Critical Minerals Analysis

Photo: Impala Canada, Lac des Iles Mine

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Photo: KGHM, McCreedy West Mine

Critical Minerals Framework

Critical Minerals Overview

The Canadian and Ontario economies have seen a drastic transformation over the last few decades. The shift towards a knowledge-based, decarbonized economy, coupled with the rise of new technologies and products and services, such as information and communications technologies, renewable energy and electric vehicles (EVs), have transformed our everyday life and have had profound implications on the demand for raw materials.

Technological progress and quality of life often rely on access to a growing number of minerals. In addition, certain minerals are closely linked to decarbonization efforts – many are irreplaceable in solar panels, wind turbines, and energy-efficient lighting.

At the same time, supply chain disruptions caused by the rising geopolitical tensions and the COVID-19 pandemic have highlighted the importance of having a cohesive government strategy for stabilizing and securing the supply of critical minerals. Globally, many leading jurisdictions, including the United States (US), the European Union (EU), Japan, Australia and South Korea, have developed critical mineral strategies and lists to guide policy support, strategic investments and priorities.

Ontario is working with other provinces and territories and the federal government to advance critical minerals opportunities. These efforts also aim to strengthen Ontario's competitiveness in supplying responsibly sourced minerals to domestic and international markets.

Definition of critical minerals

"Critical minerals are a subset of the minerals that have specific industrial, technological and strategic applications for which there are few viable substitutions. These minerals are also at higher supply risk due to geopolitical considerations and market demand."[1]

Source: [1] Government of Ontario, Critical minerals framework discussion paper.

Objectives of the Report

The minerals that a jurisdiction deems "critical" depend on a number of factors, including local production and processing capabilities, geological endowment, import reliance, as well as its own domestic and economic priorities.

In this report, an in-depth analysis was performed for each of the critical minerals identified by the government of Ontario (**Table 1**). Profiles are created to demonstrate each mineral's value chain, production level in Ontario, global trade patterns, price and demand outlooks, economic and strategic importance to the Ontario economy, as well as other considerations.

In addition, a data-driven framework is developed to demonstrate the relative economic importance and supply risk of each mineral on the current list. This framework can also be used to identify additional minerals to be included.

Table 1. Ontario's Critical Mineral List (preliminary)

Minerals with exploration potential (15)			Advanced mineral projects (6)	
▪ Antimony	▪ Manganese	▪ Tin	▪ Barite	▪ Niobium
▪ Beryllium	▪ Molybdenum	▪ Titanium	▪ Chromite	
▪ Bismuth	▪ Phosphate	▪ Tungsten	▪ Graphite	
▪ Cesium	▪ Rare earth elements (REE)	▪ Vanadium	▪ Lithium	
▪ Fluorspar	▪ Tantalum	▪ Zirconium	▪ Magnesium	
Minerals being produced and/or processed (8)			**Minerals that are currently processed only (1)**	
▪ Cobalt	▪ Platinum group elements (PGE)		▪ Uranium	
▪ Copper	▪ Selenium			
▪ Indium (produced)	▪ Tellurium			
▪ Nickel	▪ Zinc (produced)			

2. Current State Analysis

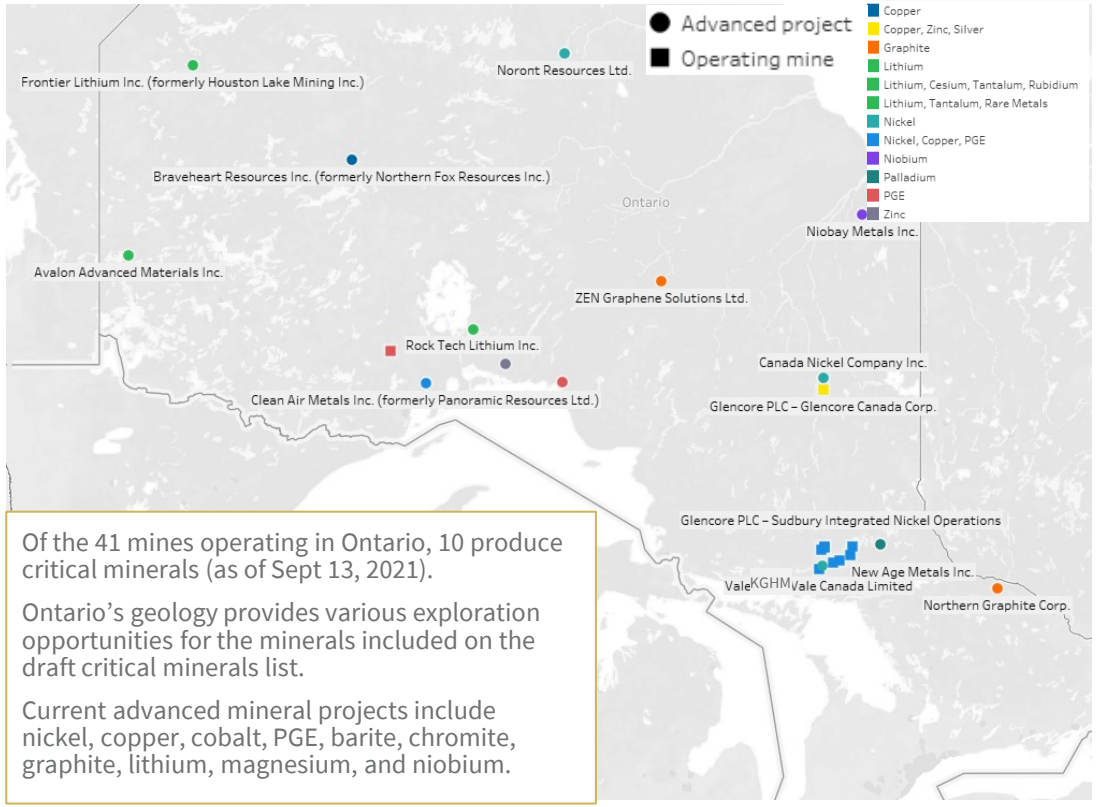
Photo: Glencore, Sudbury Integrated Nickel Operations

2.1 Ontario's Critical Minerals Production

Legend (status in Ontario):

- Exploration potential
- Advanced mineral projects
- Produced and/or processed
- Processed only

- In 2020, eight critical minerals from the Ontario's critical minerals list were produced in the province. Critical mineral production can provide opportunities for mining companies operating in Ontario to sell their product to growing global markets while also supplying local needs from downstream industries.
- The map below shows the operating mines and advanced mineral projects in Ontario.



Of the 41 mines operating in Ontario, 10 produce critical minerals (as of Sept 13, 2021).

Ontario's geology provides various exploration opportunities for the minerals included on the draft critical minerals list.

Current advanced mineral projects include nickel, copper, cobalt, PGE, barite, chromite, graphite, lithium, magnesium, and niobium.

Sources: Government of Ontario, Critical minerals framework discussion paper; Natural Resources Canada (NRCAN).

Table 2: Ontario's Critical Minerals Production (NRCAN)

Mineral	Production in Ontario, 2020 (Tonnes)	Production Value, 2020 (CAD$)	Mineral	Production in Ontario, 2020 (Tonnes)	Production Value, 2020 (CAD$)
Antimony	None	-	Nickel	63,370	$1.05B
Barite	None	-	Niobium Tantalum	None	-
Beryllium	None	-	Phosphate	None	-
Bismuth	None	-	PGE	22.86	$1.40B
Cesium	None	-	REE	None	-
Chromite	None	-	Selenium	53.52	$2.60M
Copper	121,196	$888.1M	Tellurium	7.67	$790,000
Cobalt	542	$24.17M	Tin	None	-
Fluorspar	None	-	Titanium	None	-
Graphite	None	-	Tungsten	None	-
Indium	6.29	$2.33M	Uranium	None	-
Lithium	None	-	Vanadium	None	-
Magnesium	None	-	Zinc	*	*
Manganese	None	-	Zirconium	None	-
Molybdenum	None	-	Note: Mineral production data entries with "*" are classified as confidential by NRCAN		

2.1 Ontario's Critical Minerals Production

- **Tables 3 and 4** provide a list of operating facilities that produce critical minerals in Ontario.
- **Table 5** lists the mines that are at the advanced mineral project stage.

Table 3: Critical Mineral Mining Operations

Mines		
Operation	**Company**	**Critical Minerals**
Lac des Iles Mine	Impala Platinum Canada Ltd	PGE, Nickel, Copper
Kidd Creek Mine	Glencore, KIDD	Zinc, Copper
McCreedy West Mine	KGHM International Ltd	Nickel, Copper, PGE
Coleman, Copper Cliff, Creighton, Garson, Totten Mine	Vale Canada Ltd	Nickel, Copper, PGE, Cobalt
Fraser, Nickel Rim South Mine	Glencore, Sudbury Integrated Nickel Operations (SINO)	Nickel, Copper, PGE, Cobalt

Table 4: Processing Facilities for Metal Mines

Refinery		
Operation	**Company**	**Critical Minerals**
Blind River	Cameco Corp	Uranium
Copper Cliff	Vale Canada Ltd	Nickel, Copper, PGE, Selenium, Tellurium
Port Colborne	Vale Canada Ltd	Cobalt, PGE

Smelter		
Operation	**Company**	**Critical Minerals**
Sudbury	Glencore, SINO	Nickel, Copper, PGE, Cobalt
Copper Cliff	Vale Canada Ltd	Nickel, Copper, PGE, Selenium, Tellurium

Conversion Facility		
Operation	**Company**	**Critical Minerals**
Port Hope	Cameco Corp	Uranium

Sources: Ontario Mining Exploration – Directory and Resource Guide 2021, Ontario Critical Minerals Framework Discussion Paper.2

Table 5: Advanced Critical Mineral Projects

Graphite	
Project Name	**Company**
Bisset Creek	Northern Graphite
Albany Graphite	ZEN Graphene Solutions

Lithium	
Project Name	**Company**
PAK	Frontier Lithium
Georgia Lake	Rock Tech Lithium
Separation Rapids	Avalon Advanced Materials

Nickel and Copper	
Project Name	**Company**
Victoria	KGHM International
Onaping Depth	Glencore
Eagle's Nest	Noront Resources

Niobium	
Project Name	**Company**
James Bay	Niobay Metals

Platinum Group Elements	
Project Name	**Company**
River Valley	New Age Metals
Marathon PGM-CU	Generation Mining
Thunder Bay North	Clean Air Metals

Zinc	
Project Name	**Company**
Pick Lake/Winston Lake	Superior Lake Resources

2.2 Canada's Critical Minerals Production

- Critical mineral production also takes place in a number of Canadian provinces.
- Quebec and Newfoundland have a presence in the market for a number of critical minerals, while some production also occurs in British Columbia (BC) and Manitoba.
- Copper and zinc are the most common minerals, with production from coast to coast. Cobalt production is also fairly widespread in Canada, with production across four provinces.
- Saskatchewan is a producer of uranium; most uranium processed in Ontario is mined in Saskatchewan.

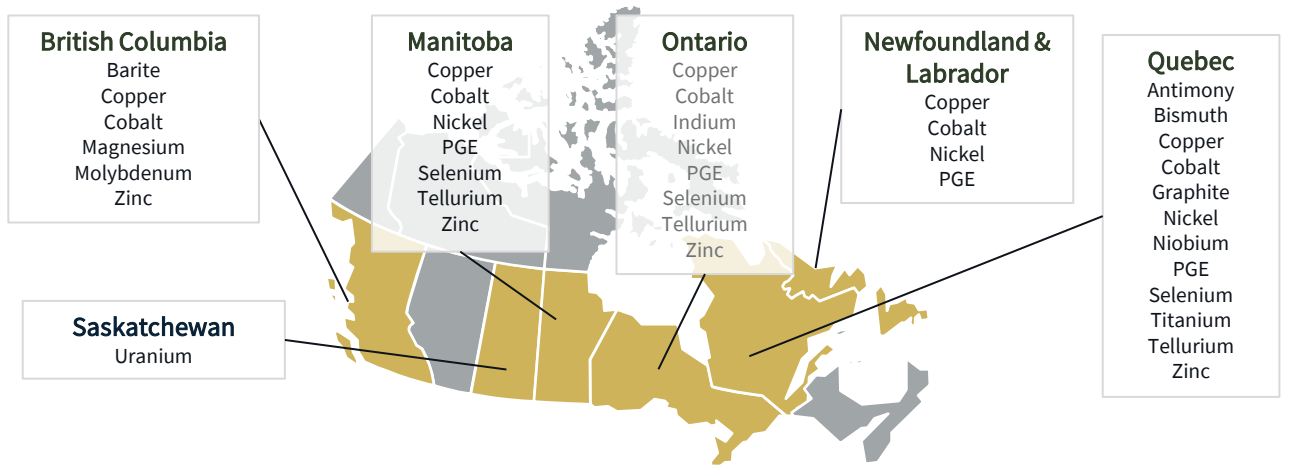


Table 6: Canadian Critical Minerals Production (NRCAN)

Mineral	Production, 2020 (Tonnes)							
	Ontario		Quebec	Newfoundland and Labrador	British Columbia	Manitoba	Saskatchewan	Canada
	Provincial Production	Share of Canada						
Antimony	-	-	1.8	-	-	-	-	1.8
Barite	-	-	-	-	*	-	-	*
Bismuth	-	-	3.7	-	-	-	-	3.7
Copper	121,196	24%	36,361	*	277,488	22,169	-	495,154
Cobalt	542	15%	1,285	*	-	198	-	3,535
Graphite	-	-	11,937	-	-	-	-	11,937
Indium	6.29	100%	-	-	-	-	-	6.29
Molybdenum	-	-	-	-	2,655	-	-	2,655
Nickel	63,370	39%	52,845	32,987	-	14,160	-	163,362
Niobium	-	-	*	-	-	-	-	*

Source: NRCAN.

Note: Mineral production data entries with "*" are classified as confidential by NRCAN

2.2 Canada's Critical Minerals Production (continued)

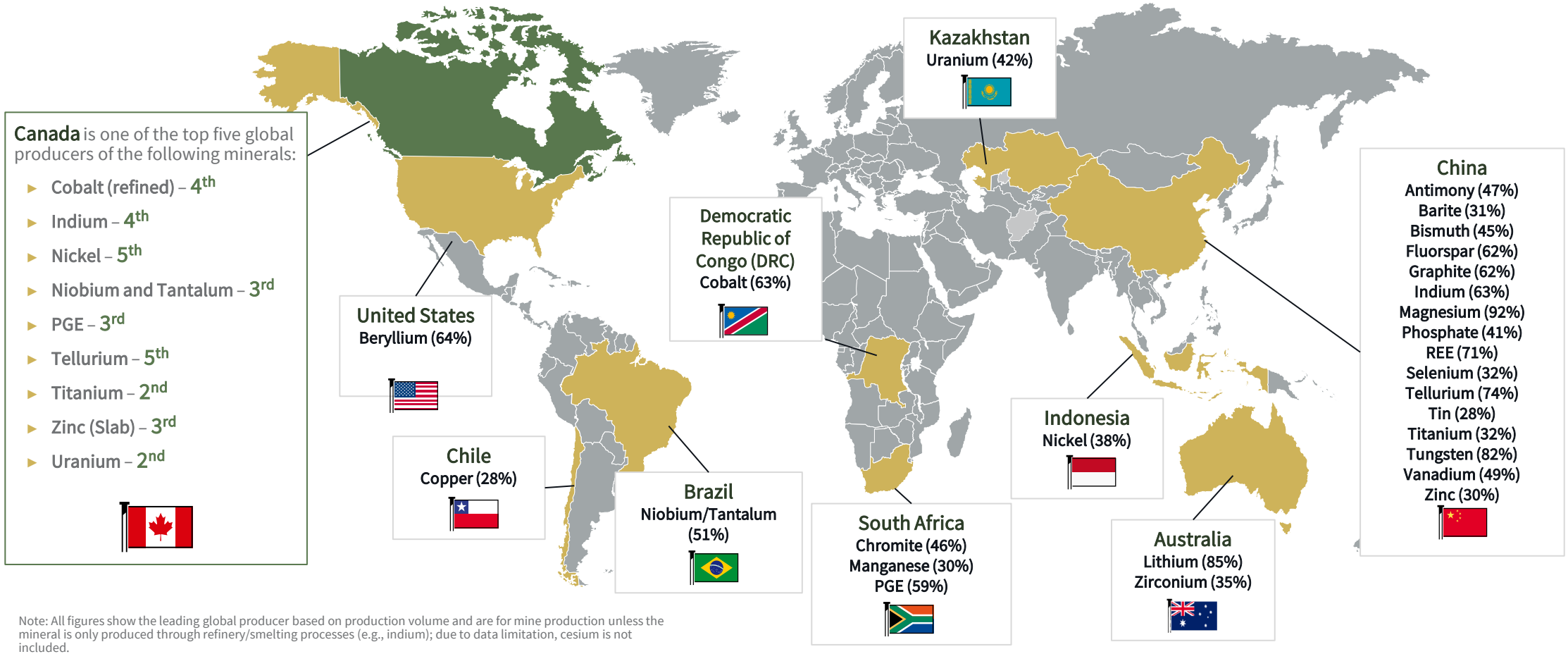
Mineral	Production, 2020 (Tonnes)							
	Ontario		Quebec	Newfoundland and Labrador	British Columbia	Manitoba	Saskatchewan	Canada
	Provincial Production	Share of Canada						
PGE	22.86	77%	6.7	0.02	-	0.23	-	29.77
Selenium	53.52	53%	31.5	-	-	16.5	-	101.60
Tellurium	7.67	59%	3.2	-	-	2.1	-	12.97
Titanium	-	-	*	-	-	-	-	*
Uranium	-	-	-	-	-	-	4,121	4,121
Zinc	*	-	78,750	-	*	*	-	184,846
Note: Mineral production data entries with "*" are classified as confidential by NRCAN								

Minerals on Ontario's critical minerals list that are not produced in Canada include beryllium, cesium, chromite, fluorspar, lithium, magnesium, manganese, phosphate, REE, tin, tungsten, vanadium, zirconium.

