous Hydroelectric Power Stations:** Both private and crown corporations operate many dams and power stations in the region, including the Waneta Dam, Waneta Dam expansion (Fortis BC), Seven Mile Dam, Brilliant, Arrow Lakes, and Kootenay Canal. Teck used to own and operate the Waneta Dam to power its smelter, but sold it to BC Hydro through several acquisitions, which were finalized in 2018.

5.3.3 Transport Infrastructure

5.3.3.1 Assets

- **Railway, Highways, and Truck Routes:** The infrastructure for moving concentrates, products, and materials is already in place. Several railways and operators are present in the cluster, with a more direct route to travel east. The Canadian Pacific Kansas City still links the cluster to the Lower Mainland and Vancouver while also connecting it to Alberta. Kettle Falls International Railway and the St. Paul and Pacific Northwest Railroad connect the cluster directly to the U.S. going southward.
- **Optimized Logistics:** Raw zinc ores destined for Trail originate from the Alaskan Red Dog mine, operated by Teck. The ore is shipped from the Red Dog mine to tidewater, barged down the B.C. coast, transported by rail to Waneta and trucked to the Trail smelter. Steelmaking coal is extracted from the Elk River Resources sites, then transported by rail to the Roberts Bank Superport or the Port of Vancouver before being shipped to overseas markets such as Japan and South Korea.[45] Those mines were previously operated by Teck but it has now been sold to Glencore as of 2024.

5.3.3.2 Challenges

- **Winter Conditions:** During winter, road conditions are difficult, which can result in 3 to 4 days of transport loss.
- **Access to Space:** Generally, the mountainous terrain can be challenging for infrastructure development or expansion.

5.3.3.3 Strategic Investments and Opportunities

- **Upgrading Capacity:** Upgrading or expanding railway or road capacity may be necessary depending on new projects.

5.3.4 Active Ecosystem

5.3.4.1 Assets

- **Fenix Advanced Material**: Fenix is a small off-taker for the Trail smelter, refining and processing 5 or 6 of the Trail smelter's byproducts to make high-purity niche metals.

5.3.4.2 Challenges

- **Dependence on the U.S. Market:** Lead and Zinc from Trail are primarily exported to the U.S., which can make the smelter relatively vulnerable to tariffs.
- **Need to Diversify the Region:** Economic development agencies emphasize the need for diversification of value chains, as well as finding different off-takers and promoting various producing companies.
- **Teck's Diversification:** Teck is also interested in diversifying its off-takers and products. As the smelter makes a wide variety of byproducts that are not always utilized, adding value to them can be an opportunity to explore different markets.

5.3.5 Innovation & Research

5.3.5.1 Assets

- **UBC Okanagan Battery Research:** The Battery Innovation Research Excellence Cluster is an interdisciplinary research team dedicated to developing robust and sustainable battery technology, aiming to accelerate Canada's net-zero transition.
- **Teck R&D:** Teck operates a research centre in Trail, known as the ART (Applied Research & Technology) centre, which focuses on ore characterization, processing, evaluation, and implementation of technologies, as well as the development of solutions to mitigate environmental impacts.

5.3.5.2 Strategic Investments & Opportunities

- Metal Tech Alley's Recommendations:
    - **R&D Facility**: MTA recommended the development of an R&D centre focused on bulk and surface materials science, specifically on developing recycling processes and recovering critical minerals. This could optimize material circularity in the cluster.

6 Western Alberta

6.1 Summary

Value Chain Segment	1 Extraction	2 Processing	3 Advanced Material	4 Batteries	5 Circularity
Operational Sites	Oil, Gas, Coal	/	/	/	/
Advanced Projects	Li Brine	Li DLE	/	/	/
Future Cluster Value	Fe, V, PO_4 (Clear Hills)	Li Processing (Centralized) Fe, PO_4	Synth. Graphite, LFP pCAM/CAM	/	/
Cluster Assessment	Skilled Workforce	Abundant Green Energy	Transport Infrastructure	Active Ecosystem	Innovation & Research
Now	O&G workforce, but remote, competition	C-Intensive. Scaling NG possible, deregulated	Railway, Roads	Too early, show production first	Proximity to Calgary-Edmonton Cluster
Gaps	Training, Attractivity	Renewable, CCUS, Geothermal, BC grid integration, SMRs	Upgrading	Secure off takers, connection with domestic clusters	Li DLE AOSTRA

Figure 6.1.1 Summary of the Western Alberta Cluster Assessment

Western Alberta Cluster: An Emerging Upstream Centre for Lithium and LFP Battery Minerals

The Western Alberta Cluster, encompassing the Peace River and Grande Prairie areas, is rich in oil and gas resources and infrastructure and home to significant lithium brine resources in oil-bearing aquifers. The area is innovative and entrepreneurial, boasting a skilled workforce closely tied to the energy and traditional oil and gas industries. However, growing demand will require expanded training in chemical processing and non-fuel mineral extraction. Several companies project to extract this lithium using DLE, while other regional resources include iron, phosphate, vanadium and coal. The transport infrastructure is well-developed, featuring extensive roads and rail systems; however, access to green energy remains limited, presenting a significant challenge. The Alberta grid is deregulated and offers scalability, but its energy mix still relies heavily on fossil fuels. For now, this cluster primarily comprises projects along the upstream segment of the critical mineral value chain; however, no operational or commercial activity has been undertaken yet. This cluster is likely to have many connections with the nearby Calgary-Edmonton Cluster for mid- and downstream integration.

Key points for future cluster value:

- Unlock Alberta's Critical Mineral Potential and Support Lithium Extraction: The region requires supportive policies, lower mineral tenure fees, and finalized incentives, such as the ITC, to attract investment. Lithium extraction will likely be the focus of the cluster.
- Clean Power: Alberta must scale low-carbon power sources, such as CCUS-enabled natural gas, geothermal, and SMRs, and expand grid integration with BC to secure clean electricity.
- Scale Midstream Infrastructure: Projects like the Greenview Industrial Gateway offer key advantages, including access to gas, water, roads, and significant power potential. This could host centralized facilities for processing lithium, iron, vanadium, and phosphate.
- Build the LFP Cathode Supply Chain: With local lithium, potential iron/phosphate sources, and emerging graphite technologies (derived from coal or natural gas), Western Alberta could support the production of precursor and cathode active materials.
- Connect & Coordinate: Strengthen inter-cluster offtake, especially with the Calgary-Edmonton Corridor. Develop lithium research network, and enhance training through academic-industry partnerships.

6.2 Value Chain Analysis

6.2.1 Extraction

6.2.1.1 Advanced Projects

Aside from several active coal mining operations (Coal Valley, Vista, Grande Cache), most extraction sites are still in the planning stages. There is a large number of projected lithium DLE sites, with Neolithica, LithiumBank, Volt Lithium and Empire Metals as key players. It can be considered that those lithium projects are still more than five years away from first production. The Clear Hills site is an iron deposit rich in vanadium, with other mineral occurrences including lithium, cobalt, gold, and phosphate. Finally, First Helium is seeking to develop a helium production site in the Leduc Formation, called the Worsley project.

