BMAC Battery Metals Association of Canada

The Transition Accelerator | L'Accélérateur de transition

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FOCUS ON IRON

FROM ROCKS *TO* POWER

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

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From Rocks to Power: Strategies to Unlock Canada's Critical Minerals for Global Leadership in Energy Storage, EVs, and Beyond

Focus on Iron

Author

Sosthène Ung, Senior Future Economy Analyst, The Transition Accelerator

Contributors

Liz Lappin, Battery Metals Association of Canada

Eric Pelletier, Battery Metals Association of Canada

Bentley Allan, The Transition Accelerator

Derek Eaton, The Transition Accelerator

About Us

BMAC | Battery Metals Association of Canada

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 | L'Accélérateur de transition

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.

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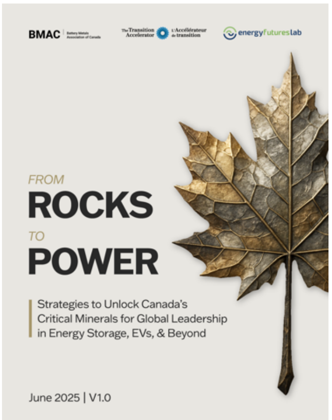
The Energy Futures Lab is an award-winning, Alberta-based not-for-profit that brings together a diverse network of innovators, influencers, and system actors from across Canada's energy landscape. Established in 2015, the Lab was created to address growing polarization around Canada's energy transition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

About This Report



This chapter is part of a larger report, *From Rocks to Power: Strategies to Unlock Canada's Critical Minerals for Global Leadership in Energy Storage, EVs, and Beyond*. The full report identifies clear, investable priorities in eight minerals, each of them critical to building resilient EV and energy storage value chains. By looking at specific opportunities and providing detailed justifications for its recommendations, *From Rocks to Power* offers a way out of our perpetual planning cycle and towards a new momentum for Canada's critical minerals sector—and our future economic prosperity.

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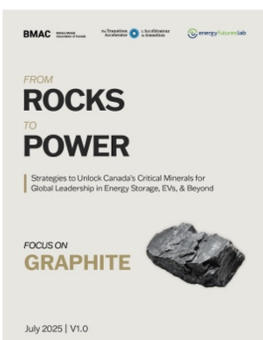

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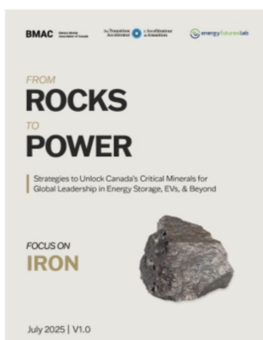

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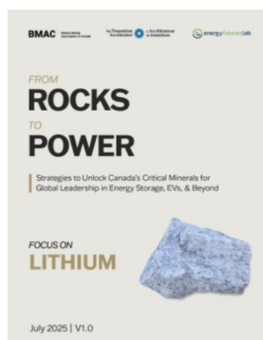

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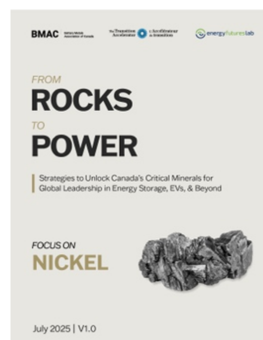

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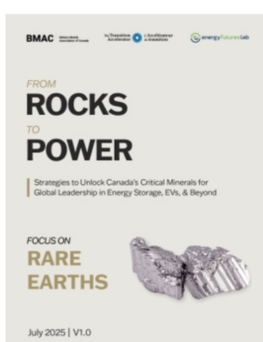

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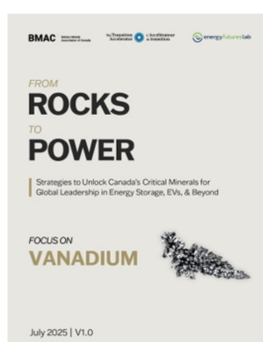

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1 The Canadian Strategy for Iron

1.1 Targets

Table 1 Iron Targets

Iron Mandated Benchmark (10% of 2030 North American Market)		
	2030	**2040**
Iron (ktpa elemental)	38	75

1.2 Scenario Outline

Canada already has significant operations in high-purity iron ore mining and steelmaking, and the mandated benchmark quantity of supplementary iron necessary for LFP cathode manufacturing is unlikely to be a bottleneck. However, iron sulfate is traditionally the chemical intermediate necessary to produce precursors to LFP cathodes. Canada can encourage iron sulfate production from steel mills, it should also support the commercial viability and scaling of new pCAM and CAM processes using iron powder or iron oxide to bypass iron sulfate and avoid controversial sodium sulfate waste issues.