Source: NRCAN

2.3 Leading Critical Minerals Producers

- To understand the global market and supply chain for critical minerals, global mineral production data was assessed in order to identify the top producer for each mineral and their respective market shares. Based on 2019 production volumes, China dominates the global critical minerals mining market with the highest production share in 16 minerals included on Ontario's critical minerals list.
- Ontario's endowment with critical mineral deposits represents an opportunity for the province to produce and market responsibly procured natural resources to some of the major jurisdictions, including the US and the EU, whose advanced industries rely on global minerals' supply chains.



Note: All figures show the leading global producer based on production volume and are for mine production unless the mineral is only produced through refinery/smelting processes (e.g., indium); due to data limitation, cesium is not included.
Source: British Geological Survey (BSG).

2.4 Substitutability and Importance in Major Jurisdictions

- Some industrial applications can use multiple source materials, while others require very particular and limited inputs. In order to assess the substitutability of each critical mineral, this report analyzes each mineral's applications and availability of alternative materials with comparable properties and performance for the most common industrial needs.
- Assessing substitutability with the mineral's criticality status in major jurisdictions (as defined by national critical minerals frameworks in each country included in the analysis) provides a view of the overall economic and strategic importance of these minerals on a global scale.

Table 7: Ontario's Critical Minerals: Substitutability and Importance in Major Jurisdictions

Mineral	Status in Ontario	Substitutability (Low-High)	Minerals Included on Critical Minerals List						
			EU	US	UK	Canada	Japan	Australia	Total Jurisdictions
Antimony	Exploration Project	Moderate	√	√	√	√	√	√	6/6
Barite	Advanced Mineral Projects	Moderate	√	√					2/6
Beryllium	Exploration Potential	Low	√	√	√			√	4/6
Bismuth	Exploration Potential	High	√	√		√		√	4/6
Cesium	Exploration Potential	Moderate		√		√			2/6
Chromite	Advanced Mineral Projects	Low		√		√	√	√	4/6
Copper	Produced and Processed	Low				√		√	2/6
Cobalt	Produced and Processed	Moderate	√	√	√	√	√	√	6/6
Fluorspar	Exploration Potential	High	√	√	√	√			4/6
Graphite	Advanced Mineral Projects	Moderate	√	√	√		√	√	5/6
Indium	Produced	Low	√	√	√	√	√	√	6/6
Lithium	Advanced Mineral Projects	Moderate	√	√		√	√	√	5/6

Note: Status in Ontario indicated the most advanced stage for a given mineral. Most minerals that are produced as of 2021 also have advanced mineral projects and exploration potential. Complete critical minerals lists of comparable jurisdictions are provided in **Appendix B**.
Sources: United States Geological Survey (USGS); Critical Minerals lists of the EU, the US, the United Kingdom (UK), Japan, Canada, and Australia (Critical mineral lists of major jurisdictions).

2.4 Substitutability and Importance in Major Jurisdictions (continued)

Mineral	Status in Ontario	Substitutability (Low-High)	Minerals Included on Critical Minerals List						
			EU	US	UK	Canada	Japan	Australia	Total Jurisdictions
Magnesium	Advanced Mineral Projects	High	√	√	√	√	√		5/6
Manganese	Exploration Potential	Low		√		√	√	√	4/6
Molybdenum	Exploration Potential	Low				√		√	2/6
Nickel*	Produced and Processed	High		√		√		√	3/6
Niobium/Tantalum	Advanced Mineral Projects/ Exploration Potential	Moderate	√/√	√/√	√/√	√/√	√/√	√/√	6/6
Phosphate	Exploration Potential	Low	√						1/6
PGE	Produced and Processed	Moderate	√	√	√	√	√	√	6/6
REE	Exploration Potential	Moderate	√	√	√	√	√	√	6/6
Selenium	Produced and Processed	Moderate						√	1/6
Tellurium	Produced and Processed	Moderate		√		√			2/6
Tin	Exploration Potential	High		√		√		√	3/6
Titanium	Exploration Potential	Moderate	√	√		√	√	√	5/6
Tungsten	Exploration Potential	Low	√	√	√	√	√	√	6/6
Uranium	Processed Only	Moderate		√		√			2/6
Vanadium	Exploration Potential	Moderate	√	√		√	√		4/6
Zinc*	Produced	High		√		√			2/6
Zirconium	Exploration Potential	Moderate		√			√	√	3/6

Notes: *Nickel and Zinc were added to the US Critical Minerals List based on the 2021 US Administration review. Complete critical minerals lists of comparable jurisdictions are provided in **Appendix B**.
Sources: USGS; Critical Minerals lists of the EU, the US, UK, Japan, Canada, and Australia (Critical mineral lists of major jurisdictions).

2.5 Applications in Priority Technologies and Industries

- Critical raw materials supply is essential for advanced manufacturing industries, including automotive and aerospace manufacturing in Ontario and other major economies. Access to critical raw materials can also contribute to the transition to a low-carbon economy, in particular, through the development of renewable energy sectors, such as wind and solar energy.
- The table below shows the mapping of each critical mineral into its common uses in priority downstream technologies and industries.

Table 8: Ontario's Critical Minerals Applications in Priority Technologies and Industries

Mineral	Batteries	Fuel Cells	Electronics	Aerospace and Defence	Agricultural Technologies	Medical Equipment and Technologies	Wind Energy	Solar Energy
Antimony				√				
Barite			√					
Beryllium			√	√				
Bismuth				√				
Chromite				√		√	√	√
Copper	√		√		√		√	√
Cobalt	√		√		√		√	
Fluorspar		√						
Graphite	√	√	√	√				√
Indium	√		√	√				√
Lithium	√	√	√	√				
Magnesium			√	√				
Manganese	√		√				√	
Molybdenum							√	√

Note: Priority industries and technologies are defined based on the Government of Ontario's Critical Minerals: Framework Discussion Paper. Due to data limitation, cesium is not included.

Sources: Ontario's Critical Minerals: Framework Discussion Paper; EU Critical Minerals Factbook.

2.5 Applications in Priority Technologies and Industries (continued)

Mineral	Batteries	Fuel Cells	Electronics	Aerospace and Defence	Agricultural Technologies	Medical Equipment and Technologies	Wind Energy	Solar Energy
Nickel	√	√	√	√		√	√	√
Niobium/Tantalum			√	√			√	
Phosphate					√			
PGE	√	√	√	√		√		
REE	√	√	√	√		√	√	
Selenium					√			√
Tellurium			√					√
Tin								√
Titanium		√	√	√		√		
Tungsten			√	√				
Uranium								
Vanadium		√	√	√				
Zinc					√	√		√
Zirconium		√	√					

Note: Priority industries and technologies are defined based on Government of Ontario, Critical Minerals: Framework Discussion Paper. Due to data limitation, cesium is not included.

Sources: Ontario's Critical Minerals: Framework Discussion Paper; EU Critical Minerals Factbook.

2.6 Ontario's Critical Minerals Import Dependence

- Access to critical minerals is important for Ontario's economy as these raw materials serve as inputs to advanced manufacturing sectors and may enable the transition to a low-carbon economy.
- In order to understand Ontario's current import dependence, Ontario's trade data was analyzed and each mineral's importance in priority industries was assessed .
- Based on Statistics Canada trade data from 2017-2020, Ontario was a net exporter of 9 minerals included in the analysis and was a net importer of 19.
- Generally, reliance on imports for critical minerals may indicate a higher supply chain risk for the province's industries.

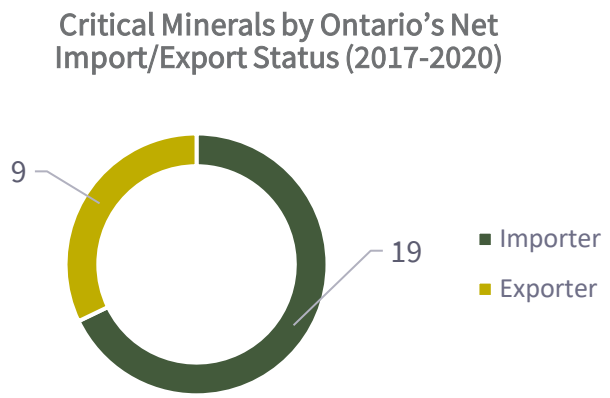


Table 9: Ontario's Critical Minerals Import Dependence Summary

Mineral	Used in 2+ Priority Industries	Net Importer or Exporter (2017-2020)	Mineral	Used in 2+ Priority Industries	Net Importer or Exporter (2017-2020)
Antimony		Importer	Nickel	√	Exporter
Barite		Importer	Niobium/Tantalum	√	Exporter
Beryllium	√	Importer	Phosphate		Importer
Bismuth		Importer	PGE	√	Exporter
Chromite		Importer	REE	√	Importer
Copper	√	Importer	Selenium	√	Exporter
Cobalt		Exporter	Tellurium	√	Exporter
Fluorspar		Importer	Tin		Importer
Graphite	√	Importer	Titanium	√	Importer
Indium	√	Exporter	Tungsten	√	Importer
Lithium	√	Importer	Uranium		Exporter
Magnesium	√	Importer	Vanadium	√	Importer
Manganese	√	Importer	Zinc	√	Exporter
Molybdenum	√	Importer	Zirconium	√	Importer

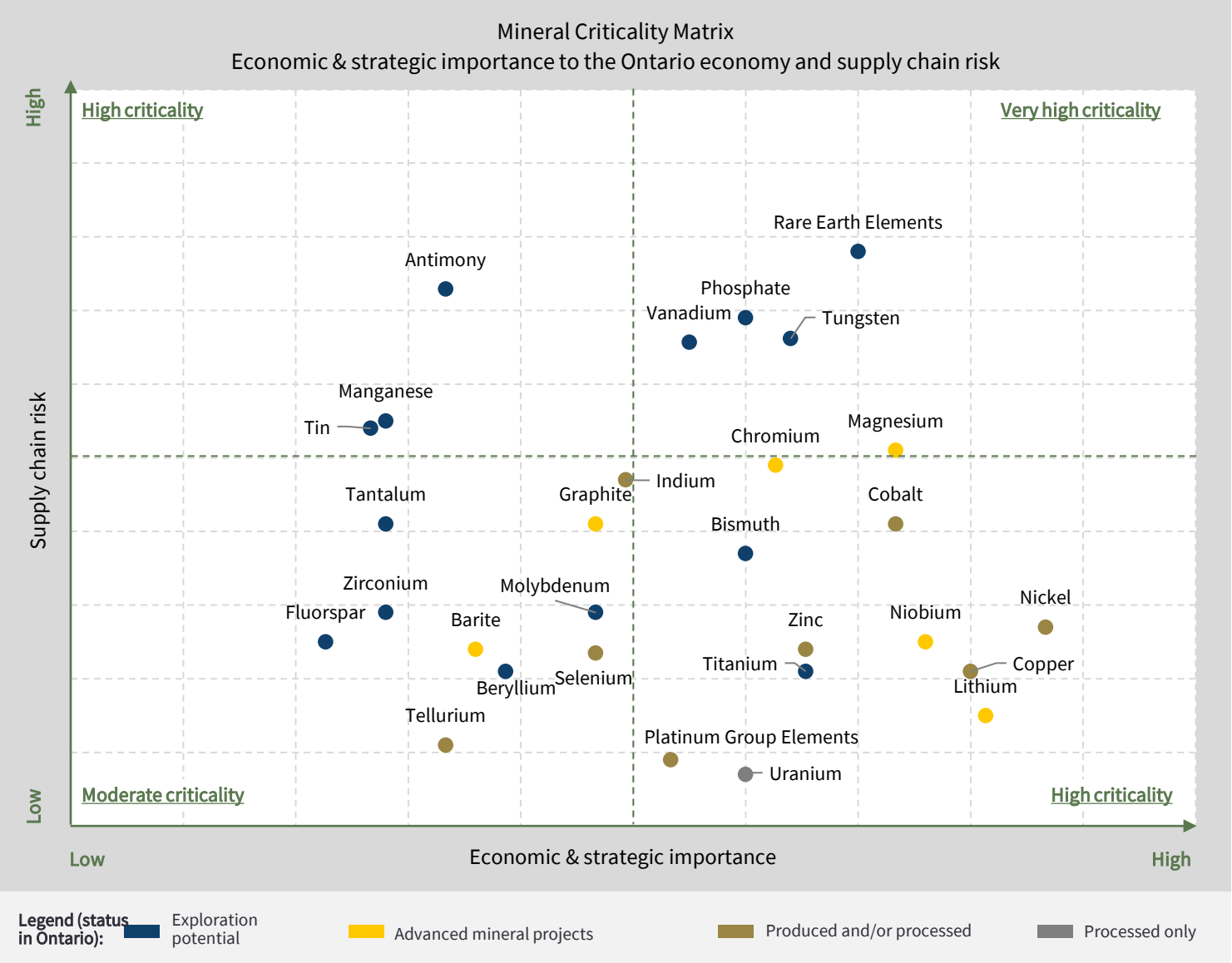
Note: Priority industries and technologies are defined based on the Government of Ontario's, Critical Minerals: Framework Discussion Paper. Due to data limitation, cesium is not included. Based on the Harmonized Item Description and Coding System (HS) codes included in the analysis, trade data indicate that Ontario is a net exporter of chromite and vanadium; however, as no production takes place in the province, Ontario is classified as net importer for these two commodities. The HS codes included in the analysis are provided in Appendix A.

Sources: Statistics Canada; Ontario's Critical Minerals: Framework Discussion Paper; EU Critical Minerals Factbook.

3. Mineral Criticality Assessment and Market Outlook

Photo: Noront

Mineral Criticality Assessment for the Ontario Economy



Key Insights

- The mineral criticality matrix summarizes the results of the criticality assessment, which aims to quantify the economic importance and supply chain risk associated with each critical mineral in Ontario.
- The positioning of a mineral on the matrix indicates its level of criticality. Minerals with higher levels of economic importance and more susceptibility to supply chain disruptions have the highest level of criticality (top right). Conversely, minerals that are associated with lower value-added activities, and have abundant and diversified supplies (or produced domestically) have the lowest level of criticality (bottom left). And, minerals in between have medium to high criticality.
- The economic importance metric provides insight on a mineral's end-use applications in Ontario's priority sectors and technologies (as identified in the preceding sections). Through the synthesis of public research and analysis of Ontario's economy, a higher score is assigned to minerals (1) with more versatile applications; (2) that are indispensable for priority technologies and sectors; and (3) that are associated with high value-added activities.
- The supply chain risk metric is evaluated based on a number of factors, including (1) geopolitical stability and diversity of suppliers; (2) concentration of ore production, processing and reserves; (3) historical price volatility; and (4) domestic self-sufficiency. Minerals' substitutability is also accounted for in the analysis given that access to substitutes could reduce the risk of supply disruptions for a mineral.

Sources: Analysis based on Natural Resources Canada, Statistics Canada, USGS and EU data. Note: Due to data limitation, cesium is not included. Criticality assessment methodology is described in **Appendix A**.

Summary of Market Outlook

Neutral	Positive	Negative

The table below summarizes the market outlook for each of the critical minerals. Price and demand outlooks are developed based on a combination of supply-demand dynamics, macroeconomic considerations, global economic priorities, and existing and anticipated applications in the downstream industries.

Mineral	Price outlook		Demand outlook		Mineral	Price outlook		Demand outlook	
	Near-term*	Medium-to-long term**	Near-term	Medium-to-long term		Near-term	Medium-to-long term	Near-term	Medium-to-long term
Antimony	↗	→	↗	→	Nickel	↗	↗	↗	↗
Barite	→	↘	→	↘	Niobium/Tantalum	→	↗	→	↗
Beryllium	↗	↗	↗	↗	Phosphate	→	→	↗	→
Bismuth	→	→	↗	↗	PGE	→	↘	↗	↘
Chromite	↗	→	↗	↗	REE	↗	↗	↗	↗
Copper	↘	→	↗	↗	Selenium	→	→	→	↗
Cobalt	↗	→	↗	↗	Tellurium	↗	→	→	↗
Fluorspar	→	→	↗	↗	Tin	→	↘	↗	↗
Graphite	→	→	↗	↗	Titanium	→	↗	↗	↗
Indium	→	↗	↗	→	Tungsten	↗	↗	↗	↗
Lithium	↗	↗	↗	↗	Uranium	→	↗	↗	↗
Magnesium	→	↗	↗	↗	Vanadium	→	→	↗	↗
Manganese	↗	↗	↗	↗	Zinc	→	↘	↗	→
Molybdenum	↘	→	↗	↗	Zirconium	↗	→	↗	↗

Sources: Analysis based on Natural Resources Canada, Statistics Canada, USGS and EU data. Note: due to data limitation, cesium is not included. Detailed market outlooks for each mineral are included in the Critical Mineral Profiles. *Near-term is defined as the next 1-5 years; **Medium-to-long term is defined as the next 5-15 years.

4. Supply Chain Risks in Ontario's Priority Technologies

Photo: Cameco, Blind River Refinery

Ontario Mining Association EST. 1920

Supply Chain Risks in Ontario's Priority Technologies

- Ontario is home to several advanced manufacturing clusters, including automotive and mobility, and aerospace and defence. Innovation and application of new technologies, such as advanced information and communication technologies, EVs, and electronics, help the economy grow and stay competitive. Moreover, the shift to a low-carbon economy is increasing the demand for clean technology and consequently the required raw materials.
- In this section of the report, six technologies expected to contribute to greenhouse gas emission reductions and which are closely connected to the provincial priority manufacturing sectors are assessed. This report identifies critical minerals that are most commonly used in these technologies and analyzes their potential supply disruption risk for Ontario.