Table 6.2.1 List of Advanced Projects for Extraction Sites in Western Alberta (Non-exhaustive)

Project	Operator	Commodity
Peace River	Neolithica	lithium
Boardwalk	LithiumBank	lithium
Park Place	LithiumBank	lithium
Clear Hills	LithAlta/Lincoln Ventures/Prism Diversified	lithium, iron, vanadium, cobalt, gold, phosphate
Rainbow Lake	Volt Lithium	lithium
Fox Creek	Empire Metals	lithium
Worsley	First Helium	helium

6.2.1.2 Future Cluster Value

- **Support Non-fuel minerals Extraction:** The region is currently under-equipped to extract and process non-fuel minerals.
  - **Policy:** A more supportive policy environment and incentives are necessary for the development of critical minerals projects in the province.
  - **Rental Fee Barrier:** High mineral tenure fees in Alberta create barriers for small companies and affect other development opportunities.
  - **ITC:** The Investment Tax Credit (ITC) needs to be defined and finalized.

- **Lithium Prices:** Current low lithium prices create headwinds for project development. Strong future demand is anticipated, but current low prices pose a challenge. Developing a pricing mechanism could help project development.[46]

- **Indigenous Economic Reconciliation:** Indigenous partnerships and benefits are key considerations for the successful development of industrial projects, encompassing training, procurement, collaborative undertakings, royalty, and equity participation. This concerns not only the extraction segment but the entire value chain.

6.2.2 Processing

6.2.2.1 Advanced Projects

As with most DLE projects, the ones presented above involve converting lithium brine into lithium compounds, such as lithium carbonate or hydroxide.

6.2.2.2 Future Cluster Value

- **Industrial Project:** The Greenview Industrial Gateway (GIG) is an industrial development project that features natural gas processing, manufacturing, and data centre operations, located approximately 40 kilometers south of Grande Prairie.
  - Access to gas, water, rail, and roads, as well as the potential for 6-10 GW of power.
  - This can be an excellent opportunity and location for developing the midstream industry within the cluster.
- **Centralized *vs.* Decentralized Lithium Processing:** Investigate whether a Centralized Processing Facility (CPF) to upgrade technical-grade to battery-grade lithium from DLE lithium, servicing multiple producers across Alberta, could be viable.
  - Need coordination between producers on shared infrastructure and processing.
  - Waste management
  - Can we attract investors for a central facility? Public-Private Partnership?
  - If not possible in the West AB cluster, would this work in Industrial Heartland?
- **Investigate Possible Metallurgy for Iron, Vanadium, and Phosphate Processing:** In addition to lithium, which should be the development priority for this cluster, there are opportunities to extract iron, vanadium, and phosphate in the region, especially with the Clear Hills siderite/goethite deposit. Can processing projects be in this cluster?

- **EAF for Iron and Vanadium:** Investigate whether an electric arc furnace (EAF) can be used to process the Clear Hills iron-vanadium concentrates.
  - **Vanadium Pentoxide Production:** Vanadium slag could be processed all the way to vanadium pentoxide through an alkali salt route. It could then be sent to the Calgary-Edmonton Corridor for electrolyte synthesis and perhaps the manufacture of vanadium redox flow batteries.
  - **Iron Powder:** Locally produced iron powder could be integrated into an LFP pCAM supply chain. Alternatively, leaching iron sources and steel scrap could produce iron sulfate, thereby supplementing the same supply chain.
- **Phosphoric Acid Production:** Assuming phosphate mining is viable, and a local supply of sulfuric acid is available, phosphoric acid can be produced through the wet process in this cluster. Upgrading to purified phosphoric acid (PPA) would be necessary to feed an LFP pCAM supply chain.

6.2.3 Advanced Material

6.2.3.1 Future Cluster Value

- **Cathode Material Production for LFP Batteries:** Given the presence of lithium DLE projects, and the opportunity to source and perhaps process iron and phosphate locally, the production of precursors and cathode active material for lithium iron phosphate batteries (LFP) should be considered.
  - Need access to reagents: acid, base
  - Need waste management, especially for sodium sulfate. Or opt for a different process.
  - Depending on feasibility, this could make more sense to centralize pCAM and CAM production, even for LFP, in the Calgary-Edmonton corridor cluster.
- **Graphite from Coal:** Depending on the maturity and viability of available technology, upgrading coal from local sources to battery-grade graphite is an option.
- **Graphite from Natural Gas:** methane pyrolysis could also provide synthetic graphite and hydrogen from natural gas.

6.2.4 Battery

Battery manufacturing is not the priority for this cluster.

6.2.5 Circularity

The uptake of scrap steel and iron should be implemented for iron processing. Phosphogypsum can be utilized in construction or other applications to add value to the phosphoric acid byproduct. Viable salt-splitting to convert sodium sulfate should be investigated for pCAM production. Repurposing coal waste for graphite should be considered.

6.3 Cluster Success Analysis

6.3.1 Skilled Workforce

6.3.1.1 Assets

- **Oil & Gas Workforce:** the current workforce has expertise in oil and gas extraction and distribution; this asset should be leveraged.
- **Entrepreneurial Region:** The area is innovative & entrepreneurial.

6.3.1.2 Challenges

- **Non-fuel Mineral Extraction and Processing Are Lacking:** There is a need for increased mineral processing expertise. The same applies to chemical processing and refining expertise. A skills gap exists and is likely to worsen in the future.
- **Labour Competition:** Competition for labour with other major projects (LNG, *etc.*)
- **Remote Operations:** Remote operations face additional workforce challenges.

6.3.1.3 Strategic Investments & Opportunities

- **Training:** Enhancing coordination between academic institutions, training centres, and institutes, such as the Northwestern Polytechnic Programs, through partnerships like Invest AB and the NW Invest Association.
- **Workforce Needs Assessment:** A deeper investigation into the workforce and training requirements necessary to develop the critical mineral extraction potential of this cluster should be conducted.

6.3.2 Abundant Green Energy

6.3.2.1 Assets

- **Natural Gas:** Abundance of natural gas projects and ability to scale up electricity.
- **Alberta's Deregulated Electricity Market.**
- **ATCO transmission lines.**
- **GIG:** The Greenview Industrial Gateway (GIG) has 144 kW lines available. This could host centralized processing facilities for the cluster.

6.3.2.2 Challenges

- **Decarbonized Power** is a key constraint:
  - Alberta's electricity grid remains carbon-intensive, posing challenges for clean-tech investment. Critical mineral investors prioritize access to clean energy.
  - Clean power capacity is limited in western Alberta and eastern British Columbia, constraining project siting.
  - Alberta has the potential to scale clean power through natural gas with carbon capture; however, high costs and uncertainty surrounding CCUS efficiency and incentives create risk.
  - Geothermal energy is possible, but most geothermal projects in the area are stalled.

6.3.2.3 Strategic Investments & Opportunities

- **DLE Projects Need Scale:** New DLE projects are expected to require around 100 MW each. Some proponents plan to generate their own power.
- **Supportive Policies for Low-Carbon Energy:** Clear, supportive policies should be implemented to create momentum for expanding low-carbon and carbon-neutral energy solutions. This included, but should not be limited to, CCUS.
- **Untapped Geothermal Potential:** Geothermal remains a promising but underdeveloped option in the cluster.
- **Grid Integration Opportunity:** Large-scale integration of the BC-Alberta grid could unlock access to clean hydroelectricity for Western Alberta.
- **The Nuclear Option:** Alberta's SMR collaboration with Saskatchewan, Manitoba, and Ontario could be transformative, especially if aligned with the timelines of major industrial developments.