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

2 Iron: An Abundant Material Needed Mostly for Steel but also LFP Cathodes

Iron, a silvery grey and soft metal in its pure form, is the 4th most abundant element in the Earth's crust. On top of being indispensable for life processes, as iron-bearing proteins are required for oxygen transportation in blood, iron has also become the most used metal through nearly 5,000 years of metallurgical innovations. Iron is a cost-effective and versatile material thanks to its wide availability and various physical properties (high strength, malleability, ductility, magnetic properties, *etc.*). Mainly combined with carbon in **steel** (< 2% C) and **cast iron** (2–4% C), iron's properties can be finely tuned with different metal alloys: for instance, the addition of chromium and nickel increases corrosion resistance in **stainless steels**, while tungsten, molybdenum and vanadium can enhance hardness and wear resistance in **tool steels**. Consequently, iron and steel are found everywhere in modern society: in consumer goods, mechanical & electrical equipment, vehicles (cars, trucks, ships and rail), infrastructure, and buildings.

Figure 1 Examples of applications for steel and iron materials

The popularity of iron also results in its high energy requirement and large carbon footprint: the manufacturing of iron and steel accounts for almost **7% of global GHG emissions** and **8% of global energy demand**. Additionally, a boost in steel demand from emerging countries will most likely drive a global increase in steel production: the IEA's Stated Policies Scenario forecasted a global steel production growth from around 1.9 Gt in 2019 to over 2.5 Gt in 2050.[1]

In parallel with the steelmaking processes, commercially available iron compounds, such as **iron(II) sulfate heptahydrate** $FeSO_4.7H_2O$ or **iron(III) chloride** $FeCl_3$**, are primarily obtained from the treatment of steel scrap with acids** or the leaching of iron sulphides or ilmenite.[2,3] Iron sulfate is the traditional reagent used as a precursor to cathode material for lithium-iron-phosphate (LFP) batteries. For more details of this process, please refer to the phosphate section of this report.