Sector

Automotive and Mobility

Ontario is home to a well-established automotive cluster with five global original equipment manufacturers (OEMs), including Toyota, Honda, General Motors, Ford, and Fiat Chrysler Automobiles. Additionally, leading automotive parts manufacturers are headquartered in Ontario. In 2016, Ontario's automotive sector employed approximately 115,000 workers.[1]

Aerospace and Defence

Ontario is home to multiple global aerospace companies, including OEMs and Tier 1 suppliers. Approximately 16,700 workers were employed in the aerospace product and parts manufacturing sector in 2016.[2] The industry is closely interconnected with other advanced manufacturing sectors and technologies.

Renewable Energy

Ontario is taking steps to decarbonize their economy and produce clean energy that are reliant on the low-carbon metals and minerals produced and processed in Ontario. The Ontario government's carbon taxation scheme, the Emission Performance Standard, sets out targets to reduce carbon emissions in the province, and is one way the sector will meet net-zero objectives.

Technology

Batteries

Li-ion batteries have important electronics, EVs, and stationary storage applications; the demand from the e-mobility sector is expected to be high.

Fuel Cells

Fuel cells (FCs) are electrochemical devices that convert fuel directly into electricity without combustion; they provide a clean energy solution to a number of sectors.

Electronics

Electronics covers a broad range of digital technologies that enable modern industries; electronic components include sensors, displays, memory, semi-conductors, etc.

Robotics

Robotics is a field leveraging hardware and software automation technology with applications in many sectors, including automotive and aerospace.

Wind Turbines

Wind turbines are considered one of the most cost-effective technologies for the transition to clean energy. Wind turbines are used in onshore and offshore site conditions.

Solar Photovoltaic Technology

Solar photovoltaics (PV) is a technology that produces electricity through the conversion of sunlight into energy.

Average Supply Risk

Batteries	Fuel Cells	Electronics	Robotics	Wind Turbines	Solar Photovoltaic Technology
Total Critical Minerals: 6	Total Critical Minerals: 6	Total Critical Minerals: 10	Total Critical Minerals: 9	Total Critical Minerals: 7	Total Critical Minerals: 7
Low	Low	Moderate	Low	Moderate	Low

Sources: [1,2] Statistics Canada, Census 2016

Critical Minerals in Priority Technologies

Legend (status in Ontario):

- Exploration potential
- Advanced mineral projects
- Produced and/or processed
- Processed only

Batteries

Industries:

- Li-ion battery is a technology that draws a lot of attention due to its importance in electronics, EVs, and stationary storage applications.[1] As the transition to EVs is anticipated to accelerate in the next decade, a secure supply of battery materials may help Ontario attract new investment into battery manufacturing and strengthen its automotive sector's competitiveness.
- Currently, the two most common battery types used in the EVs are lithium nickel manganese cobalt oxide (NMC), and lithium nickel cobalt aluminium oxide (NCA) cathode chemistry batteries, while graphite is commonly used as anode material.[2]
- The battery materials included in Ontario's critical minerals list are shown in the table below. Of these, three minerals (copper, cobalt, nickel) are currently produced in the province while graphite and lithium projects are at the advanced mineral projects phase. In 2019, the US was Ontario's top import partner for graphite, lithium, and manganese as no domestic production takes place in Canada.
- Overall, battery material supply risk in Ontario ranges from very low to moderate; on average, the supply disruption risk is low.
- China currently dominates EV and battery production,[4] which may pose geopolitical risks to other major jurisdictions. This could present an opportunity for Ontario to leverage its position and mineral endowment to become a battery producer.

Raw Materials Used in Li-ion Batteries

Mineral	Common Use Cases	Supply Risk
Copper	Wires, collector foil at anode side	Low
Cobalt	Cathode material	Moderate
Graphite	Anode electrode	Moderate
Lithium	Cathode material	Very Low
Manganese	Cathode material	Moderate
Nickel	Hydroxide or intermetallic compounds	Low

Fuel Cells

Industries:

- FCs offer an attractive clean energy solution and may contribute to sustainable and secure energy sources in the medium-to-long term. Canada is home to a significant concentration of global hydrogen and FC expertise, including various elements within the supply chain, such as raw materials.[4]
- FCs are electrochemical devices that convert fuel, such as hydrogen, directly into electricity without combustion. FCs use PGEs for the fuel to power conversion.[5]
- The FC materials included in Ontario's critical minerals list are shown in the table below. Of these, four minerals (copper, cobalt, nickel, and PGE) are currently produced in the province; graphite projects are at the advanced mineral projects phase - in 2019, the US was Ontario's top import partner of graphite, as no domestic production takes place in Canada while titanium is produced in Canada at the Rio Tinto's Lac Tio titanium mine in Quebec.
- Overall, FC material supply risk in Ontario ranges from very low to moderate; on average, the supply disruption risk is low.
- Based on the current development of the Canadian FCs industry, Ontario's manufacturing sector may be well-positioned to contribute to the domestic and international markets for FCs, in particular, to FC powered buses, trains, back-up and stationary power, aerospace, and distribution and storage sectors.

Raw Materials Used in Fuel Cells

Mineral	Common Use Cases	Supply Risk
Copper	Wires, anode catalyst	Low
Cobalt	Catalyst	Moderate
Graphite	Material for construction of bipolar plates	Moderate
Nickel	Material for coating bipolar plates	Low
PGE	Catalyst material	Very Low
Titanium	Metallic bipolar plate and anode	Low

Sources: [1, 5] European Commission, Critical Raw Materials for Strategic Technologies and Sectors in the EU [2,4] EV volumes [3] Statistics Canada [5] Canadian Hydrogen and Fuel Cell Association

Critical Minerals in Priority Technologies

Legend (status in Ontario):

- Exploration potential
- Advanced mineral projects
- Produced and/or processed
- Processed only

Electronics

Industries:

- The electronics sector refers to the manufacturing of electronic equipment and consumer electronics, including mobile devices, televisions, and circuit boards. The most profitable sector within electronics is the semi-conductor industry, which has grown to be worth more than USD$464 billion in 2020.[1]
- Ontario produces four of the critical minerals necessary for this technology but has exploration potential for another six.[2] Ultimately, the supply chain risk in the province is moderate.
- As society becomes fueled by digitalization, large amounts of data will be produced and stored in data centres and enterprise infrastructures. Critical minerals listed in the table below will play a crucial role in the production of connected equipment.

Raw Materials Used in Electronics

Mineral	Common Use Cases	Supply Risk
Cobalt	Semi-conductors, circuits and hard drives	Moderate
Lithium	Primary batteries	Very Low
Manganese	Memory storage	Moderate
Copper	Connectors, circuits, wiring, semi-conductors	Low
PGE	Glass for displays	Very Low
Graphite	Graphene used in many applications, for electrical and thermal conductivity	Moderate
Indium	Screens and indium-in oxide	Moderate
Magnesium	Aluminum-Magnesium alloys	Moderate
REE	Displays, LED, lasers, circuit boards	High
Tungsten	Dielectric materials, transistors, light bulbs	High

Robotics

Industries:

- As an emerging technology, robotics has enormous potential for many applications across several industries, such as agriculture, medicine, transportation, social services, military, space exploration, and undersea operations. Within Ontario, the automotive industry accounts for 57% of all robots used.[3]
- Out of the 16 most common raw materials along the robotics value chain, nine can be found on Ontario's critical mineral list and include indium, chromite, copper, titanium and molybdenum.
- Overall, the raw materials supply risk within Ontario for robotics is low based on the domestic production of key minerals.
- Within robotics, there is a need for continued development in design at both the system and component levels. Gears, motors, and power units need to become lighter and smaller, and critical minerals such as titanium can help do that.

Raw Materials Used in Robotics

Mineral	Common Use Cases	Supply Risk
Beryllium	Alloys, electro-optical systems	Low
Indium	Electro-optical and power systems	Moderate
Chromite	Stainless steel and alloys	Moderate
Copper	Wiring, corrosion resistant alloys	Low
Manganese	Steel alloys	Moderate
Molybdenum	Stainless steel alloys	Low
Nickel	Electroplating, stainless steel frames and connectors	Low
Niobium	Microalloying in high strength steel	Low
Titanium	Alloys, high strength structural steel	Low

Sources: [1] International Data Corporation [2] Electronics Products and Technology [3] Industrial Automation and Robotics

Critical Minerals in Priority Technologies

Legend (status in Ontario):
- Exploration potential
- Advanced mineral projects
- Produced and/or processed
- Processed only

Wind

Industry:

- According to the Canadian Wind Energy Association, wind energy is as or less expensive compared to all other sources of new electricity generation, and supplies approximately 6% of Canada's electricity demand.[1] Ontario remains Canada's leader in clean wind energy with 5,436 megawatts of installed electricity generating capacity as of December 2019.[2]
- Modern wind turbines consist of several high-performance components, including generators, drivetrains, rotors and blades. Use of REEs in permanent magnet generators offers advantages in terms of efficiency, dimension, and maintenance. Wind turbine blades also require a high strength-to-weight and fatigue resistance properties, which can be enabled by materials such a high-performing alloys.[3]
- The most common wind turbine materials included in Ontario's critical minerals list are shown in the table below. Of these, only two (nickel and copper) are currently produced in the province while chromite and niobium are at the advanced mineral project stage. Overall, the supply risk for wind energy materials for Ontario is estimated to be moderate.

Raw Materials Used in Wind Energy

Mineral	Common Use Cases	Supply Risk
Chromite	Stainless steel alloys in rotor and blades	Moderate
Manganese	Steel alloys in parts of turbine	Moderate
Molybdenum	Stainless steel composition for turbine	Low
Nickel	Nickel alloys and stainless steel for turbine	Low
Niobium	Element for high strength structural steel for towers of a turbine	Low
Copper	Cables, inverters, generator winding	Low
REE	Permanent magnets	High

Solar Photovoltaic Technology

Industry:

- Solar PV is a technology that produces electricity through the conversion of sunlight into energy. In Canada, the share of solar energy as a percentage of total energy use stood at 1% as of 2019.[3] The cost to install solar has declined by about 50% in the US over the past five years; these costs have fallen in Canada as well.[4] Similar to other technologies contributing to clean energy generation, solar PVs offer an opportunity for the province to transition to achieve its low-carbon economy goals.
- For instance, Canadian Solar is a leading Ontario manufacturer of solar PV modules, provider of solar energy and battery storage solutions, and developer of utility-scale solar power and battery storage projects.[5]
- The most common solar PV materials included in Ontario's critical minerals list are shown in the table below. Of these, five minerals (copper, nickel, selenium, tellurium, and zinc) are currently produced in the province while there are known reserves of molybdenum and tin. Overall, the supply risk for solar PV materials for Ontario is estimated to be low, providing an opportunity for Ontario to leverage its endowment and strengthen its position in the solar PV manufacturing sector.

Raw Materials Used in Solar PV

Mineral	Common Use Cases	Supply Risk
Copper	Wires, cables, inverters	Low
Molybdenum	Back contact for CIGS and stainless steel frames	Low
Nickel	Electroplating, stainless steel frames	Low
Selenium	Thin-film CIGS solar cells	Low
Tin	Soldering or in conductive layers	Moderate
Tellurium	Thin-film cadmium PV	Very low
Zinc	Transparent conductive oxide in the front contact of solar cells	Low

Sources: [1,2] Canadian Wind Energy Association [3] European Commission, Critical Raw Materials for Strategic Technologies and Sectors in the EU [3,4] NRCAN [5] Canadian Solar

5. Ontario's Competitive Position and Market Opportunities

Photo: Impala Canada, Lac des Iles Mine

Overview of Ontario's Competitiveness and Opportunities

- Given Ontario's endowment with diverse minerals deposits, the province has an opportunity to capitalize on its geological potential to become a sustainable and politically stable source for critical minerals for other leading advanced manufacturing jurisdictions, such as the US and the EU.
- In this section of the report, Ontario's competitiveness position is assessed across key factors, including mineral potential, business costs, research and development (R&D) activity, and policy climate.
- To understand Ontario's attractiveness and identify opportunities for future mineral development, a jurisdictional scan is conducted of four comparable jurisdictions: Quebec, the US, Australia, and the EU. Australia, Quebec, and the US are selected as they represent competition for Ontario in supplying some of the critical minerals to the global market. Additionally, the EU and the US are considered from the perspective of potentially becoming key target export markets for Ontario's critical minerals producers.

Mining Sector Competitiveness Factors

Mineral Potential

Includes geological endowment by mineral, number of exploration projects, and exploration intensity

Quality of Infrastructure

Includes the level of physical infrastructure required to enable mining activities

Regulatory Costs

Includes time and resources spent on permitting, and costs of exports and imports

Energy Sources

Includes assessing the reliance of the mining and industrial sectors on renewable vs. non-renewable sources

Cost of Doing Business

Includes some of the key operating costs, such as electricity, labour costs, and taxes

Financial Incentives

Includes financial incentives for mining exploration and production activities

Processing Capabilities

Includes having the domestic capacity to process minerals

R&D Intensity

Includes enterprise spending on in-house research and development activities in the sector

Comparative Jurisdictions

Quebec

- Quebec is one of the leading Canadian mining jurisdictions
- The province has established gold and iron sectors as well as critical minerals production and exploration

USA

- Top commodities produced domestically are copper and iron
- The US is dependent on foreign supply chains for many minerals and has a federal strategy to ensure secure and reliable supplies

Australia

- Mineral extraction is an important contributor to Australia's economy and exports
- Its critical minerals approach is targeted at increasing exploration and production of in-demand commodities

EU

- The EU has limited domestic mineral production capacity
- As its policy emphasizes the transition to the green economy, the EU's critical minerals list and strategy have been developed to create resilient manufacturing value chains

Comparator Profiles

Quebec

Mineral Production	► Quebec's mining sector is ranked as one of the top ten most attractive regions for investment by the mining companies internationally and the second (after Saskatchewan) among Canadian provinces.[1] ► The top three commodities produced in Quebec in 2020 (in terms of shipment value) were: (1) gold (second-largest Canadian producer after Ontario), (2) iron (largest Canadian producer), and (3) nickel.[2] ► As of 2020, there were almost 150,000 active mining titles and 21 active mines, including gold, iron, nickel, zinc, titanium, niobium, graphite, and salt operations.[3]
Exploration Activity	► In terms of exploration and deposit appraisal expenditures, Quebec ranked second after Ontario in 2019 and 2020 with just over $500 million spent annually.[4] ► Some of the notable deposit appraisal mining projects and projects under development include: (1) Iron, including titanium and vanadium, (2) gold, (3) nickel, (4) zinc, (5) REEs, (6) lithium, including tantalum, and (7) graphite.[5] ► Quebec offers a number of competitive tax incentives that are expected to attract more investment from mineral producers.[6]
Critical Minerals Approach/Strategy[7]	► The Government of Quebec recognizes the increasing demand and importance of minerals supply for new technologies and innovative sectors, including green technologies. ► Quebec considers the following minerals as strategic: cobalt, graphite, lithium, magnesium, nickel, niobium, PGEs, REEs, scandium, tantalum, titanium and vanadium. ► Currently, 12 minerals from Ontario's critical minerals list are extracted in Quebec, including battery minerals, such as cobalt, nickel, and graphite. Additionally, lithium projects are in development in Northern Quebec.

United States

Mineral Production[8]	► The top mineral commodities produced domestically are copper, iron, sand and gravel, stone. Top materials processed domestically are aluminum, brick, cement, copper, fertilizers, and steel. ► The top five US states by mineral production value are: (1) Nevada, (2) Arizona, (3) Texas, (4) California, and (5) Minnesota. ► In 2020, the US was 50% import reliant on foreign sources for some raw and processed mineral materials, including some critical minerals. The top major mineral sources included China and Canada.
Exploration Activity	► Mineral exploration expenditures by mining companies in the US in 2020 totalled USD$930 million. Spending has declined slightly from 2019, likely as a result of the COVID-19 pandemic, but overall it has been growing steadily since 2016.[9] ► In an attempt to reduce reliance on China, the US government is planning to fund domestic REE projects. Projects under development include Energy Fuels Inc, NioCorp Developments Ltd, Texas Mineral Resources Corp, among others.[10]
Critical Minerals Approach/Strategy	► The US critical minerals list developed in 2018 includes 35 mineral commodities that are deemed essential to economic and national security. The 2021 review of the critical minerals list advised to include two additional commodities - nickel and zinc.[11] ► Of the minerals included on Ontario's critical minerals list, the US produces barite, beryllium, copper, magnesium, molybdenum, phosphate rock, REEs, and zinc. ► In 2021, the US and Canada hosted the third US-Canada Critical Minerals Working Group to discuss the implementation of the cooperation on critical mineral supply chains to support the clean energy transition.[12]

Sources: [1] Fraser Institute [2] NRCAN [3,5,6] Government of Quebec, Investing in Quebec's Mining Sector [4] NRCAN [7] Government of Quebec, Development of critical and strategic minerals in Quebec [8] USGS [9] The Standard and Poor's (S&P) Capital IQ [10] Reuters [11] USGS [12] US Department of State

Comparator Profiles

Australia

Mineral Production[1]	► Australia is one of the world's leading producers of bauxite (aluminum ore), iron ore, lithium, gold, lead, diamond, REE, uranium, and zinc. Australia also has large mineral sand deposits of ilmenite, zircon and rutile. ► Mining occurs in all states of Australia, the Northern Territory and Christmas Island.
Exploration Activity[2]	► Mineral exploration expenditures by mining companies in Australia in 2020 totalled USD$1.4 billion. ► As of September 2021, there were a total of 535 mineral projects at the advanced exploration stage in Australia, the majority of which were gold, coal, and iron projects. ► Australia is home to several battery minerals projects, including three for cobalt, five for lithium, eight for graphite, and 35 for nickel.
Critical Minerals Approach/Strategy[3]	► Australia is a major producer and exporter of mineral commodities, but a relatively small consumer. As of 2019, mineral exports accounted for slightly less than 60% of all export merchandise, and 12% of the gross domestic product (GDP). ► The long-term sustainability and investment exploration projects are a priority for the Australian mining sector as it has the potential to provide a stable supply of critical materials to other major jurisdictions. ► 23 minerals are listed in Australia's Critical Minerals Strategy 2019, which is designed to enable mineral sector program planning and contribute to the development of Australia's mineral resources. ► Regarding minerals on Ontario's critical minerals list, Australia is currently the leading global producer of lithium and zirconium, and one of the top 5 global producers of cobalt, REEs, uranium, and zinc.