6.3.3 Transport Infrastructure

6.3.3.1 Assets

- **Excellent infrastructure** is in place, including roads and railways.
- **GIG:** The Greenview Industrial Gateway has access to Highway 40 and the Canadian National Railway.

6.3.3.2 Strategic Investments & Opportunities

- **Upgrading:** Upgrading and expanding the transport capacity might be needed.

6.3.4 Active Ecosystem

6.3.4.1 Assets

- **Too Early to Tell:** As the cluster is not active yet in our sectors of focus, the activity on the critical mineral value chain remains a collection of projects so far. The various brine players are the pipeline to start production in 5 years or more.

6.3.4.2 Challenges

- **Difficulty in Competing with China:** It is difficult to compete with China on costs without policy support.
- **Prove Production First:** OEMs are interested in getting supplies from the region, but they need proven commercial production first.

6.3.4.3 Strategic Investments & Opportunities

- **Prioritize Friendly Supply Chains:** Depending on geopolitical constraints, targeting domestic, North American and allied nations as key off-takers for critical mineral products should be prioritized.
- **Enable Inter-Cluster Offtake:** Strengthen links between regional industrial clusters to support and share offtake as part of an integrated value chain, when possible.

6.3.5 Innovation & Research

6.3.5.1 Assets

- **Proximity to Innovative Clusters,** such as the Calgary-Edmonton Corridor, featuring academic and industrial research.

6.3.5.2 Strategic Investments & Opportunities

- **Develop a Lithium Processing Research Centre Similar to AOSTRA:** Coordinating research resources across Alberta, Saskatchewan, and British Columbia between academia and industry would accelerate innovation and enhance the viability of DLE. Refer to **section 4.3.5.2** and the strategy report for more details.

7 Calgary-Edmonton Corridor

7.1 Summary

Value Chain Segment	1 Extraction	2 Processing	3 Advanced Material	4 Batteries	5 Circularity
Operational Sites	Oil, Gas	Ni (Sherritt) Petrochemicals, Oil refineries	/	Arkon (V) Nanode (SIB)	/
Advanced Projects	Li Brine (E3, Neolithica, Conifer, Candle)	Li DLE, Cu, Bi, Au, Co (Fortune)	Aurora, Innova (Synth. graphite)	/	/
Future Cluster Value	V	Ni expansion, Cu wires	Synth. Graphite, NMC pCAM/CAM, V electrolyte	/	Integrate recycling to pCAM/CAM

Cluster Assessment	Skilled Workforce	Abundant Green Energy	Transport Infrastructure	Active Ecosystem	Innovation & Research
Now	Good O&G workforce, competition	C-Intensive. Scaling NG possible, deregulated	Great. Railway, Roads, Dry Port	Built for exports, Cuban Ni	UoC, UoA, SAIT, NAIT, O&G R&D, Alberta Innovates
Gaps	Training, Attractivity, Midstream & battery	Need scale. Renewable, CCUS, Geothermal, BC grid integration, SMRs	Connection to the North	Secure off takers, diversify, need reagents	Li DLE AOSTRA, Scale

Figure 7.1.1 Summary of the Calgary-Edmonton Corridor Cluster Assessment

Calgary–Edmonton Corridor: Powering Western Canada's Cathode and Anode Future

The Calgary-Edmonton corridor is already a key industrial hub for Canada, boasting an extensive oil and gas industry and in petrochemical production. With a strong social license for heavy industry, particularly in the Industrial Heartland, the region offers a skilled workforce and remains attractive for talent, though labour competition and processing expertise in non-fuel minerals may become constraints. As for the Western Alberta cluster, limited access to clean electricity remains a significant challenge, underscoring the need for clearer and more ambitious low-carbon energy policies and strategies in the province. The corridor benefits from excellent transport infrastructure, but the challenge remains in accessing the North. It is strategically positioned to capitalize on unique feedstocks: lithium-rich aquifers and oilfields, vanadium from petroleum fly ash, and synthetic graphite potential from natural gas, petcoke, or coal. The region also hosts existing refining capacity, with Sherritt processing nickel and cobalt, and Fortune Minerals planning a metallurgical facility near Edmonton. Innovation is another strength of the cluster, as it comprises various universities, polytechnic institutes, and colleges supporting R&D capabilities for startups in battery material development and lithium processing. Strengthening midstream metallurgy, processing, and advanced material manufacturing is a clear value-added benefit for this cluster.

Key points for future cluster value:

- Anchor Canada's Midstream Backbone: Expand refining capacity for nickel, cobalt, and vanadium, and produce battery-grade sulfates to feed pCAM/CAM facilities.
- Advance Cathode and Anode Material Production: Leverage local lithium, nickel, and cobalt to establish pCAM and CAM manufacturing, while exploring synthetic graphite from petcoke and methane pyrolysis for anode production, tapping into the region's oil, gas, and petrochemical strengths.
- Accelerate Clean Energy Solutions: Scale low-carbon power options such as natural gas with CCUS, geothermal, renewables, and SMRs, and enhance grid integration with BC to ensure clean electricity access for energy-intensive processing and manufacturing.
- Invest in Talent and Technology: Launch worker transition programs and align training with future skill needs, such as solution chemistry, battery materials, and chemical engineering. Support local startups and pursue research in next-gen battery technologies, including sodium-ion and silicon anodes.
- Coordinate, Collaborate, and Compete: Foster industry collaboration to secure off-takers, attract investment, assess chemical needs, and develop advanced material suppliers—positioning the region as a globally competitive leader in battery materials.

7.2 Value Chain Analysis

7.2.1 Extraction

7.2.1.1 Advanced Projects

The cluster is more focused on oil and gas extraction rather than critical mineral extraction. However, the oilfield aquifers are also rich in lithium brines, which explains why several projects are planning to develop direct lithium extraction in the region.

Table 7.2.1 List of Advanced Projects for Extraction Sites in the Calgary-Edmonton Corridor (Non-exhaustive)

Project	Operator	Commodity
Clearwater	E3 Lithium	lithium
Bashaw	E3 Lithium	lithium
Rocky	E3 Lithium	lithium

7.2.2 Processing

7.2.2.1 Operational Sites

The cluster focuses on oil and gas processing, with several refineries, including Shell, Redwater, Suncor, and Imperial. The largest base metal metallurgical facility in the cluster is Sherritt's Fort Saskatchewan nickel and cobalt refinery. Importing mixed sulfide precipitates from its Moa Bay laterite operations in Cuba, the Fort Saskatchewan plant proceeds through an ammonia-based hydrometallurgical route to produce nickel powder. Baymag is processing mined and crushed magnesium materials from its BC operation at the Mount Brussilof mine at its Exshaw plant to magnesium oxide. If we consider the area around Medicine Hat as part of this cluster, then the Pearl site, operated by the Weil Group, is already producing and refining helium. This is also the case for Royal Helium's Steveville purification facility. Finally, Thor Resources is also operating at Manyberries.