3 The Iron Flowsheet: An Ironmaking and Steelmaking Industry Looking to Decarbonize

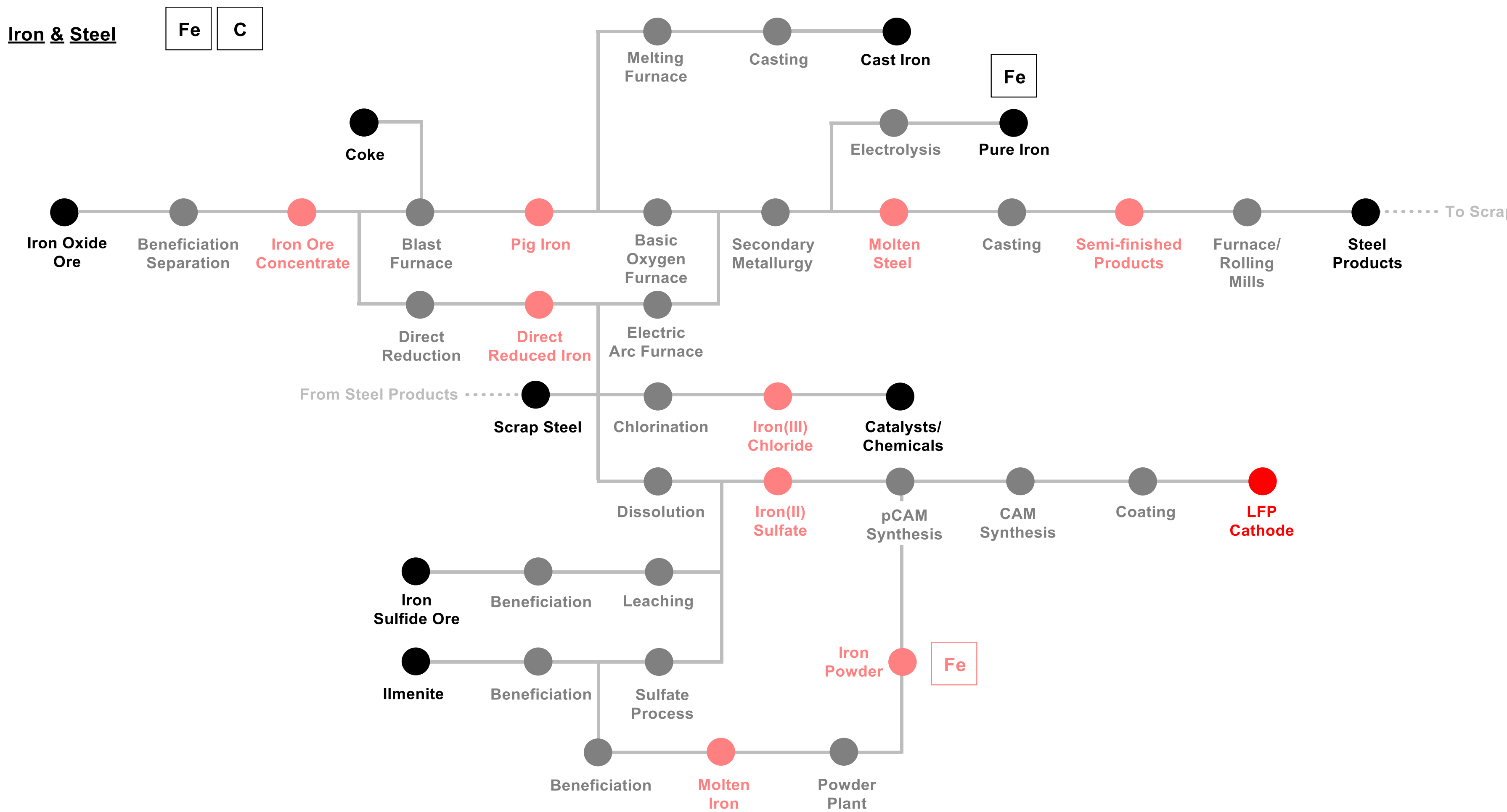

Figure 2 Simplified flowsheet of iron/steel to LFP cathodes

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Compared with other elements, iron is undeniably the primary metal extracted: 2.6 billion tonnes of iron were mined globally in 2022, representing **93% of the total mined metals**. 98% of this iron is purposed solely for steelmaking. Despite its availability, iron mainly occurs in silicate minerals, which are not economically viable to process. The mining industry thus focuses primarily on extracting oxides such as **hematite** Fe_2O_3 and **magnetite** Fe_3O_4. Two main metallurgical routes currently dominate the steelmaking industry: the integrated and mini-mill routes. However, both processes aim to separate iron from oxygen first and then control the carbon content of the steel.

The integrated, or **blast furnace–basic: oxygen furnace** route (BF-BOF) starts by smelting the iron feed with limestone using coke as a reductant. It produces **pig iron**, a high-carbon crude intermediate, refined by adding oxygen at high temperatures. Secondary metallurgy and forming steps will generate semi-finished and finished steel products. This process, closely tied to coal and fossil fuels, represents the leading route, accounting for **92% of iron and steel global production in 2022**.

The mini mill route alternative, or **direct reduced iron–electric arc furnace route** (DRI-EAF), first uses a reducing gas to produce iron from the feed. Impurities are separated while the carbon content is adjusted inside an electric arc furnace to make steel. This process has recently gained more attention as it relies mainly on electrical energy, and the reducing gas (traditionally issued by natural gas, coal or syngas) could be replaced by decarbonized hydrogen. DRI processes only represented 8% of **iron and steel global production in 2022.**

It is worth noting that while iron is virtually entirely recyclable, only **32% of the global metallic input for steel production comes from scrap**, mainly during the EAF process. Alternative steelmaking routes include smelting reduction processes, which avoid the carbon-intensive coke-making step, or novel electrometallurgical processes such as molten oxide electrolysis (MOE) or low-temperature **electrolysis** (LTE), where a strong electrical current directly reduces the iron oxide feed.