European Union

Mineral Production[4]	► The EU is an important producer of chromium, copper, lead, silver, and zinc. ► EU countries that have active metallic mines include Austria, Finland, Greece, Ireland, Poland, Portugal and Sweden.
Exploration Activity	► As of September 2021, there were a total of 91 mineral projects at the advanced exploration stage in the EU, the majority of which were gold, copper, and zinc projects.[5] ► There are several projects in battery materials, including seven lithium projects, four nickel projects, two graphite, and one cobalt project.[6] ► Finland has a diverse mineral resource endowment, possessing reserves of cobalt, copper, nickel, chromium, PGE, among others.[7]
Critical Minerals Approach/Strategy[8]	► EU's 2020 Critical Raw Materials list includes 30 commodities, most of which are not sourced domestically, and for 10 of these, China is the leading supplier. ► EU's critical materials approach highlights the importance of access to resources needed for climate neutrality goals. To enhance the EU's resilience, the European Commission developed the Raw Materials Information System with reference knowledge on raw material sources. ► The EU's action plan for critical raw materials is being developed to build resilient value chains, reduce dependency on external sources, and diversify the supply of resources. In particular, the EU is considering increasing use of recycled raw materials. ► On June 14, 2021, Canada and the EU announced a new strategic partnership around critical minerals supply chains targeted at securing sustainable sources of materials that are essential to advanced manufacturing industries.[9]

Sources: [1] Geoscience Australia [2] S&P Capital IQ [3] Geoscience Australia [4] European Commission [5,6] S&P Capital IQ [7] European Commission, Raw Materials Science Hub [8] European Commission [9] Government of Canada "Joint Statement by Canada's Minister of Natural Resources and the European Commissioner for Internal Market"

Mineral Potential

Key Observations

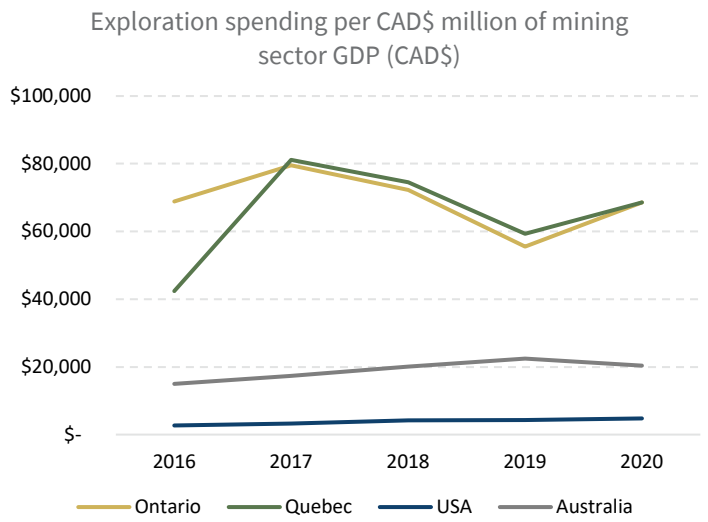
- Mineral potential is a key factor in mining competitiveness, and Ontario makes up a considerable proportion of critical mineral reserves in Canada.
- Over a half of Canada's PGE reserves are in Ontario (51%); more than a third of total nickel reserves (38%) and 13% of total graphite reserves - two of the key minerals used in EV batteries - are found in Ontario.
- Ontario's exploration intensity (as measured in exploration spending per million dollars of mining sector GDP) is on par with that of Quebec and is significantly higher than that of the US and Australia.
- There are 31 critical mineral projects in Ontario currently at advanced stages, compared to 34 in Quebec, 43 in the US, and 155 in Australia.
- Similar to other jurisdictions, Ontario's mineral production pipeline is expected to support the development of renewable and advanced manufacturing technology.

Critical Mineral In-Situ Value: Reserves,* 2021

Mineral	Ontario	Quebec	USA	Australia
	USD$, million			
Nickel	24,601	44,302	4,601	141,683
PGE	16,173	3,221	29,660	2,450
Copper	9,425	2,811	379,031	162,002
Cobalt	1,317	4,125	1,182	21,418
Zinc	1,096	2,871	19,954	53,199
Graphite	466	2,004	-	4,011
Chromite	-	-	1,487	-
Phosphate	-	52,487	58,120	20,494
Niobium	-	61,793	10,618	3,012
Lithium	-	7,430	5,433	61,317
Molybdenum	-	-	67,580	5,692
Vanadium	-	-	-	39,568
Titanium	-	-	5,195	46,500
Tungsten	-	-	-	8,363
Antimony	-	-	495	137

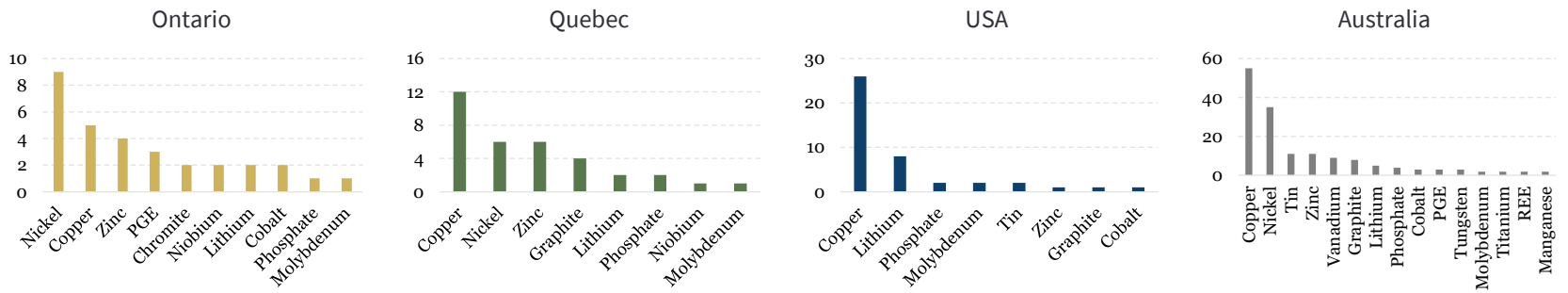
Source: S&P Market Intelligence. Note: *critical minerals are defined in the Ontario preliminary critical mineral list. The full list of mineral reserves is included in the Appendix C.1

Exploration Intensity



Source: Natural Resources Canada, S&P, Statistics Canada

Number of Projects at Advanced Stages, as of 2021



Source: S&P. Note: advanced stages include projects that are under feasibility (started and completed) and reserve development stages

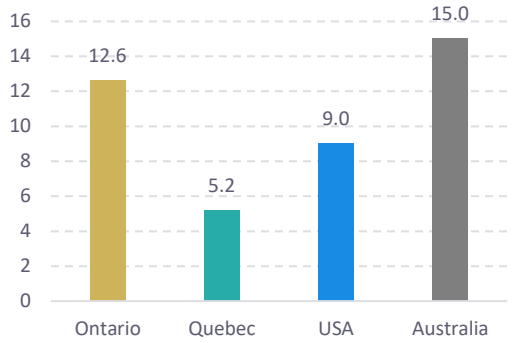
Cost of Doing Business & Quality of Infrastructure

Key Observations

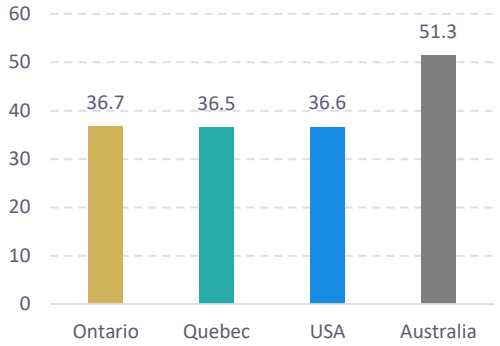
- Utilities and labour costs are some of the key inputs into mining operations. These costs are variable depending on the region of operations.
- Ontario's average electricity cost is higher than in Quebec or the US, but lower than in Australia.
- Average wages in Ontario, Quebec, and the US were almost equivalent in 2018, with Australia's being significantly higher.
- Corporate income tax in Ontario is slightly higher than in the US but lower than in Australia.
- According to the World Bank's logistics performance index, Canada is ranked lower than Australia and the US.
- Additionally, in stakeholder interviews conducted for this study, mining companies operating in Ontario have highlighted the lack of infrastructure, in particular, in the Northern regions of the province, in contrast to Quebec.
- Canada's spending on public geoscience information per million of dollars of mining sector GDP is also significantly lower than those in Australia or the US.

Cost of Doing Business

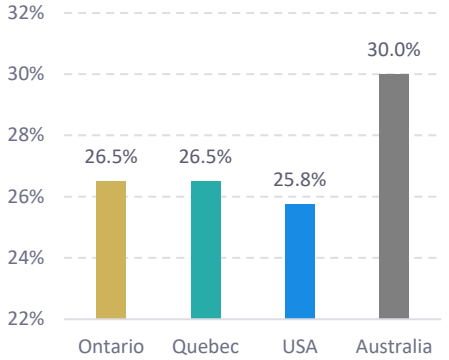
Electricity Cost, 2019 (CAD$ cents/kWh)



Average Hourly Earnings for Employees in Mining Sector (CAD$/hour)



Corporate Income Tax, 2021



Sources: Statistics Canada, Australian Bureau of Statistics, Bureau of Labor Statistics

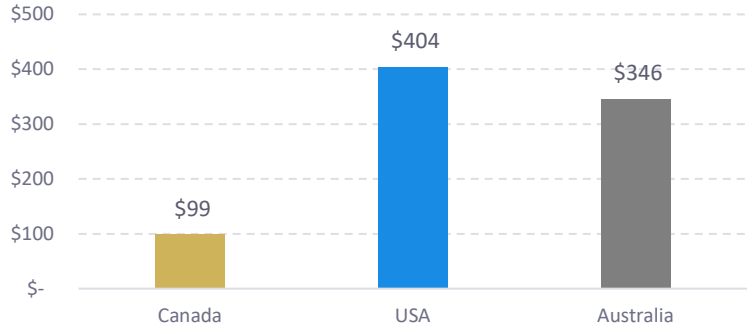
Quality of Infrastructure

Performance of the Logistics Network Index, 2018 (scale of 1-5)

Indicator	Canada	USA	Australia
Customs	3.6	3.8	3.9
Infrastructure	3.8	4.1	4.0
International shipments	3.4	3.5	3.3
Logistics competence	3.9	3.9	3.7
Tracking and tracing	3.8	4.1	3.8
Timeliness	4.0	4.1	4.0
Rank (out of 160 countries)	20	14	18

Source: World Bank

Quality and Availability of Public Geoscience Information (spending per CAD$ million of mining sector GDP)



Sources: Geoscience Australia, NRCAN, USGS

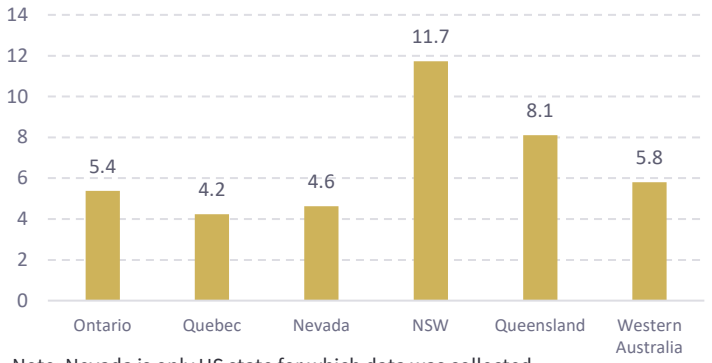
Regulatory Costs & Financial Incentives

Key Observations

- In stakeholder interviews conducted for this study, Ontario's mining companies have indicated that the permitting process in the province is uncertain, expensive, and lengthy compared to other leading mining jurisdictions.
- Findings from the Fraser Institute's Annual Survey of Mining Companies show that on average permitting takes longer in Ontario than in Nevada, or Quebec. However, permitting times tend to be longer in Australian states.
- Cost to import and cost to export, including necessary border and documentary compliance, is highest in Australia, followed by Canada and the US.
- To attract investment to the mining sector, some jurisdictions are offering financial incentives, including tax credits and/or grants.
- Financial incentives for Canadian and Australian jurisdictions are shown in the table on the right-hand side. No federal tax advantages or incentives specific to the mining sector seem to be in place in the US.

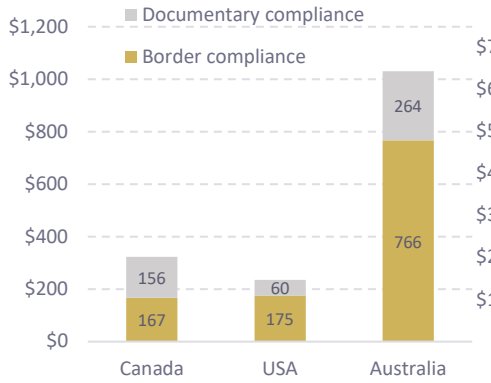
Regulatory Costs

Average Permitting Time, 2020 (months)

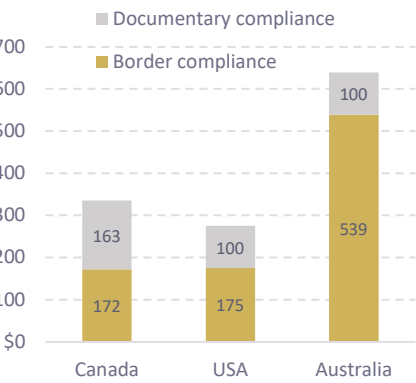


Note: Nevada is only US state for which data was collected
Source: Fraser Institute, Annual Survey of Mining Companies

Cost to Export, 2018 (USD$)



Cost to Import, 2018 (USD$)



Source: World Bank

Financial Incentives

Canada	Australia
Federal - Canadian Exploration Expenses (CEE) - Flow-Through Shares (FTS) - The Mineral Exploration Tax Credit (METC) - Prospector's and Grubstaker's Shares Deduction	Federal - Junior Minerals Exploration Incentive - Industry Growth Centres Initiatives
Ontario - Flow-Through Share Tax credits - Prospector Grants - Ontario Junior Exploration Program (OJEP)	New South Wales (NSW) - New Frontiers Exploration Initiative (NFEI)
Quebec - Flow-Through Share Tax Deductions - Tax credit relating to resources - Mining tax regime exploration provisions - Venture capital for mineral exploration and development	Queensland - Strategic Resources Exploration Program (SREP) - Collaborative Exploration Initiative
	Western Australia - Exploration Incentive Scheme (EIS)
	Victoria - TARGET Minerals Exploration Initiative

Note: Descriptions of the incentives are provided in Appendix C.2

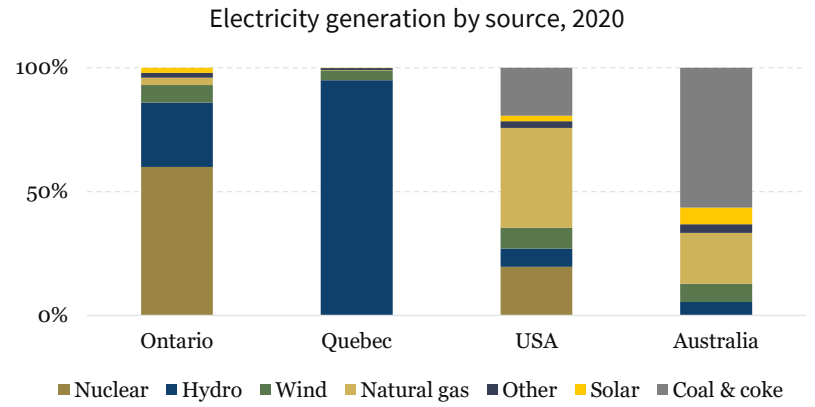
Sources: Prospectors & Developers Association of Canada (PDAC), Australian Taxation Office, NSW Government, Queensland Government, Government of Western Australia, Victoria State Government

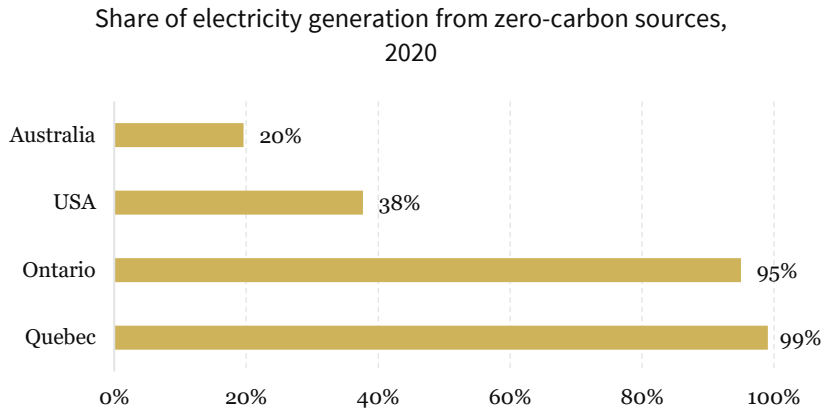
Energy Source, R&D Intensity, and Processing Capabilities

Key Observations

- Mining is energy intensive, therefore electricity generation contributes to the sector's overall carbon footprint
- Nearly 95% of electricity in Ontario is produced from zero carbon sources, including nuclear, hydro, wind and solar. This is slightly lower than Quebec, where close to 100% of electricity is generated from zero carbon sources.
- In comparison, electricity in the US and Australia is mainly produced from fossil fuels.
- Mining technology and innovation is an important driver of productivity growth and improvement in health and safety. Based on the most recent data available (from 2018), enterprise-level R&D intensity in Ontario's mining sector was at around the same level compared to other jurisdictions.
- There are currently 11 critical mineral processing facilities in Ontario (e.g., refineries and smelters).