Table 7.2.2 List of Operational Processing Sites in the Calgary-Edmonton Corridor (Non-exhaustive)

Project	Operator	Commodity
Fort Saskatchewan Refinery	Sherritt	nickel, cobalt
Exshaw Processing Facility	Baymag	magnesium oxide
Manyberries facility	Thor Resources	helium
Pearl facility	Weil Group	helium
Steveville purification facility	Royal Helium	helium

In addition to large-scale industrial processing sites, the cluster hosts numerous innovative companies specializing in processing technology development. There is a significant number of direct lithium extraction technology providers, such as Summit Nanotech, Litus, Candle Lithium, and Volt Lithium, although some of these have plans to develop extraction on their properties in parallel. Innova Cleantech innovate the synthetic graphite value chain by allowing the conversion of natural gas to graphite and hydrogen.

Table 7.2.3 List of Operational Technology-Providing Processing Companies in the Calgary-Edmonton Corridor (Non-exhaustive)

Company	Technology	Product
Summit Nanotech	denaLi DLE technology	lithium carbonate
Litus Inc.	LiNC DLE technology/portable demonstration plant	lithium compounds
Candle Lithium	DLE technology	lithium carbonate, hydroxide
Volt Lithium	DLE technology	lithium carbonate, hydroxide
Innova Cleantech	methane pyrolysis	graphite, hydrogen

7.2.2.2 Advanced Projects

The cluster has several advanced industrial processing projects, such as the DLE demonstration plant and the lithium carbonate conversion plant by E3 lithium, the Calgary DLE pilot plant project by LithiumBank, and the NICO refining facility planned in Alberta's industrial heartland where concentrates from the Northwest Territories will be processed to copper cement, bismuth, cobalt and gold.

Table 7.2.4 List of Advanced Processing Projects in the Calgary-Edmonton Corridor (Non-exhaustive)

Project	Operator	Commodity
NICO refining facility	Fortune Metals	copper, bismuth, cobalt, gold
Demonstration Facility/Carbonate plant	E3 Lithium	lithium
Calgary Pilot Plant	LithiumBank	lithium

7.2.2.3 Future Cluster Value

- **Government Incentives:** Provinces such as Quebec are directly involved in critical minerals and battery value chain projects, but this type of incentive is lacking in Alberta.
- **Expand Nickel Refining Capacity and Diversify Supplies**. As proposed in the strategy report, the Sherritt refining plant should consider expanding and importing laterite-derived feeds from other sources than Cuba, such as mixed hydroxide precipitates from Southeast Asia.
- **Nickel and Cobalt Sulfate:** Although several already operational and planned facilities will refine nickel and cobalt, battery-grade chemicals must be produced in the area to feed into prospective pCAM/CAM facilities. As such, individual plants should be expanded to produce battery-grade nickel sulfate and cobalt sulfate. If not, a centralized leaching and recrystallization facility could be considered.
- **Vanadium Extraction and Processing:** Fly ash from crude oil can be leached to recover vanadium salts. This pathway, as well as the production of vanadium pentoxide, should be investigated and planned in the cluster. Several vanadium extraction research projects were already funded in the past, but their current status is unknown and their industrial implementation should be pursued.
- **Copper Rod and Wiring Manufacturing:** Depending on the purity of the locally produced copper cement and market demand, a copper rod casting plant, as well as a copper wiring plant, may be considered in the cluster.

7.2.3 Advanced Material

7.2.3.1 Operational Sites

The cluster specializes in petrochemicals, with the presence of Nova Chemicals, Dow Chemical, Shell Chemical, Arkon Solutions and the Heartland Petrochemical Complex. Concerning the critical minerals and battery value chain, Nanode is an innovative cleantech startup that manufactures thin film anode and anode materials for sodium-ion batteries. Although Rio Tinto Alcan's Strathcona facility produces material for aluminum smelters, it is included here as it might be amenable to a potential synthetic graphite value chain. Finally, Makesens is a Calgary-based startup developing next-generation silicon-based anode materials for lithium-ion batteries.

Table 7.2.5 List of Operational Advanced Material Manufacturing Sites in the Calgary-Edmonton Corridor (Non-exhaustive)

Company	Technology	Product
Rio Tinto Alcan	Petcoke calcining	Anode-grade coke for aluminum smelters
MakeSens	Silicon anodes	Silicon-based anodes for li-ion batteries
Nanode	Tin-based anode synthesis	Anode material for sodium-ion batteries

7.2.3.2 Future Cluster Value

- **Precursors and Cathode Active Materials Manufacturing:** Given the proximity of nickel and cobalt refining, and the future production of lithium compounds, there is a great opportunity for pCAM and CAM production for NMC batteries:
    - Need access to reagents: acid and base. Those are available in the cluster.
    - The Industrial Heartland is a good candidate for a prospective location.
    - Lithium will come from the Calgary-Edmonton Corridor cluster and the Western Alberta cluster
    - Nickel and cobalt could be supplied from Sherritt and cobalt from Fortune Metals.
    - However, the sodium-sulfate waste would have to be managed:
        - Storage
        - Treatment, which can be costly
        - Salt-splitting to useful sulfuric acid and sodium hydroxide, which could be very costly under current technology
        - Opt for a process that avoids sodium sulfate byproducts

    - Although NMC is the priority battery technology for cathode material production in this cluster, LFP cathode material production is also feasible.
- Anode Material Manufacturing:
    - **From Synthetic Graphite:** Upgrading petcoke to synthetic graphite is a viable pathway to explore, given the cluster's specialization in oil and gas, as well as petrochemicals.
        - A Novonix-type process, or at least a less emission-intensive and energy-intensive process than the current Chinese method, should absolutely be considered for producing synthetic graphite.
        - The Strathcona calcination facility, operated by Rio Tinto Alcan, may be amenable to petcoke upgrading, as it is currently producing anode-grade coke for aluminum smelters.
        - Petcoke can be available from neighboring Saskatchewan as well
    - **From Methane Pyrolysis:** Utilizing natural gas to synthesize hydrogen and carbon-based materials, or directly producing graphite (Innova Clean Tech, Aurora Hydrogen) might be another option. This option would be linked to the existing natural gas infrastructure and is expected to operate with low-to-zero carbon emissions.
- **Pursue Research and Scale-up of Next-Generation Battery Technologies:** The presence of two battery material-producing startups focusing on sodium-ion battery anodes or silicon anodes in the cluster is a regional advantage. This should be leveraged to pursue a bold strategy to advance the development of the next-generation battery supply chain.

7.2.4 Batteries

There is currently no large-scale battery manufacturing in this cluster. A future value for this region could be the production of vanadium electrolyte and vanadium redox flow batteries.

7.2.5 Circularity

All planned and proposed processing and advanced material manufacturing projects should facilitate the uptake of feedstock from recycling and scrap.