Table 2 Estimated reserves & mined production of iron content by country in thousands and millions of tonnes

Country	Iron content mined in 2022 (in tonnes x 10^3)[a]	Country	Iron content reserve in 2024 (in tonnes x 10^6)[b]
Mexico	6,800	Chile	NA
Mauritania	7,950	Mauritania	NA
Kazakhstan	8,890	Mexico	NA
Turkey	10,700	Turkey	99
Chile	11,100	Sweden	600
Peru	12,900	South Africa	620
Ukraine	21,300	Kazakhstan	900
US	24,700	Peru	1,200
Sweden	27,700	US	1,300
Other Countries	32,200	Iran	1,500
South Africa	40,500	**Canada**	**2,300**
Canada	**41,400**	Ukraine	2,300
Iran	51,300	India	3,400
Russia	55,800	China	6,900
India	156,000	Other Countries	9,500
China	170,000	Russia	14,000
Brazil	276,000	Brazil	15,000
Australia	584,000	Australia	27,000
World Total Rounded	**1,540,000**	**World Total Rounded**	**87,000**

[a]Data from the 2024 U.S. Geological Survey in thousands of tonnes of iron content mined.
[b]Data from the 2024 U.S. Geological Survey in millions of tonnes of iron content mined.

Table 3 Estimated production of pig iron and raw steel by country in millions of tonnes

Country	Pig Iron production in 2022 (in tonnes x 10^6)[a]	Country	Raw Steel production in 2022 (in tonnes x 10^6)[a]
Mexico	2	Ukraine	6
Iran	3	**Canada**	**12**
Italy	3	Mexico	18
Canada	**6**	Vietnam	20
Ukraine	6	Taiwan	21
Turkey	9	Italy	22
Vietnam	12	Iran	30
Taiwan	13	Brazil	34
U.S.	19.8	Turkey	35
Germany	24	Germany	37
Brazil	27	South Korea	66
South Korea	42	Russia	72
Russia	52	U.S.	80.5
Japan	64	Japan	89
Other countries	67	India	125
India	80	Other countries	195
China	866	China	1,020
World Total Rounded	**1,300**	**World Total Rounded**	**1,880**

[a]Data from the 2024 U.S. Geological Survey in millions of tonnes of iron content mined.

Australia, Brazil, China, and India are responsible for 67% of iron ore production in iron content. China's steelmaking capacity is heavily concentrated, representing 54% of global crude steel production.[4,5] Canada is historically a significant iron and steel producer: The U.S. Geological Survey estimated that Canada ranked 7th on global iron extraction in iron content in 2022, 7th on international iron reserves and that Canada was the 15th raw steel producer the same year, with almost 12 million tonnes of crude steel produced. NRCan reports eight iron ore extraction sites: 3 in Labrador, 4 in Northern Quebec and one in Nunavut.[6] Canada's mining operations concentrate mainly on the Labrador Through, a geological iron belt formation between Labrador and Quebec. As for steel production, Ontario holds most of the BF-BOF steelmaking plants. Electric Arc Furnace/mini-mills operations are more spread out: they can be found in Alberta, Saskatchewan, Manitoba, and Ontario. Almost 46% of Canadian-made steel originates from the EAF route.[7] Finally, it is worth noting that the only DRI-EAF plant is the ArcelorMittal operation in Contrecœur, QC.

To bypass the use of iron sulfate and avoid the sodium sulfate/sulfate salts waste issues linked to pCAM and CAM manufacturing, the Canadian company NanoOne developed a one-pot process using pure iron powder or iron oxide as an iron source. They have partnered with Rio Tinto to use their high-purity iron powder produced in Sorel-Tracy, Quebec as a by-product of their RTIT titanium smelter. First Phosphate, a Quebec-based company seeking to develop phosphate deposits, a phosphoric acid plant, and a cathode active material plant for LFP batteries, has recently been collaborating with GKN Powder Metallurgy to lease their metal-powder-making technology for producing iron powder.[8,9]

Endnotes

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