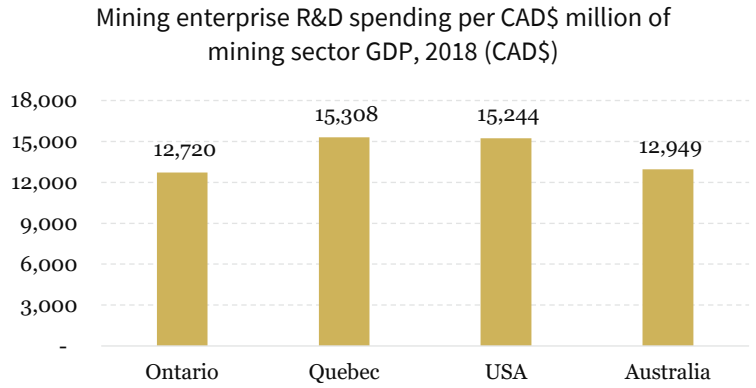
Energy Source





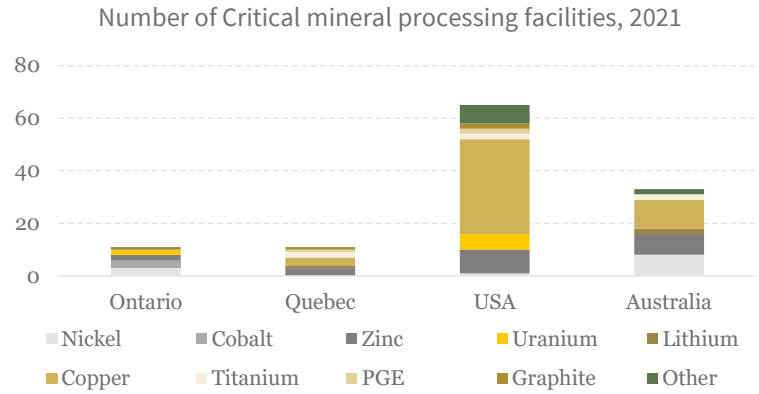
Source: Canada Energy Regulator, US Energy Information Administration, Australia Department of Industry, Science, Energy and Resources

Enterprise R&D Intensity



Source: The Organisation for Economic Co-operation and Development (OECD)

Domestic Processing Capabilities



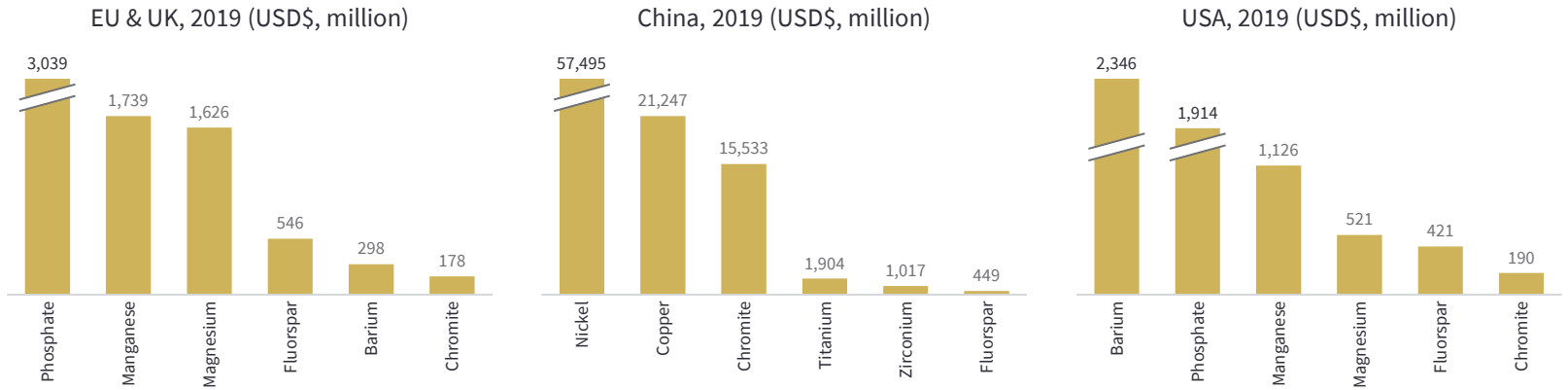
Source: S&P

Ontario's Competitive Advantages

Key Observations

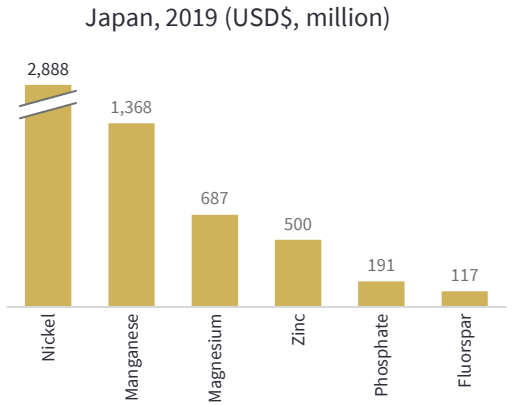
- Trade balance measures the difference between the value of a country's exports and imports. Net import indicates a country imports more goods from other countries than it exports.
- Analysis of global trade data suggests that jurisdictions with significant manufacturing capabilities import large quantities of critical minerals from foreign producers.
- Combining trade analysis with Ontario's critical mineral reserves and future project pipeline, five critical minerals with high market potentials are identified. Of those, nickel and chromite appears to have the highest potential given their strong and growing demand in key markets, as well as significant reserves and robust project pipeline. In particular, Ontario may likely become the only North American source for chromium.
- It is worth noting that phosphate often occurs in the same deposits as niobium and REEs. Boosting phosphate exploration investment in Ontario could also provide opportunities for new discoveries of niobium and REEs.

Net Imports of Select Critical Minerals Among Jurisdictions with Significant Manufacturing Capabilities



Source: The United Nations (UN) Comtrade. Note: Trade statistics include stage one & two minerals (i.e., mined, smelted and/or refined materials). A full list of net imports statistics is presented in the Appendix C.3.

Net Imports (Cont'd)



Source: UN

Ontario's Market Potential

Mineral	Nickel	Phosphate	Chromite	Copper	Zinc
Demand in key markets	Very high Japan and China are major net importers	High EU & UK and Japan are net importers	High EU & UK and USA are net importers	Very high China is a major net importer	Moderate Japan is a net importer
Ontario's mineral reserves	High USD$207.7b in reserves	Moderate USD$13b in reserves	High USD$61.8b in reserves; not found in USA or Australia	Moderate USD$39.6b in reserve	Moderate USD$11b in reserve
Ontario's project pipeline	9 advanced projects	1 advanced project	2 advanced projects	5 advanced projects	4 advanced projects

Ontario's Competitiveness and Potential Market Opportunities

On a global scale, Ontario's mining sector has a number of competitive advantages, including strong mineral endowment and exploration potential, and the ability to contribute to the transition to the green economy.

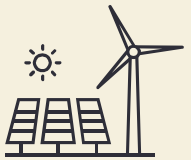
The province can leverage its endowment to become one of the leading global suppliers of critical materials to other jurisdictions whose advance manufacturing sectors are reliant on imports.

Mineral Potential

- Diverse mineral endowment is possibly Ontario's strongest competitive advantage
- Of the 30 minerals included on Ontario's critical minerals list, 8 are currently produced and/or processed with many active advanced exploration projects
- As of 2020, exploration intensity in the province was significantly higher than in Australia and the US, and on par with Quebec

Policy and Business Climate

- Globally, Ontario is one of the few sustainable and politically stable critical mineral suppliers
- Business costs, permitting times, and cost to export/import are more competitive than those in Australia
- 95% of the electricity in Ontario comes from zero-carbon sources as opposed to 20% in Australia
- Ontario offers financial incentives for mining companies, including OJEP, tax credits and prospector grants



Green Energy and Technologies

- Ontario's mineral production and exploration activities support the development of green technologies; this may contribute to the development of clean domestic manufacturing industries and export markets
- For instance, Ontario currently produces nickel, cobalt, and copper, which are key inputs for batteries and FCs
- Selenium and tellurium, used in solar PVs, are also produced in the province

Global Demand and Markets

- As the exploration takes place in the "Ring of Fire", Ontario will likely become the only North American source of chromium, which is a key input in the US steel industry
- Ontario has significant nickel reserves and a robust project pipeline that includes 9 advanced projects, making Ontario a strong contender in supplying nickel to countries with strong Li-ion battery manufacturing capabilities, such as China and Japan

Sources: Expert analysis and Stakeholder Interviews

6. Critical Mineral Profiles

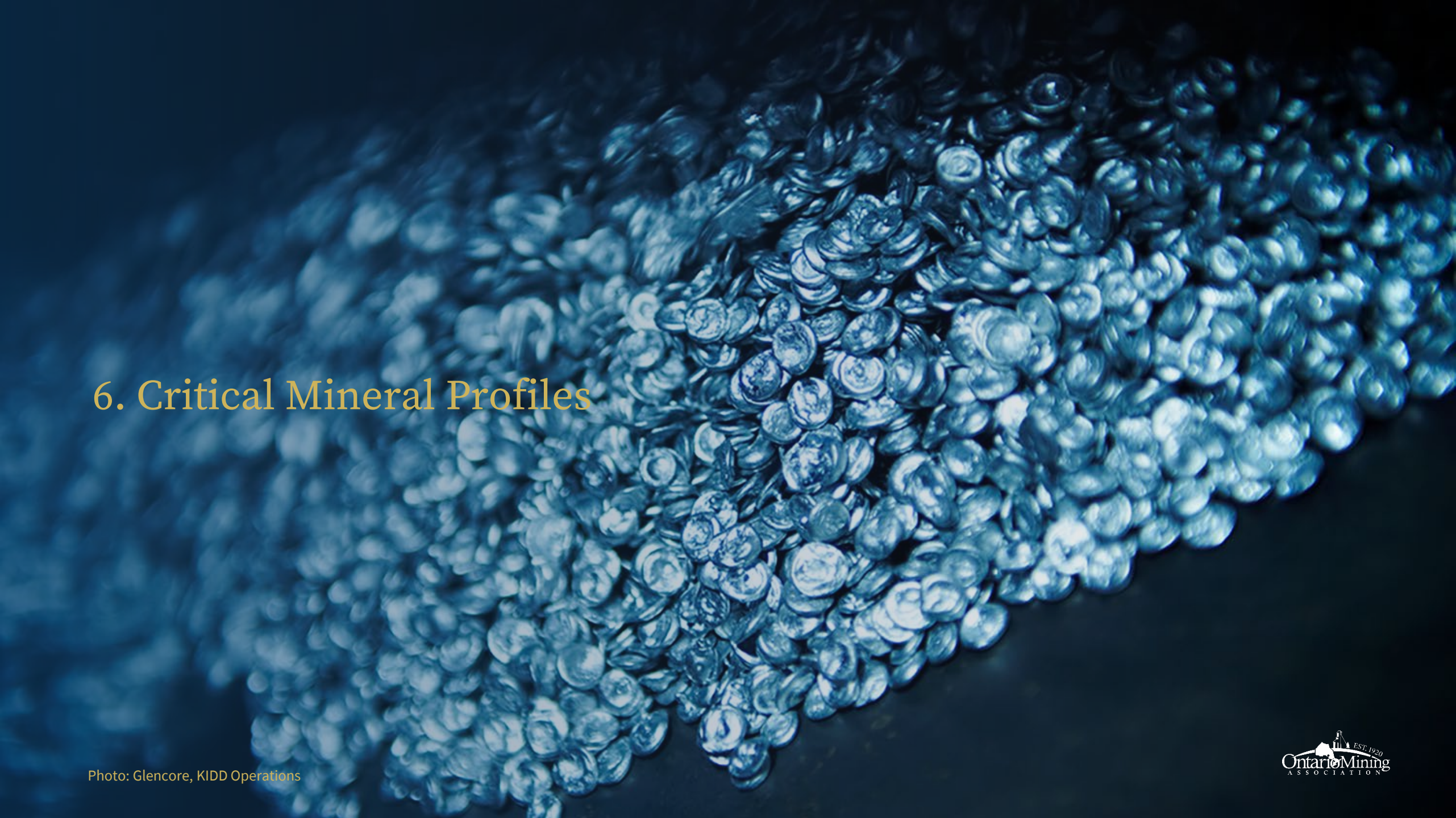


Photo: Glencore, KIDD Operations

Ontario's Critical Minerals

In this section of the study, key economic indicators were collected and analyzed for each mineral on Ontario's draft critical minerals list. The table below highlights the minerals included in the analysis and their production status in Ontario.

Status in Ontario

Exploration Potential	Advanced Mineral Projects	Not a Critical Mineral (excluded from the analysis)
Produced and/or Processed	Processed Only	

H Hydrogen															He Helium
Li Lithium	Be Beryllium										B Boron	C Carbon (Graphite)	N Nitrogen	O Oxygen	F Fluorine (Fluorspar)	Ne Neon
Na Sodium	Mg Magnesium										Al Aluminium	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine	Ar Argon
K Potassium	Ca Calcium (Fluorspar)	Sc Scandium	Ti Titanium	V Vanadium	Cr Chromium	Mn Manganese	Fe Iron	Co Cobalt	Ni Nickel	Cu Copper	Zn Zinc	Ga Gallum	Ge Germanium	As Arsenic	Se Selenium	Br Bromine	Kr Krypton
Rb Rubidium	Sr Strontium	Y Yttrium	Zr Zirconium	Nb Niobium	Mo Molybdenum	Tc Technetium	Ru Rutherium	Rh Rhodium	Pd Palladium	Ag Silver	Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine	Xe Xenon
Cs* Cesium	Ba Barium	57-71 **	Hf Hafnium	Ta Tantalum	W Tungsten	Re Rhenium	Os Osmium	Ir Iridium	Pt Platinum	Au Gold	Hg Mercury	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine	Rn Radon
Fr Francium	Ra Radium	89-103 **	Rf Rutherfordium	Db Dubnium	Sg Seaborgium	Bh Bohrium	Hs Hassium	Mt Meitnerium	Ds Damstadium	Rg Roentgenium	Cn Coepernicum	Uut Ununtrium	Fl Flerovium	Uup Ununpentium	Lv Livermroium	Uus Ununseptium	Uuo Ununoctium

La Lanthanum	Ce Cerium	Pr Praseodymium	Nd Neodymium	Pm Promethium	Sm Samarium	Eu Europium	Gd Gadolinium	Tb Terbium	Dy Dysprosium	Ho Holmium	Er Erbium	Tm Thulium	Yb Ytterbium	Lu Lutetium
Ac Actinium	Th Thorium	Pa Protactinium	U Uranium	Np Neptunium	Pu Plutonium	Am Americium	Cm Curium	Bk Berkelium	Cf Californium	Es Einsteinium	Fm Fermium	Md Mendelevium	No Nobelium	Lr Lawrencium

*Due to data limitation, cesium is not included.