7.3 Cluster Success Analysis

7.3.1 Skilled Workforce

7.3.1.1 Assets

- **Skilled Local Workforce:** The region already hosts experts in:
  - Plant construction and Engineering Talent
  - Geo-science (Geologists, Geophysicists, Subsurface Engineers)
  - Equipment vendors (pipe, valve, instrumentation, electrical, *etc.*)
  - Extraction: construction, design.
- **Leverage Oil & Gas Talent:** Workers from the oil and gas sector could bring transferable skills well-suited to lithium brine extraction, synthetic graphite production, and vanadium recovery.
- **Strong Technical Training Ecosystem**: Institutions like NAIT, SAIT, and Red Deer Polytechnic provide a steady pipeline of industry-ready talent.
- **Labour Attraction Advantage:** The cluster's industrial base and quality of life help attract skilled workers from across Canada and internationally.

7.3.1.2 Challenges

- **Skill Gaps Between Sectors:** New mineral extraction and refining, such as lithium brine processing, require different expertise, focused on solution chemistry rather than traditional base metal metallurgy.
- **Shortage of Processing Talent**: Specifically, there is a general lack of chemical and process engineers trained for lithium and other emerging critical minerals.
- **Battery Expertise Is Limited:** The region lacks specialized skills related to battery materials and manufacturing.
- **Labour Market Pressure:** A shared labour pool across Western Canada creates competition for workers, with significant projects in LNG, CCUS, and petrochemicals driving up costs and straining availability.
- **Slow Training Response Time:** Workforce needs to evolve quickly, but post-secondary program changes require long lead times, making proactive planning essential.

7.3.1.3 Strategic Investments & Opportunities

- **Worker Transition Programs:** Targeted initiatives can help reskill workers for in-demand roles in critical minerals and battery sectors.
- **Stronger Training Coordination Needed:** Better alignment between academic institutions, training centres, and industry is essential to meet evolving workforce needs.
- **Focus on Future Skills:** Develop programs in solution chemistry, chemical engineering, and battery materials to build the midstream and battery talent pipeline. This is especially crucial if cathode active material production is pursued in the region.

7.3.2 Abundant Green Energy

7.3.2.1 Assets

- **Abundant Natural Gas and Scalable Power:** Alberta has a strong natural gas infrastructure and the capacity to expand industrial-scale electricity generation.
- **Deregulated Electricity Market:** Alberta's open market model allows for flexibility and innovation in power generation.

7.3.2.2 Challenges

- **Lack of Clean Electricity:** Midstream facilities and investors increasingly demand clean energy; Alberta's carbon-intensive grid puts the region at a disadvantage compared to provinces such as Quebec, Ontario, and British Columbia.
- **Physical Power Preferred:** While virtual PPAs are growing, physically integrated clean power is preferred for large industrial users.
- **Need for Large-Scale Supply:** Projects require access to power at scales exceeding 500 MW, whether physical or virtual.
- **Policy and Regulatory Uncertainty:** Ongoing ambiguity around provincial and federal electricity policies limits investor confidence.
- **CCUS Uncertainty:** Natural gas with carbon capture could provide lower-carbon electricity; however, costs, incentives, and technical viability remain uncertain, raising concerns about competitiveness. There is a risk that relying on natural gas combined with CCUS alone will make power too expensive to be competitive with clean grid provinces, such as Quebec, Ontario, or British Columbia.
- **Geothermal Still Stalled:** Though promising, most geothermal projects in the region are currently inactive or delayed.

7.3.2.3 Strategic Investments & Opportunities

- **Policy Momentum for Low-Carbon Energy:** Supportive policies are needed to drive interest in cleaner power solutions, including but not limited to CCUS.
- **Regulatory Impact Ahead:** Proposed Clean Electricity Regulations will shape the pace and direction of clean energy development in Alberta.
- **Untapped Geothermal Potential:** Geothermal remains an underdeveloped but promising clean energy option in the region.
- **Grid Integration Opportunity:** Strengthening BC–Alberta grid connections could unlock access to clean hydroelectricity for Western Alberta and the Calgary-Edmonton Corridor.
- **Renewable Energy Growth:** Alberta has significant untapped potential to expand wind and solar power generation.
- **SMRs on the Table:** A multi-province agreement on Small Modular Reactors (SMRs) presents a transformative long-term option, especially if aligned with primary industrial project timelines.

7.3.3 Transport Infrastructure

7.3.3.1 Assets

- **Strong Industrial Transport Network:** The transport infrastructure of the cluster is already excellent, thanks to Alberta's industrialized ecosystem and the benefits associated with oil and gas infrastructure.
    - Highways
    - Access to the U.S.
    - Railways
    - DryPort like Port Alberta in Edmonton

7.3.3.2 Challenges

- **Limited Northern Access:** Connections to the North are constrained, with only two main highways (Highway 35 and the Liard Highway) servicing the region.

7.3.3.3 Strategic Investments & Opportunities

- **Expand Northern Links:** Connections to the Northwest Territories through roads and highways can be built and upgraded, providing a good prior engagement with the affected local communities and ensuring they can benefit.

7.3.4 Active Ecosystem

7.3.4.1 Assets

- **Cuban Nickel Supplies:** Sherritt's nickel supplies are sourced from upgraded laterites in Cuba. The mixed precipitates are produced at Moa Bay and shipped to Fort Saskatchewan, AB, for refining.
- **Export-Oriented Industry:** Most Industrial Players from the Heartland are built for export, though local off takers remain limited.

7.3.4.2 Challenges

- **Lack of Large Off-takers:** While some small off-takers exist, securing long-term and large-scale off-take agreements is essential to build the value chain.
- **Export Limitations:** Sherritt's Cuban nickel cannot be sold to the U.S., restricting market access.
- **Price Volatility Risk:** Local players may face challenges in managing exposure to commodity price fluctuation.

7.3.4.3 Strategic Investments & Opportunities

- **Strengthen Industry Collaboration:** Build momentum among critical mineral and battery stakeholders for joint advocacy, investment attraction, and securing off takers. Diversification is needed.
- **Assess Chemical Demand:** Quantify the volume of reagents and chemicals needed for midstream processing.
- **Grow Specialty Chemical Supply:** Support the development of domestic specialty chemical suppliers to serve the battery materials sector.

7.3.5 Innovation & Research

7.3.5.1 Assets

- **Thriving Innovation Ecosystem:** Alberta is home to a dynamic startup environment and numerous innovators in the energy and cleantech sectors.
- **Strong Research Institutions:** Anchored by the University of Alberta, University of Calgary, and Alberta's polytechnic network.
- **Corporate R&D Strength:** Local Industries, such as Oil and gas companies, already invest in R&D
- **Alberta Innovates:** Alberta Innovates plays a pivotal role in supporting R&D, commercialization, and pilot-scale projects across energy and cleantech sectors.

7.3.5.2 Challenges

- **Scaling Innovation:** Startups need more support to transition from pilot to commercial scale.
- **Restrictive Incentives:** Some public funding mechanisms limit eligibility based on technology type, rather than desired outcomes, hindering innovation flexibility.

7.3.5.3 Strategic Investments & Opportunities

- **Establish a Lithium R&D Centre:** Create a lithium processing innovation hub, particularly for DLE, modeled after AOSTRA, to coordinate academia-industry partnerships across Alberta, British Columbia, and Saskatchewan. Refer to **section 4.3.5.2** and the strategy report for more details.

8 Synergies between Clusters

8.1 Links and Flows Between Clusters

While analyzing the details of the gaps and opportunities within each of the five British Columbia and Alberta clusters, the unique features and possible economic futures of each cluster were emphasized. Although the recommendations provided demonstrate how those regional industrial clusters can succeed independently, a network of clusters sharing objectives and synergies would offer numerous benefits.

As a thought experiment, we can consider simplified, highly prospective, but still reasonable material flows that could occur between those regional clusters if they were to evolve according to the proposed recommendations. This could inform how each cluster can benefit from others by specializing in specific value chain segments or commodities according to their overall strengths. Additionally, this will demonstrate how a group of clusters working together can add considerable value.

Six possible value chain flows are briefly examined in the following section:

- Lithium Value Chain
- LFP cathode
- NMC Cathode
- Anodes
- REE and permanent magnets
- Copper for wires
- Battery Manufacturing and End-of-Life

8.1.1 Lithium

The future lithium value chain is straightforward. Lithium brine could be extracted from the numerous DLE operation projects in Alberta and converted into either lithium carbonate or hydroxide (**Western Alberta** and the **Calgary-Edmonton Corridor**), utilizing technologies and equipment developed by Lithium processing technology providers (**Vancouver Lower Mainland** and the **Calgary-Edmonton Corridor)**. Spodumene concentrates from the **Northwest Territories** could be processed in the **Calgary-Edmonton Corridor, Saskatchewan** or **Manitoba.**

8.1.2 LFP Cathodes

For LFP cathodes, lithium, iron, and phosphate are necessary. Iron is not extracted or processed on a large scale in Western Canada. Clear Hills in Alberta (**Western Alberta**) or magnetite from British Columbia (**Vancouver Lower Mainland** and **Northern BC**) could be prospective regions for iron extraction. Realistically, metallic iron powder can be transported from Quebec, and iron sulfate could be produced locally from steel scrap or steel mills. For phosphate, the sedimentary deposits in Wapiti and Fernie (**Kootenays**) and the Clear Hills (**Western Alberta**) could be utilized for phosphate extraction. Subsequently, conversion to phosphoric acid through the wet process, and particularly upgrading it to battery-grade PPA (purified phosphoric acid), would be necessary. Such an acid processing plant would require sulfuric acid and could be located in BC (**Kootenays** and **Northern BC**) or in Alberta (**Calgary-Edmonton Corridor**). For LFP cathode fabrication, pCAM and CAM plants would likely be located in Alberta's Industrial Heartland (**Calgary-Edmonton Corridor**).

8.1.3 NMC Cathodes

For NMC cathodes, lithium, nickel, manganese, and cobalt are necessary. For Nickel, extraction at a great scale will mostly occur in **Northern BC**. The smelting of sulfide concentrates to nickel matte or nickel sulfate would be possible at a prospective smelter/metallurgical plant in the same cluster, while awaruite could be leached to nickel sulfate. An alternative location for metallurgical operations could be in **the Kootenays**. Providing capacity expansion, the Sherritt nickel refining plant in the **Calgary-Edmonton Corridor** could process more imported laterite-derived products such as precipitates (MSP or MHP). Those precipitates that originate from Southeast Asia could transit through ports in the **Vancouver Lower Mainland** cluster. Realistically, manganese should probably be imported; however, there are deposits **in Northern BC**, and a manganese sulfate plant can be considered. The feedstock of manganese sulfate could also be sourced from recycled batteries in the **Kootenays**. For cobalt, several routes are possible. Mining in the **Northwest Territories**, followed by further metallurgical processing and conversion to cobalt sulfate in the **Calgary-Edmonton Corridor**, is the most probable route. An alternative would be the extraction and concentration of ores in **Northern BC**, and their processing in a nearby prospective copper or nickel smelter or hydrometallurgical facility. Cobalt sulfate could be produced there, or in the **Calgary-Edmonton Corridor**. Finally, for NMC cathode fabrication, the pCAM and CAM plants would likely be located in Alberta's Industrial Heartland (**Calgary-Edmonton Corridor**).

8.1.4 Anodes

Li-ion anode material can be manufactured from natural graphite, synthetic graphite, and/or silicon. Graphite occurring in **the Kootenays** can be extracted, shaped, and possibly coated there, or it could be processed in the **Calgary-Edmonton Corridor** for use as an anode active material. Synthetic graphite necessitates petrochemical infrastructure, making the **Calgary-Edmonton Corridor** and **Saskatchewan** clusters potential locations for its production. Petcoke that is currently wasted could be used as a source. Natural gas pyrolysis could also produce graphite in those clusters. The conversion of coal to graphite remains a topic of research; however, optimized technologies could potentially enhance graphite synthesis in coal-producing regions, such as Northern BC, the Kootenays, Western Alberta, the Calgary-Edmonton Corridor, and **Saskatchewan**. Silica could be extracted from **Northern BC**, **the Kootenays** and **Western Alberta**, and processing in those clusters or in the **Calgary-Edmonton Corridor** should be considered. In some chemistries, metallic lithium is used as an anode; refer to the lithium section above for more information.

8.1.5 REE and Permanent Magnets

Mined and concentrated rare earth deposits from **Northern British Columbia and the Northwest Territories** could supply the SRC Rare Earth Processing Facility in **Saskatchewan**. Alloying and permanent magnet manufacturing plants should be considered for development, either in **Saskatchewan** close to the SRC facility, or in **Ontario**, closer to the EV factories.

8.1.6 Copper Wires

Copper extraction is already operational in **Northern BC** and **the Kootenays**, but new mining operations from those clusters and **Yukon** are probable. A copper metallurgical facility supplied by copper sulfide concentrates from those three clusters could produce copper anode. Such a smelter should be located in **Northern BC**, but **the Kootenays** could be an alternative. A copper refinery, converting raw copper anodes to pure copper cathodes, can also be located in BC, more broadly, where electricity is cheap and abundant. Other refining processes could include leaching and cementation of copper powder from e-waste, or tailings, or maybe anodes. Copper concentrates from the **Northwest Territories** will also be leached and cemented in the **Calgary-Edmonton Corridor**. Down the value chain, copper rod plants and wire plants are necessary to produce copper wire. While it makes sense to locate copper rod plants near the production of refined copper (**Northern BC** or other **BC clusters** and **Calgary-Edmonton Corridor**), wiring plant location will depend on proximity to off-takers. The list of off-takers includes wind turbines, transformers, alternators, electric vehicle (EV) motors, and transmission cables manufacturers. Copper circularity can be advanced by smelting or leaching copper.

8.1.7 Battery Manufacturing and End-of-Life

As mentioned above, for Li-ion battery manufacturing, cathode and anode active materials should probably be produced in the **Calgary-Edmonton Corridor**. However, cell, module, and pack manufacturing need urban areas near transport infrastructure linked to international markets, making the **Vancouver Lower Mainland** cluster a suitable location. Advanced materials would transit between these two clusters, while finished battery products would be ready to ship for international markets. As for used batteries, domestic and international collection could occur in the **Vancouver Lower Mainland**, while refurbishment and recycling should be done in **the Kootenays**. Metal salts and chemicals produced from the recycling could supply the pCAM/CAM facilities in the **Calgary-Edmonton Corridor**.