Antimony

Status in Ontario: Exploration Potential

Description and Key Facts

Antimony in its elemental form is a silvery white, brittle crystalline solid that exhibits poor electrical and heat conductivity properties. It is relatively rare in the Earth's crust.[1]

- No antimony production has occurred in Ontario in the past 5 years. Nationally, production takes place in Quebec; additionally, significant deposits have been discovered in Newfoundland and Labrador (NL), including at the Beaver Brook Mine near Gander, NL.
- Leading uses of antimony include flame retardants, metals products, and ceramics and glass.
- China is the largest producer of antimony, making up 50% of the world's total production.
- China is Ontario's largest import partner, accounting for 85% of Ontario's antimony imports.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Found in more than 100 mineral species, typically with elements such as mercury, silver, and gold	• Unwrought metal • Oxides • Powders	• Flame retardants • Lead-acid batteries • Lead alloys • Plastics, grass, ceramics	• Chemical products • Electrical equipment • Fabricated metal products

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

1.8 tonnes
Canadian production in 2020[3]

Antimony has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Thunder Bay North
- Kenora
- Timmins

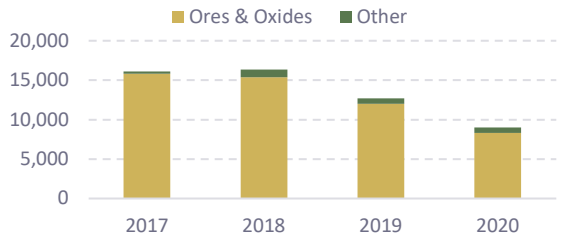
Ontario's Trade Balance: Importer

Top Import Partner: China (85%)

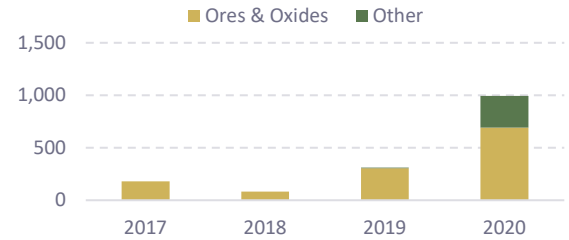
Top Export Partner: United States (99%)

Note: Trade balance total across years 2017-2020

Antimony Imports (CAD$, thousands)[5]



Antimony Exports (CAD$, thousands)[6]



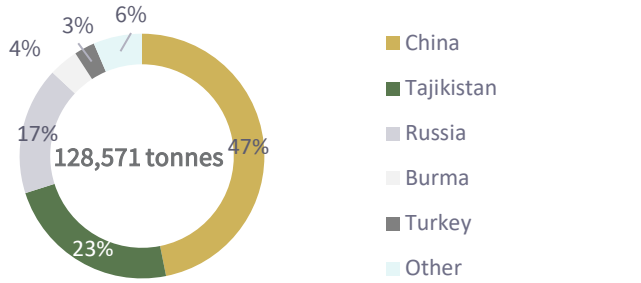
Note: HS codes include 261710, 282580, 811010, 811020, 811090

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	480,000
2. Russia	350,000
3. Bolivia	310,000
4. Kyrgyzstan	260,000
5. Australia	140,000
6. Turkey	100,000
Total*	1,900,000

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Ores	Refined Metal	Oxides
Laos (171.6K)	China (13K)	China (42.1K)
Russia (23.7K)	India (2.2K)	Belgium (9.6K)
Ukraine (12.0K)	Mexico (1.6K)	France (9.2K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal	Oxides
China (65.9K)	Belgium (8.2K)	Germany (4.7K)
Russia (17.9K)	USA (6.7K)	Italy (4.2K)
Japan (10.3K)	Spain (2.3K)	India (4.1K)

Sources: [1] USGS [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study [8] USGS [9] BGS, [10,11] UN Comtrade Database

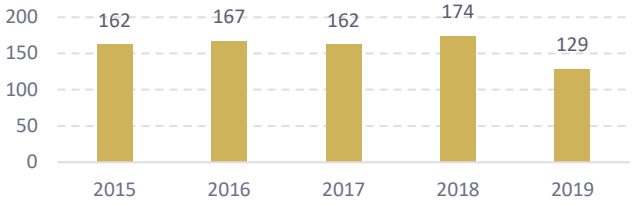
Antimony

Status in Ontario: Exploration Potential

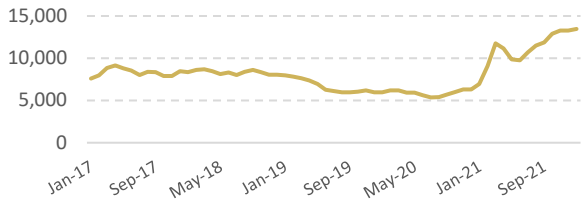
Market Conditions

- Price: Over the last five years, the price of antimony ranged from ~USD$5,000 to ~USD$13,000 per tonne. Price has risen considerably in 2021, primarily driven by reduced supply resulting from disruptions due to the COVID-19 pandemic.
- Production: China is the leading producer of antimony and accounts for nearly half of the total global supply. Global production has seen a decline in 2019, mostly due to the Chinese government's mining industry reforms, which aims to reduce mine overproduction.[1]

Global Antimony Mine Production (kilo-tonnes)[1]



Antimony Price, 99.65% CIF NEW (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Antimony is on the critical mineral list of 6 major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Moderate): Compounds of chromium, tin, titanium, zinc, and zirconium can be substituted for antimony in the manufacturing of pigments and glass, but is harder to substitute in its main application, as a flame retardant. While compounds such as alumina trihydrate can partially substitute for this use, they are inferior to antimony-based flame retardants.[6]

Use in strategic downstream industries: Antimony is primarily used in the manufacturing industry due to its hardness and strength and ability to act as a flame retardant.[7]

Geopolitical factors: 47% of the antimony production occurs in China. According to World Bank Governance indicators, the country is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] Consequently, political factors could influence demand and supply via trade war related pressures.

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Due to the COVID-19 pandemic and the consequent tight supply of raw materials, operations at China's refineries were constrained. As a result, prices are expected to remain elevated.[3]	A new antimony plant in Oman with an annual capacity of 20,000 tonnes is coming online. Additional supply means price outlook will remain neutral over the medium-to- long term.[4]	Antimony is mainly used as a flame retardant. Near-term demand will be propped up by increasingly stringent fire regulations in many parts of the world.[5]	Due to environmental considerations, the use of antimony in lead-acid batteries is expected to be displaced by tin alloys over the medium-to-long term.[6]

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

- More than 87% of the current mine production is concentrated in China, Tajikistan, and Russia
- Antimony is moderately substitutable; therefore, supply chain disruptions in manufacturing industries could be mitigated
- Imports from China is Ontario's primary source of antimony; 85% reliance on China's supplies, and limited Canadian production may pose a relatively high supply chain risk to Ontario's industries

Opportunities for Ontario

- Ontario's antimony resources and exploration potential may provide an opportunity for the province to supply the mineral to local downstream industries, and to other jurisdictions, including current top global importers
- As antimony is not currently produced in the US or the EU, Ontario can become one of the key sources of the mineral for major jurisdictions that include this mineral on their critical minerals lists

Sources: [1] BGS and USGS [2] S&P Global Market Intelligence [3] S&P Global Market Intelligence, [4] USGS, [5] Critical mineral lists of major jurisdictions , [6] EU Critical Minerals Study, [7] USGS, [8] World Bank

Barite

Low — Economic importance

Low — Supply risk

Status in Ontario: Advanced Mineral Projects

Description and Key Facts

Barite is an abundant and economically important mineral produced worldwide. It is a naturally occurring barium sulphate mineral; it is inert, non-toxic, has a high density, high fusion point and brightness, and low oil absorption.[1]

- No significant barite production has been reported in Ontario in the past 5 years, however, barite is produced in BC. Major projects include the Fireside Mine in BC.
- The global leader in mine production is China, making up 31% of global supply in 2019.
- The oil and gas industry is the main user of barite, where it is used as a weighting agent in drilling
- Ontario is a net importer of barite, and the US is Ontario's top import and export partner for the mineral.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Barite ores	• Barite aggregates • Ground barites • Micronized barite • Blanc fixe (barium sulphate)	• Weighting agent • Heavy filler • Barium oxide • Barium carbonate • Barium metal	• Oil and gas industry • Automotive • Rubber, paints, and plastic • Electronics

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

No public data on Canadian production in 2020[3]

Barite has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Kirkland Lake
- Timmins
- Sudbury

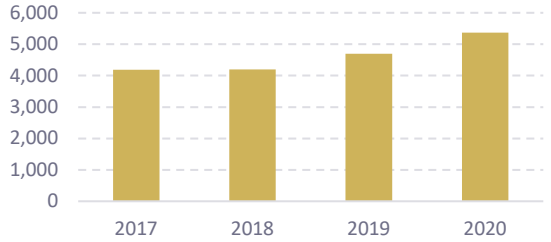
Ontario's Trade Balance: Importer

Top Import Partner: United States (49%)

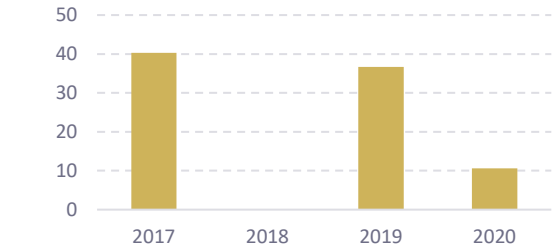
Top Export Partner: United States (95%)

Note: Trade balance total across years 2017-2020

Barite Imports (CAD$, thousands)[5]



Barite Exports (CAD$, thousands)[6]



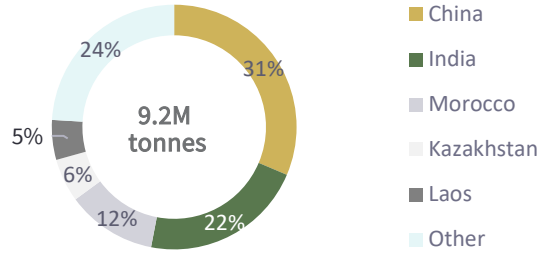
Note: HS codes include 251110, 251120, 283327, 283660

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Iran	100M
2. Kazakhstan	85M
3. India	51M
4. Pakistan	40M
5. China	36M
6. Turkey	35M
Total*	390M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Carbonates	Oxides	Sulphates
China (104K)	USA (0.9K)	India (1.9M)
India (20K)	France (0.1K)	China (1.2M)
USA (3.5K)	Brazil (0.1K)	Morocco (1.1M)

Top Importers (2019, tonnes)[11]

Carbonates	Oxides	Sulphates
France (16.9K)	Kuwait (41.3K)	USA (2.4M)
Japan (7.4K)	Nigeria (5K)	Saudi (634K)
Mexico (5.4K)	Guyana (0.6K)	Kuwait (209K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS [9] BGS, [10,11] UN Comtrade Database

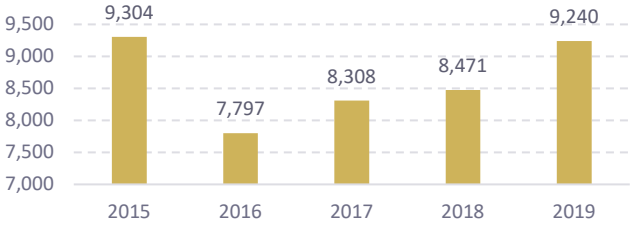
Barite

Status in Ontario: Advanced Mineral Projects

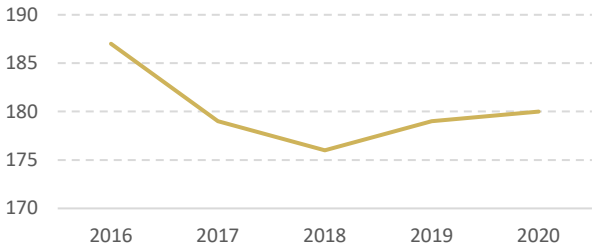
Market Conditions

- Price: Barite prices have remained stable over the recent years, ranging from USD$176 to USD$187 per tonne. Ample supply from major producers is a key contributor to relatively stable prices.
- Production: China, India and Morocco are three of the largest producers, with a combined market share of close to 65%. Barite is primarily used as a weighting agent for fluids used in the oil and gas drilling, and its production level closely follows global energy trends.[1]

Global Barites Minerals Production (kilo-tonnes)[1]



Barite Price (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Barite is on the critical mineral list of two other major jurisdictions: EU, and US.[7]

Substitution (Moderate): As a weighting agent for the oil and gas industry, hematite, ilmenite, and calcium carbonate could be used but would be less economical. For fillers, the main substitutes are clays, but they do not match in heaviness, sound proofing, and radiation shielding. There are no substitutes for medical applications or dielectrics.[8]

Use in strategic downstream industries: The use of barite can be found in industries such as oil and gas, automotive, and chemicals.[9]

Geopolitical factors: 71% of barite production occurs in China, India, Morocco, and Kazakhstan. According to World Bank Governance indicators, the countries are all ranked in the bottom half according to a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[10] Consequently, political factors could influence demand and supply via trade war related pressures, lack of formal trade agreements, and lack of transparency associated with production processes.

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	↘	→	↘
With the global economy recovering from the pandemic, oil demand is expected to pick up again. However, excess capacity suggests exploration activity may not revert to pre-pandemic levels.[3]	Implementation of decarbonization policies and electrification in the automotive industry will reduce overall demand for oil, and thus have a negative impact on barite demand.[4]	Given its role in oil & gas exploration, demand for barite may be muted over the near-term. However, as the global economy continues to recover, demand may trend upwards again.[5]	Reliance on oil will likely decrease with the implementation of decarbonization policies in major economies. This will result in moderation of demand for barite.[6]

Legend: → Neutral; ↗ Positive; ↘ Negative

Key Takeaways

Supply chain risks

- Global barite production is relatively concentrated, but supply chain risk may be somewhat low
- Barite is on the critical minerals list of only two major jurisdictions
- There are a number of substitutes available for major barite applications
- Ontario is currently reliant on import sources of barite, primarily from the US
- Based on the combination of factors assessed, the supply risk for Ontario is relatively low

Opportunities for Ontario

- With advanced mineral projects underway in Ontario, the province has an opportunity to provide a stable and reliable supply of barite to the local and Canadian downstream industries, in particular to the oil and gas sector

Sources: [1] BGS and USGS [2, 9, 11] USGS, [3,4,5,6] EU critical raw materials factsheets and USGS [7] Critical mineral lists of major jurisdictions [8] EU: Critical Minerals Study [10] World Bank

Beryllium

Low — Economic importance

Low — Supply risk

Status in Ontario: Exploration Potential

Description and Key Facts

Beryllium is a lightweight, dark, silver-grey metal with high stability and conductivity. Cost of beryllium is high compared to other materials due to its unique properties and applications.[1]

- No significant production of beryllium has been reported in Canada in the past 5 years.
- The US is the global leader in beryllium production, as of 2019.
- Beryllium has applications in aerospace and defence, industrial components, automotive electronics and telecommunications infrastructure.
- Ontario is a net importer of beryllium, and the US is the largest import and export partner for the province.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Beryllium ores: two minerals, bertrandite and beryl, are necessary to ensure a stable supply of high-purity beryllium	• Oxides and hydroxides • Unwrought and powders • Alloys and master alloys	• Ceramics • Products from beryllium metal and alloys	• Electronics • Aerospace and Defence • Industrial components

Ontario Production and Trade Statistics

No Beryllium production in Ontario in 2020[2]

No Canadian production in 2020[3]

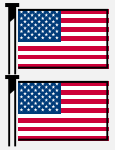
Beryllium has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Timmins
- Red Lake

Ontario's Trade Balance: Importer

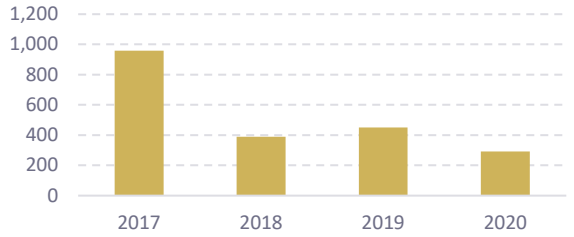
Top Import Partner: United States (85%)

Top Export Partner: United States (99%)

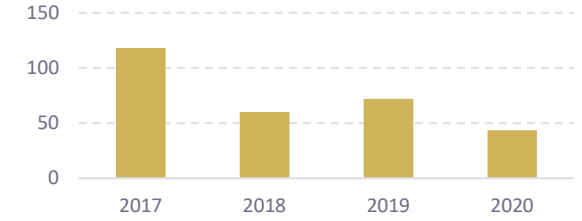


Note: Trade balance total across years 2017-2020

Beryllium Imports (CAD$, thousands)[5]



Beryllium Exports (CAD$, thousands)[6]



Note: HS codes include 811212, 811213, 811219

Global Production and Trade Statistics

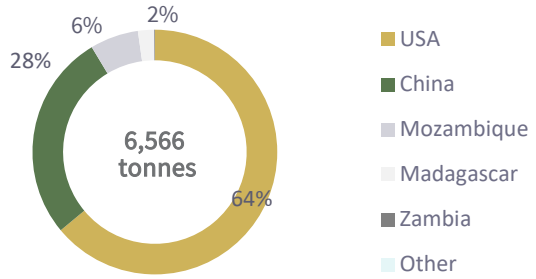
Reserves[8]

World beryllium reserve estimates are not available.

The US has very little beryl that can be economically hand sorted from pegmatite deposits. In Utah, an epithermal deposit, contains a large bertrandite resource, totalling about 20,000 tonnes of contained beryllium.

USGS estimates that total global production of beryllium is approximately 240 tonnes. Beryl is the mineral required to produce high-quality beryllium materials (oxides, metals, etc.).

Mine Production (2019)[9]



Top Exporters (2019, tonnes)[10]

Refined Metal

1. Malaysia (110)	4. Singapore (21)
2. Switzerland (85)	5. Kazakhstan (15)
3. USA (28)	6. UK (9)

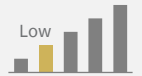
Top Importers (2019, tonnes)[11]

Refined Metal

1. Malaysia (66)	4. USA (33)
2. Poland (63)	5. Germany (27)
3. S. Africa (42)	6. Canada (19)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS [9] BGS, [10,11] UN Comtrade Database

Beryllium

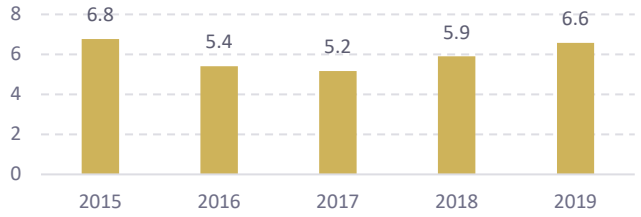


Status in Ontario: Exploration Potential

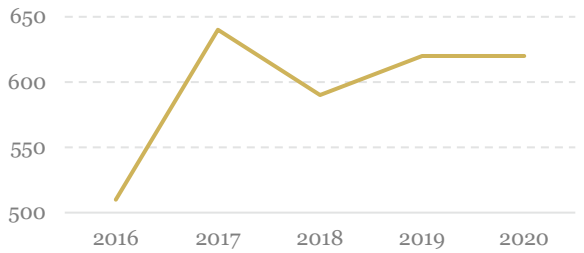
Market Conditions

- Price: Beryllium is traded through direct contracting between producers and end users. As such, its price is less transparent and can vary greatly depending on its form.[1]
- Production: USA and China combined produce nearly 95% of global beryllium ores. Refined beryllium is primarily supplied by the USA, Kazakhstan and Japan. Production level has remained relatively stable over time.[2]

Global Beryllium Mining Production (kilo-tonnes)[2]



Beryllium Price (USD$/kg)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Beryllium is on the critical mineral list of four major jurisdictions: EU, US, UK, and Australia.[5]

Substitution (Low): Substitution will always lead to loss of performance, and the share of applications in which beryllium can be substituted is less than 10%, especially in some applications in the defence, transportation and energy sectors.[6]

Use in strategic downstream industries: Key uses of beryllium are in the electronic and telecommunication equipment industry, and in transport/defence for auto and aerospace components.[7]

Geopolitical factors: 64% of the beryllium production occurs in the US , a country with which Ontario has an extensive historical trade relationship. Another 28% comes from China, which, according to World Bank Governance indicators, is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
As end users of beryllium, including defence, medical and semi-conductor processing equipment producers are less price sensitive, price is likely to remain elevated over the near-term.	Development of new nuclear reactor technology may drive higher demand for beryllium. Fewer suppliers and a lack of centralized market means prices will likely remain high.	Primary users of beryllium were impacted by the pandemic to a lesser extent, as such the demand outlook remains positive in the near-term.	As few substitutes exist in the defence, energy and semi-conductor industries, demand for beryllium is expected to grow in the medium-to-long term.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

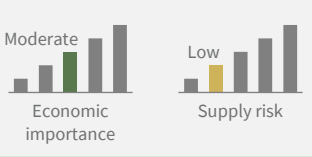
- Currently, production of beryllium is highly concentrated in the US and China, which may result in supply chain risks for other jurisdictions; however, given Ontario's extensive trade volume with the US, supply chain disruption risk for the province is relatively low
- Ontario's imports of beryllium are relatively low; however, it is an important element for priority manufacturing sectors such as aerospace and defence, electronics, and transportation

Opportunities for Ontario

- Ontario's beryllium exploration potential in several regions may provide an opportunity for the province to supply the mineral to the local downstream industries and to other jurisdictions, including current top global importers

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Bismuth



Status in Ontario: Exploration Potential

Description and Key Facts

Bismuth is a very brittle metal with pink metallic lustre. Among the heavy metals, it is the heaviest and the only non-toxic metal.[1]

- No significant production has been reported in Ontario. Quebec currently produces less than 5 tonnes of bismuth per year.
- Bismuth's low melting point makes it a unique alloying element, with applications in pharmaceuticals, fire-detection, refrigeration, and ceramics.
- Ontario is a net importer of bismuth, and the US is Ontario's top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• By-product of lead and tungsten	• Refined bismuth • Technical grade • Pharmaceutical grade	• Powders • Alloys • Chemicals	• Pharmaceutical and cosmetics • Ceramics and pigments

Ontario Production and Trade Statistics

No bismuth produced in Ontario in 2020[2]

3.7 tonnes
Canadian production value in 2020[3]

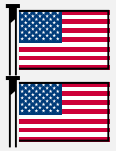
Bismuth has been discovered in the following districts:[4]

- Southeastern Ontario
- Kenora
- Timmins
- Sault Ste. Marie
- Sudbury

Ontario's Trade Balance: Importer

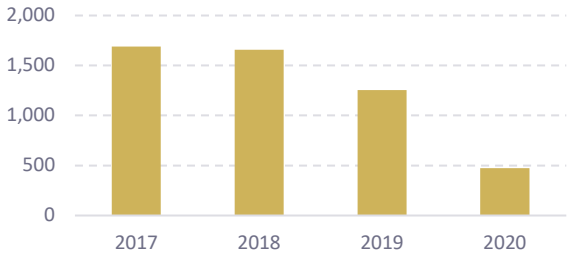
Top Import Partner: United States (41%)

Top Export Partner: United States (39%)

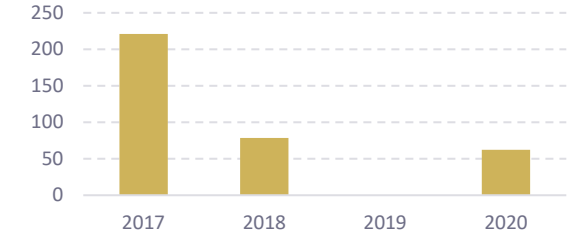


Note: Trade balance total across years 2017-2020

Bismuth Imports (CAD$, thousands)[5]



Bismuth Exports (CAD$, thousands)[6]



Note: HS codes include 810600

Global Production and Trade Statistics

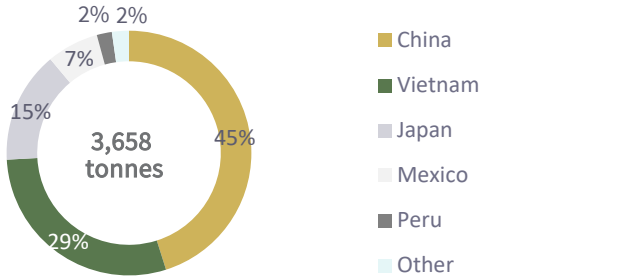
Reserves[8]

Quantitative estimates are not available, as bismuth reserves are usually estimated based on the bismuth content of lead resources.

In China and Vietnam, bismuth is produced as a by-product of tungsten and other ores.

There are only two primary bismuth mines, in China and Bolivia.

Mine Production (2019)[9]



Top Exporters (2019, tonnes)[10]

Refined Metal	
1. China (4.0K)	4. Hong Kong (1.4K)
2. Laos (1.8K)	5. S. Korea (0.9K)
3. Belgium (1.8K)	6. USA (0.7K)

Top Importers (2019, tonnes)[11]

Refined Metal	
1. USA (2.4K)	4. Germany (1.5K)
2. Belgium (1.6K)	5. Netherlands (0.6K)
3. Hong Kong (1.5K)	6. Italy (0.4K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS [9] BGS, [10,11] UN Comtrade Database

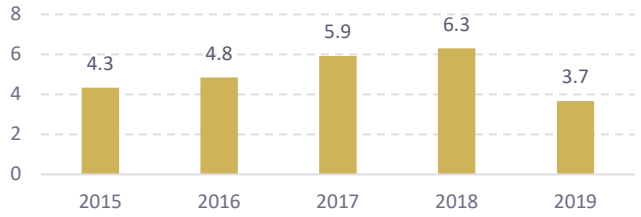
Bismuth

Status in Ontario: Exploration Potential

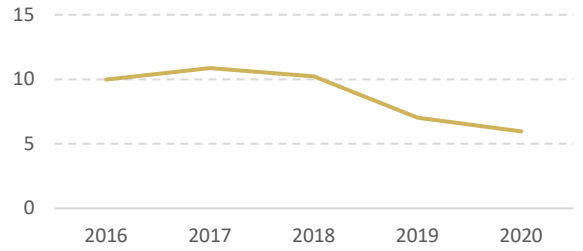
Market Conditions

- Price: Bismuth prices have trended downwards in recent years. Oversupply resulting from the sale of the significant bismuth stockpiles held by the now defunct Fanya Nonferrous Metals Exchange in China is the likely cause of the price slump.[1]
- Production: China is the dominant producer of bismuth metal, accounting for over 80% of global supply. New policies aiming to reduce the environmental footprint of mining activity in China have resulted in many smelters suspending production for inspections, leading to decreased production.[2]

Global Bismuth Mining Production (kilo-tonnes)[2]



Bismuth Price (USD$/kg)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Bismuth is on the critical mineral list of four major jurisdictions: EU, US, Canada, and Australia.[5]

Substitution (High): Substitutes exist in many applications. In pharmaceutical applications, it can be replaced by aluminum, calcium carbonate and magnesia. In pigment uses, by titanium dioxide-coated mica flakes, and in fire sprinklers, by glycerine filled glass tubes. Resins can replace bismuth alloys for holding metal shapes during machining.[6]

Use in strategic downstream industries: Uses of bismuth are widespread in the pharmaceutical, animal feed industries, and other manufacturing industries.[7]

Geopolitical factors: Almost three quarters of production occurs in Vietnam and China, ranked by the World Bank Governance indicators at 143rd and 144th respectively (out of 214 countries) in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] Vietnam in particular faces corruption as an obstacle for doing business in the country, and the use of facilitation payments are widespread.

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	↗	↗
It was announced that the significant stockpile in China will be used internally for manufacturing, which is expected to alleviate the oversupply and stabilize prices in the near-term.	Price of bismuth in the long term depends on development of new applications, substitutions in pharmaceutical and cosmetic and additional supplies coming online.	Solid demand in pharmaceutical and cosmetic applications will drive growth. As a non-toxic replacement for lead in brass, demand will increase as the US moves towards lead-free pipes.	There are emerging applications in semi-conductors and thermoelectric materials that could lead to the development of new semi-conductor compounds and alloys that contain bismuth.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

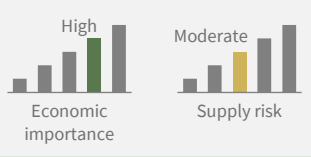
- Bismuth production is highly concentrated in three countries – China, Vietnam, and Japan, which may create moderate supply chain disruptions on a global scale
- Some substitution for bismuth exists; thus, in case of supply chain disruptions, some risks to manufacturing industries may be mitigated
- With Canadian production occurring in Quebec, Ontario does have access to a domestic source of bismuth; thus, the supply risk for the provincial industries is relatively low

Opportunities for Ontario

- Ontario's bismuth exploration potential in several regions may provide an opportunity for the province to supply the mineral to the local downstream industries, and to other jurisdictions, including current top global importers
- As the US currently does not produce bismuth and is dependent on imports from China, Ontario could become an alternative source due to its geographical proximity[9]

Sources: [1,9] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank [9] USGS

Chromite



Status in Ontario: Advanced Mineral Projects

Description and Key Facts

Chromite is the mineral source of the metal chromium. Chromium has a wide range of uses in metals, chemicals, and refractories. Its use in iron, steel, and nonferrous alloys improves hardenability and resistance to corrosion and oxidation.[1]

- There has been no chromite production in Canada to date, although junior mining companies have been actively exploring in Ontario over the past decade. South Africa is currently the global production leader, accounting for 46% of global supply in 2019.
- Substantial deposits of chromite has been found in Northern Ontario's "Ring of Fire" area. Two of the largest deposits discovered to date are the Blackbird deposit and the Black Thor deposit.[2]
- Ontario is a net importer of chromite (trade data groups chromite, magnesite and dolomite), with the US as its top import/export partner.

Value Chain[8]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Chromite ore and concentrates primary production	• Chromium chemicals • Ferrochromium • Chromium metal • Chromium oxide	• Chromium ferroalloys • Stainless steel • Superalloys	• Stainless steel products • Heat-resistant steel products • Automotive industry

Ontario Production and Trade Statistics

No chromite produced in Ontario in 2020[3]

No Canadian production in 2020[4]

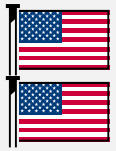
Chromite has been discovered in the following districts:[5]

- Thunder Bay North
- Thunder Bay South
- Southeastern Ontario
- Kirkland Lake
- Sault Ste. Marie
- Kenora
- Red Lake
- Timmins

Ontario's Trade Balance: Importer

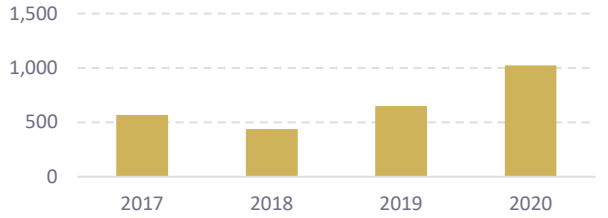
Top Import Partner: United States (28%)

Top Export Partner: United States (82%)

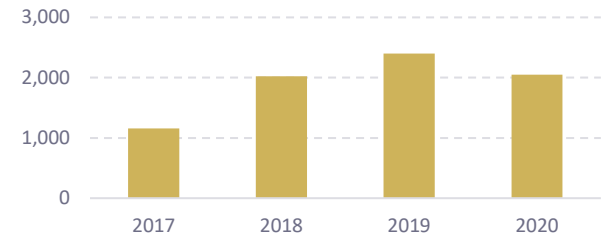


Note: Trade balance total across years 2017-2020

Chromite Imports (CAD$, thousands)[6]



Chromite Exports (CAD$, thousands)[7]



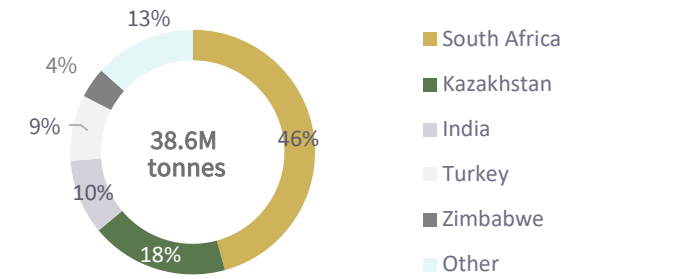
Note: HS code used is 6851591. This code groups all articles of chromite, magnesite, and dolomite. As no chromite is produced in Ontario, it is understood that the province is a net importer.

Global Production and Trade Statistics

Reserves[9]

Country	Tonnes
1. Kazakhstan	230M
2. South Africa	200M
3. India	100M
4. Turkey	26M
5. Finland	13M
6. USA	0.62M
Total*	570M

Chromium Ore Mine Production (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

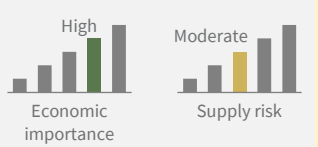
Concentrates	
1. South Africa (14.9M)	4. Zimbabwe (581K)
2. Turkey (1.3M)	5. China (358K)
3. Kazakhstan (699K)	6. Pakistan (335K)

Top Importers (2019, tonnes)[12]

Concentrates	
1. China (15.9M)	4. India (230K)
2. Russia (904K)	5. USA (211K)
3. Indonesia (447K)	6. Germany (193K)

Sources: [1] USGS, [2] Noront Resources [3,4] NRCAN, [5] Ontario Mineral Deposit Inventory, [6,7] Statistics Canada, [8] USGS, [9] USGS [10] BGS, [11,12] UN Comtrade Database

Chromite

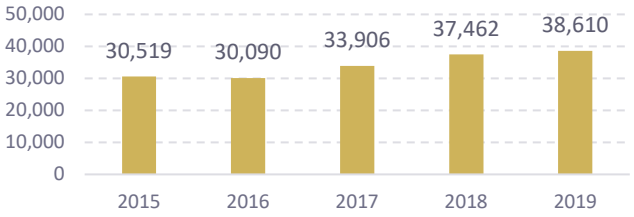


Status in Ontario:
Advanced Mineral Projects

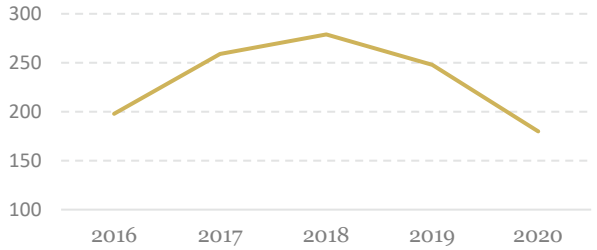
Market Conditions

- Price: Chromite prices have trended downwards in recent years, partly driven by a slowdown in China's construction and infrastructure investment. Production of ferrochromium is energy intensive and the chromite prices will be highly correlated with electricity costs.[1]
- Production: South Africa is the leading producer of chromite ore, making up over 45% of the global supply. The chromite production level has grown at a steady pace in the last five years.[2]

Global Chromium Ore Production (kilo-tonnes)[1]



Chromite Price, Ore (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Chromite is on the critical mineral list of four major jurisdictions: US, Canada, Japan, Australia.[5]

Substitution (Low): For its leading end use (steel), there are no substitutes. Neither are there any substitutes for the use of chromite as a superalloy.[6]

Use in strategic downstream industries: Chromium is used in the metallurgical, chemical, refractory materials, cast iron, and automobile industries.[7]

Geopolitical factors: Almost 65% of production occurs in South Africa and Kazakhstan, ranked by the World Bank Governance indicators at 82nd and 145th respectively (out of 214 countries) in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
As ferrochromium is highly energy intensive, constrained electrical power supply, rising energy costs, as well as public health measures in South Africa will likely result in price increases.	Price in the medium-to-long term will largely depend on the demand-supply balances. While demand is expected to continue to grow, abundant supply means price will likely remain stable.	Strong investment in infrastructure in China and the US as part of their economic development plan is expected to result in strong demand for ferrochromium, which is the key ingredient of stainless steel.	Chromium has no substitute in stainless steel production. Long-term outlook is likely positive, largely driven by growing housing construction and infrastructure investment.