8.1.8 Supplementary Material Flows

Other material flows between clusters could be studied. Vanadium extraction from oil sands fly ash in Alberta is a promising source for this metal, which shows great potential for stationary energy storage. As such, its processing to vanadium pentoxide, then to electrolyte and the final manufacturing to vanadium redox flow batteries could be performed all in Alberta (**Calgary-Edmonton Corridor**), while battery manufacturing capacity in the **Vancouver Lower Mainland** cluster could be expanded. Sulfur and sulfuric acid can be produced from sulfide concentrate smelting in a potential copper or nickel smelter in **Northern BC**, as this is already the case for the Trail smelter in the **Kootenays**. Sulfuric acid could be used for leaching and hydrometallurgy of other minerals, such as an EV battery recycling facility in the **Kootenays**, a hydrometallurgical processing facility in **Northern BC**. Sour gas and brines in Alberta can also serve as a source of sulfur and sulfuric acid for local operations, particularly in the **Calgary-Edmonton corridor**. The flows of other reagents necessary for processing and advanced material manufacturing segments, such as sodium hydroxide or lime, should be studied. Similarly, the economy, material flows, and recycling of platinum group elements (PGEs), also known as platinum group metals (PGMs), should be another topic of study, as it is linked to hydrogen production. E-waste and end-of-life batteries were already mentioned in the sections above, but many current waste streams of the critical mineral and battery value chains could also be valuable to reprocess as they still hold a high quantity of valuable elements and compounds. These technologies, such as tailings and slags reprocessing, sodium sulfate salt splitting, *etc.* are still not all economically viable, but they could affect material flows in the future.[47,48]

8.1.9 Non-Material Flows: A Call for Coordination and Collaboration

Flows between regional industrial clusters are not limited to material goods; we can also examine the flow of information and knowledge, capitals, the movement of talent, the shared network infrastructure, and the added value that comes from common coordination. Taking the example of lithium processing technology and equipment providers, there are many innovative companies in this sector within the **Vancouver Lower Mainland cluster**, which should have great interest in collaborating with the **Western Alberta** and **Calgary-Edmonton Corridor** clusters, where lithium brine extraction from aquifers and processing will occur. Coordination in research and development between top academic centres, such as universities in Vancouver and Calgary, and the industry, regardless of the value-chain segments, is undoubtedly a significant benefit. Collaboration with various levels of government to foster innovation in strategic technologies and sectors will also enhance Canada's competitive advantage in the battery value chain. The advancement of green credits, the development of standardized life-cycle assessments, and the growth of cleantech, if coordinated among government, industry, and academia, can leverage the sustainability leadership of the Canadian industry. Targeted government funding, access to private capital, pricing mechanisms, and the scaling of innovative companies would all benefit greatly from collaboration from a network of stakeholders driving these efforts.

8.2 Give and Go: An Integrated Western Canadian Battery Value Chain

Based on the variety and number of projects presented in this study, it's clear that Western Canada's battery ecosystem is beginning to take shape, not just as a scattered set of industrial nodes, but as a connected network of regional clusters. Building on our proposed future cluster values and strategic investment opportunities, there is a future vision of these critical mineral and battery value chains that can be strengthened into a more collective, collaborative, and ultimately more resilient ecosystem, which is achievable.

One illustration of this desirable future Western value chain is a coordinated movement, much like a "**give and go**" play, that flows strategically between regions to maximize value creation. This future network starts in the resource-rich North, moving through central processing in Alberta, and advances to the coastal South for final manufacturing, before circling back through recycling loops. Much like in hockey, where players pass the puck and then move into open space to receive it back, the 'give and go' in this context represents the dynamic, reciprocal flow of materials, expertise, and investment across interconnected regional clusters. This "give and go" is a metaphor and a strategic blueprint that summarizes value chain integration across mining, refining, advanced materials, and battery production in Western Canada.

The play starts in Northern British Columbia, the Territories, as well as the Kootenays, where world-class deposits of nickel, cobalt, copper, graphite, and phosphate will be mined, while at the same time, lithium brine will be extracted from Western and central Alberta. These raw materials are then transformed through metallurgical and chemical upgrading, potentially within the same clusters or sent down to the Calgary–Edmonton Corridor, a region with the potential to emerge as Western Canada's powerhouse for precursor, cathode active materials (CAM), anode production, and critical reagents. Alberta's industrial strength, existing industry and refineries, and innovation hubs make it a natural host for advanced material production.

The final leg of the give and go play brings these engineered, advanced battery materials back west to the Vancouver Lower Mainland, where proximity to international markets, ports, urban infrastructure, and a skilled workforce can support battery cell, module, and pack assembly. With end-of-life batteries flowing back through the system, particularly toward the Kootenays for recycling and refurbishment, the give and go becomes a closed loop, reinforcing circularity and supply chain resilience.

Each cluster specializes in what it does best, and when connected, the collective value created has the potential to exceed the sum of its parts. This metaphor of a give and go is a proposed vision of regional synergy and Canadian leadership in the global battery economy.

Figure 8.2.1 Simplified Map of the "Give and Go" Strategy

8.3 Going Bar Down: Building the Vertical Backbone of Western Canada Battery Supply Chain

The first leg of the give and go strategy should be supported by north-south trading corridors, linking the northern regions and territories to clean energy and transport infrastructure, while providing the southern regions with access to raw materials for processing. Past concepts have advocated for more territory and province infrastructure connections, such as the Canadian Northern Corridor. Recently, several levels of government have supported the integration of the electric grid, such as the transmission line network project that would connect Yukon to British Columbia.[49] We advocate for similar initiatives, but applied in a holistic manner to clean energy grid expansion and critical mineral transportation.

In hockey, a "Bar Down" goal is a perfect shot that hits the crossbar and drops straight into the net. In Canada's battery value chain, the concept of "Bar Down" captures a similar idea: a clean, vertical flow of materials, from the North to the industrial South, targeted with precision and to support the goal of battery production.

This vertical structure originates in the resource-rich North, specifically in Yukon, Northern British Columbia, and the Northwest Territories, where mining operations are emerging to supply lithium, cobalt, nickel, copper, and rare earth elements. These critical materials must move downward through north-south transport infrastructure and trading corridors, connecting:

- Yukon to British Columbia
- Northern British Columbia to Southern British Columbia
- The Northwest Territories to Alberta
- The Northwest Territories to Saskatchewan

These routes represent the first leg of the give and go value chain, supplying raw materials to the current and future metallurgical processing hubs in Northern British Columbia, the Kootenays, or the Calgary–Edmonton Corridor, and beyond. Investment needs would include road and rail upgrades and expansion, as well as the creation of new infrastructure and transport corridors.

However, just as important is what goes back up: clean energy, grid capacity, and infrastructure investment must move northward, enabling remote regions to electrify their operations, power mining equipment, and create the conditions for full-cycle value creation. The necessary condition for this strategy to go forward is to prioritize supporting local economic development, benefiting the welfare and opportunities of local communities, and strengthening Indigenous reconciliation.

A complementary west-east corridor, integrating the clean hydroelectric grid of British Columbia to the more carbon-emitting Alberta, should also be considered to support the industrial development and capital attractiveness of cleantech in the Calgary-Edmonton Corridor.

This two-way corridor, with resources heading south and energy and infrastructure going north, would have a significant impact on economic development. It would form a resilient backbone for Canada's battery economy, connecting geography with strategy, and transforming regional isolation into national strength.

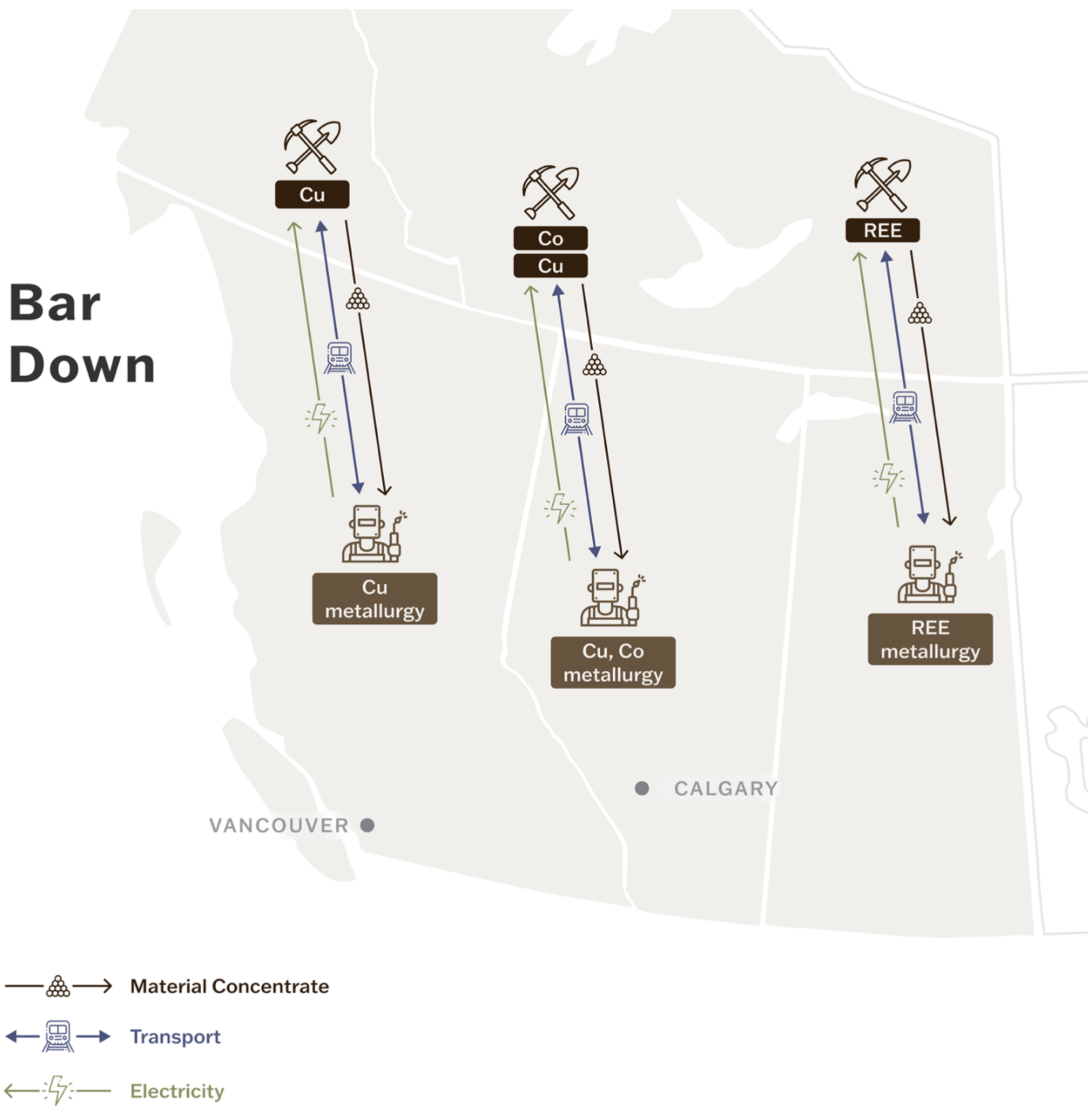


Figure 8.3.1 Simplified Map of the "Bar Down" Strategy

9 The Need for a Western Canadian Battery Value Chain

Amid rising geopolitical and trade tensions, Canada should move beyond passive resource exports and proactively strengthen its trade position by processing its natural wealth domestically. Accelerating critical mineral and battery value chain integration for Western and Northern Canada is a priority opportunity for the whole country.

This report has highlighted the potential for Western Canada to develop a globally competitive battery value chain and has outlined credible strategies that can be pursued in order to achieve this potential. The value proposition of more rapidly integrating the West and the North into this evolving national value chain is robust and compelling, with numerous benefits for Canada, including:

- **Enhancing Indigenous Economic Reconciliation:** All roads to an integrated value chain for critical minerals and batteries pass through Indigenous lands and it is imperative that the country leverage this generational opportunity to pursue economic reconciliation. The nation has the chance to situate the economic, environmental and social benefits of the evolving value chain and the interests of Indigenous communities at the core of this effort.
- **Increasing Economic Productivity:** A supercharged critical minerals and battery value chain in Western and Northern Canada can help the country get its economy back on the right track with projects that create long-term economic wealth for the country, with upstream mining and midstream processing sectors ripe with innovation potential and high-paying jobs.
- **Minimizing Social, Environmental and Climate Impacts:** In contrast to the emissions- and waste-intensive mining and processing taking place in other parts of the world, Canada can help raise climate and environmental standards for this global sector. By building a midstream processing sector the region can incentivize a demand-side draw for valuable post-consumer materials, versus having to export these recovered metals, chemicals, and black mass, and thereby enhance our national circular economy competitiveness.
- **Strengthening Supply Chain Security:** With an increasing over-concentration of critical mineral production and processing in a select few countries worldwide, Canada's supply chain and businesses are vulnerable to trade war action. This vulnerability allows foreign countries that do not share Canada's interests to potentially manipulate prices and the supply chain to achieve national goals that are contrary to ours. Onshoring this production and processing of the fundamental building blocks of our economy decreases this dependence on foreign actors.
- **Enhancing Sovereignty and Supporting Healthier Communities in the North:** Building-out Canada's northern transportation networks and wealth-generating

economic capacity through triple-use infrastructure (i.e. community, industrial, and military) not only builds healthier northern communities, but also projects Canadian northern sovereignty at a time of increased great power competition in the Arctic.

- **Stimulating Industrial Innovation and Specialized Expertise:** Establishing a more integrated supply chain entails developing what could be considered Western-world leading expertise in advanced metallurgical and chemical processing, fostering innovation in higher-tech applications, and likely leading the world in terms of emissions and waste reduction processes, technologies, and expertise in the chem-tech sector. Developing the region's midstream processing capacity can ultimately increase the technological capabilities of Canada's materials sector and develop specialized knowledge that can be exported to partner nations.

Developing and nurturing this integrated value chain requires a long-term perspective and government leadership in identifying, selecting, and appropriately supporting catalytic projects to move forward.

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