Legend: Neutral; Positive; Negative

Key Takeaways

Supply chain risks

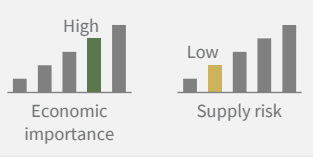
- Currently, there is no North American chromium production, and the majority of the global production takes place in South Africa and Kazakhstan
- China controls the world production of the intermediate product, ferrochrome, that is used by stainless steel producers
- Based on analysis of the combination of quantitative factors, supply chain disruption risks for downstream industries is estimated to be moderate

Opportunities for Ontario

- Ontario's endowment with chromite deposits in Northern Ontario provides an opportunity for mining companies in the province to engage in exploration activity and provide steady supply for domestic use as well as exports, primarily to the US
- With the Noront Resources Blackbird and Black Thor projects currently at the advanced mineral stage, and the potential Ferrochrome Production Facility in Sault Ste. Marie, Ontario may become the preferred chromite source for US steel producers

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Copper



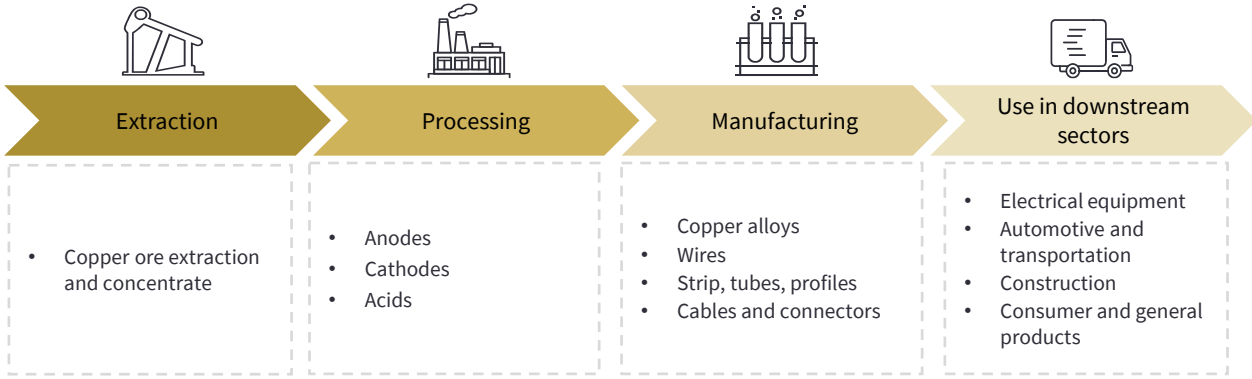
Status in Ontario: Produced/Processed

Description and Key Facts

Copper is usually found in nature in association with sulfur. Copper is one of the oldest metals ever used and historically has been one of the most economically important materials. It is widely used in electrical applications, such as power transmission and generation, wiring, etc.[1]

- Ontario is a major producer of copper, with almost $900 million worth of copper produced in 2020. As of 2021, Glencore's Kidd Creek Mine, Impala Platinum Holdings Ltd.'s Lac des Iles Mine, KGHM International Ltd.'s McCreedy West Mine, and Vale's Copper Cliff North Mine are active in Ontario.
- The mineral is produced in many jurisdictions around the globe, with China leading across copper products.
- Despite being home to several operating mines, Ontario has been a net importer of copper.

Value Chain[7]



Ontario Production and Trade Statistics

121,196 tonnes produced in Ontario in 2020[2]

$888M production value in 2020[3]

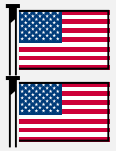
Copper has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Sault Ste. Marie
- Sudbury
- Kirkland Lake
- Kenora
- Timmins
- Red Lake

Ontario's Trade Balance: Importer

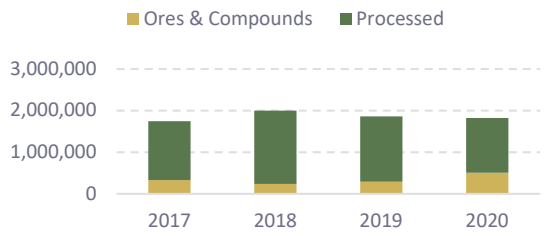
Top Import Partner: United States (16%)

Top Export Partner: United States (55%)

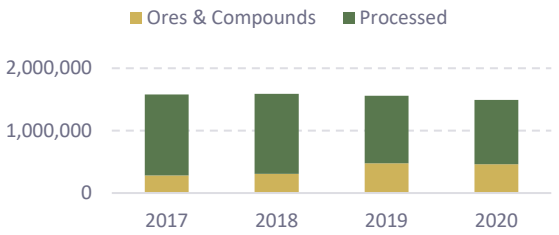


Note: Trade balance total across years 2017-2020

Copper Imports (CAD$, thousands)[5]



Copper Exports (CAD$, thousands)[6]



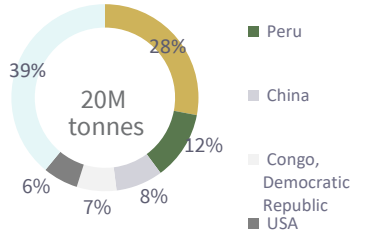
Note: HS codes include 260300, 283325, 740400, 740500, 740610, 740710, 740729, 740811, 740819, 740829, 740911, 741110, 741129, 741210 etc.

Global Production and Trade Statistics

Reserves[8]

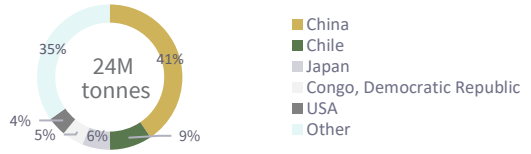
Country	Tonnes
1. Chile	200M
2. Peru	92M
3. Australia	88M
4. Russia	61M
5. Mexico	53M
6. USA	48M
Total*	870M

Mine Production (2019)[9]

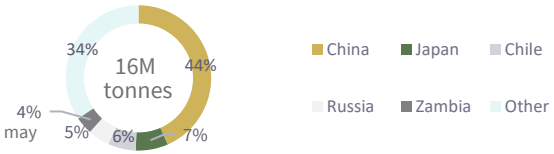


*Note: Total is for all countries, values in table may not add up.

Refined Production (2019)[10]



Smelted Production (2019)[11]



Top Exporters (2019, tonnes)[12]

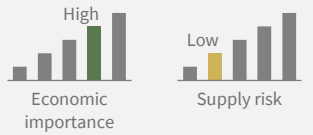
Ores	Refined Metal	Oxide
Chile (3.2M)	Chile (2.6M)	China (160K)
Australia (1.9M)	Germany (1.6M)	Germany (131K)
Mexico (1.6M)	DRC (1.2M)	Netherlands (21K)

Top Importers (2019, tonnes)[13]

Ores	Refined Metal	Oxide
China (22M)	China (6.5M)	Canada (52K)
Japan (4.8M)	Germany (1.5M)	China (9.5K)
S. Korea (1.7M)	India (0.9M)	S. Korea (6.6K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS, [8] USGS, [9,10,11] BGS, [12,13] UN Comtrade Database

Copper

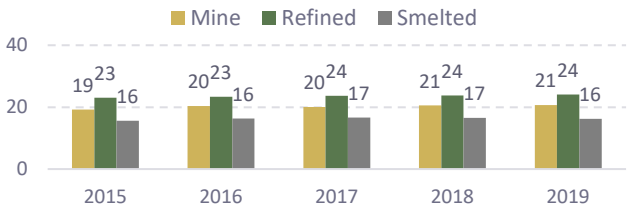


Status in Ontario: Produced/Processed

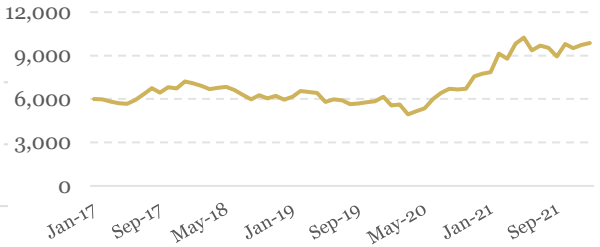
Market Conditions

- Price: After remaining relatively stable between 2016 and 2020, copper prices have reached a decade-high in 2021, largely driven by a surge in demand led by China, with investment in infrastructure and construction.[1]
- Production: Major new projects and expansions are expected to come online over the next five years in Chile, DRC, Indonesia and Peru, helping stabilize copper prices.[1]

Global Copper Production (million tonnes)[2]



Copper Price, Grade A Cash (USD$/tonne)[3]



Economic and Strategic Importance

Importance in other jurisdictions: Copper is on the critical mineral list of two major jurisdictions: Canada and Australia.[5]

Substitution (Low): While loss of performance is expected in all substitutes, some exist. For example, aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers.[6]

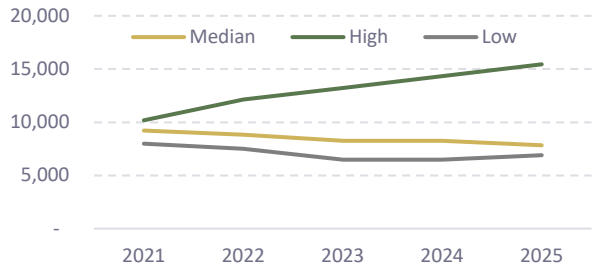
Use in strategic downstream industries: Copper is primarily used in construction, electronic manufacturing, transportation equipment, and consumer and general products.[7]

Geopolitical factors: Just over 40% of refined and smelted production of copper occurs in China, which is ranked 144/214 by the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness. The majority of reserves are in Chile, which is currently facing social unrest but is ranked 27th on the World Bank index.[8,9]

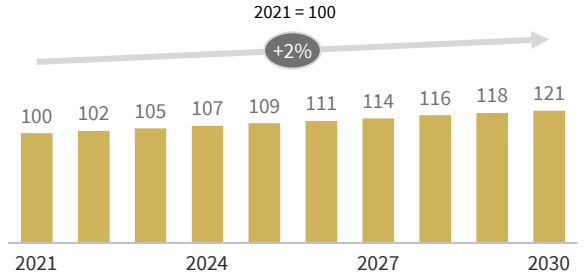
Market Outlook

- Price outlook: Copper prices are expected to trend downwards in 2022 as new supplies materialize. Over the medium term, prices are expected to remain elevated owing to strong demand from new infrastructure projects and electrification of the automotive industry.[3]
- Downstream industry demand outlook: Infrastructure investment and construction activity is a good proxy of copper demand. Over the next ten years, global infrastructure investment is expected to see healthy growth. In addition, EVs use a considerable higher amount of copper, creating additional demand.[4]

Copper Price Forecast (USD$/tonne)[3]



Global Infrastructure Investment[4]



Key Takeaways

Supply chain risks

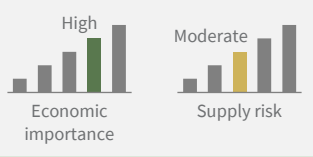
- Copper is produced in a number of different countries, with China supplying just over 40% of refined and smelted copper
- Only two countries include it on their critical minerals lists, highlighting that supply chain risk is relatively low
- Overall, substitutes for copper tend to have inferior properties, which makes the mineral a key material for downstream industries
- Ontario's domestic production of copper may help prevent potential supply chain disruptions; thus, supply risk considered to be low

Opportunities for Ontario

- In addition to current operating mines and refineries, several copper advanced mineral projects are underway in Ontario, including KGMH International's Victoria, Noront Resources' Eagle's Nest, Glencore's Onaping Depth, and Braveheart Resources' Thierry projects.
- With potential increase in domestic copper production, Ontario may become a net exporter of the mineral

Sources: [1] USGS, [2] BGS [3] S&P Market Intelligence, [4] UN, [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank [9] BNN Bloomberg, May 17 2021

Cobalt



Status in Ontario: Produced/Processed

Description and Key Facts

Cobalt is a chemical element only found in a chemically combined form, except for small deposits found in alloys of natural meteoric ion. The free element (produced by smelting) is a hard, lustrous silver-gray metal.[1]

- Vale and Glencore are currently the two cobalt producers in Ontario, operating in the Sudbury region; their operations include mining and refining of cobalt production.
- DRC has the world's largest cobalt reserves and is the leading jurisdiction for cobalt mine production.
- China is the world's leading producer of refined cobalt; most of the ore is imported from DRC.
- Approximately $190 million worth of cobalt was exported from Ontario in 2020, with more than half of exports going to Norway.

Value Chain[7]




Extraction	Processing	Manufacturing	Use in downstream sectors
• Most of cobalt ore is mined as a by-product of copper or nickel	• Metal (cathodes, ingots, granules, and powders) • Cobalt oxide, hydroxide, carbonate, sulphate, etc.	• Battery chemicals • Alloys and superalloys • Catalysts • Ceramics and pigments • Magnets • Tyre adhesives and paint dryers	• Electrical equipment • Fabricated metal products • Chemical products • Magnetic and optical products

Ontario Production and Trade Statistics

542 tonnes produced in Ontario in 2020[2]

$24.17M production value in 2020[3]

Cobalt has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Kirkland Lake
- Sault Ste. Marie
- Kenora
- Sudbury
- Red Lake
- Timmins

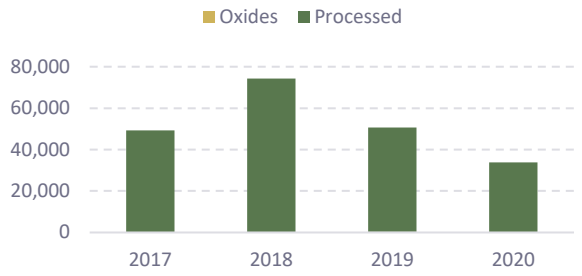
Ontario's Trade Balance: Exporter

Top Import Partner: Mexico (59%)

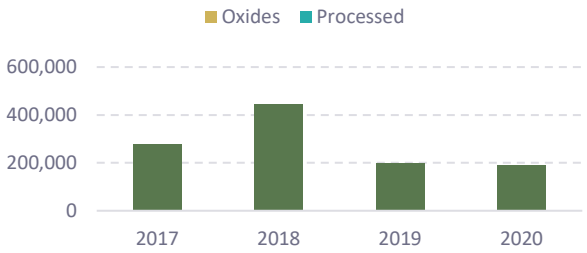
Top Export Partner: Norway (58%)

Note: Trade balance total across years 2017-2020

Cobalt Imports (CAD$, thousands)[5]



Cobalt Exports (CAD$, thousands)[6]



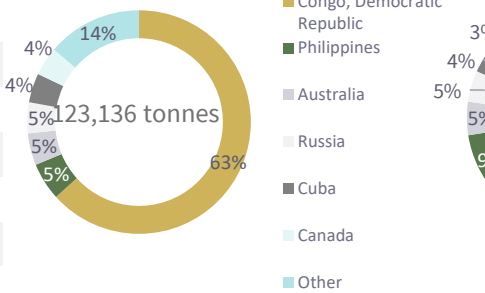
Note: HS codes include 282200, 810520, 810530, 810590

Global Production and Trade Statistics

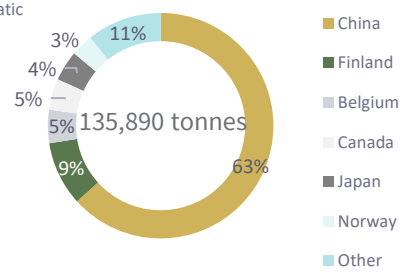
Reserves[8]

Country	Tonnes
1. DRC	3,600,000
2. Australia	1,400,000
3. Cuba	500,000
4. Philippines	260,000
5. Russia	250,000
6. Canada	220,000
Total*	7,200,000

Mine Production (2019)[9]



Refined Production (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

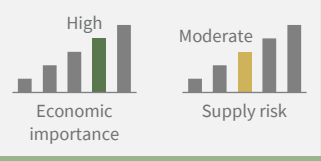
Ores	Refined Metal	Oxide
DRC (7.5K)	Malaysia (18.2K)	DRC (450.2K)
Thailand (699)	Canada (9.3K)	China (5.7K)
Malaysia (318)	Russia (8.5K)	Belgium (3.2K)

Top Importers (2019, tonnes)[12]

Ores	Refined Metal	Oxide
China (90.2K)	China (30.3K)	Zambia (8K)
Morocco (7.4K)	Malaysia (21.7K)	S. Korea (7K)
Philippines (4.5K)	USA (14.8K)	Spain (2.2K)

Sources: [1]USGS [2,3] NRCAN [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study [8] USGS, [9,10] BGS, [11,12] UN Comtrade Database

Cobalt

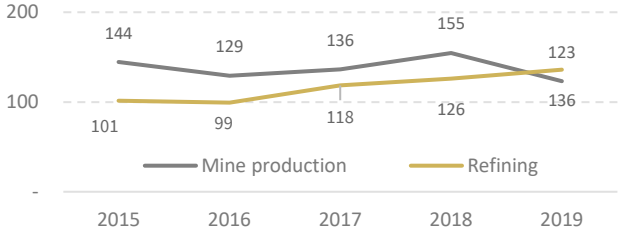


Status in Ontario: Produced/Processed

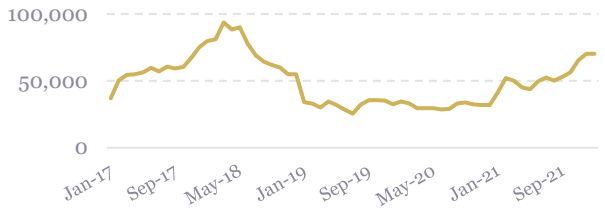
Market Conditions

- Price: Prices for cobalt vary depending on the material traded (e.g., metal powder, chemicals, cathode). Over the past five years, the price of cobalt has been volatile. In 2021, cobalt cash price has seen a steady increase in 2021, and reached over USD$70,000 by year end.
- Production: Global refined cobalt production has increased by approximately 34% from 2015 to 2019. Cobalt mining production grew in 2016-2018, but then dropped in 2019 due to the decline in price.

Global Cobalt Production (kilo-tonnes)[1]



Cobalt Price, Cash (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Cobalt is on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, Australia.[5]

Substitution (Moderate): In lithium-ion batteries, potential substitutes are iron and phosphorous; however, in most applications, substitutions for cobalt could result in inferior product quality.[6]

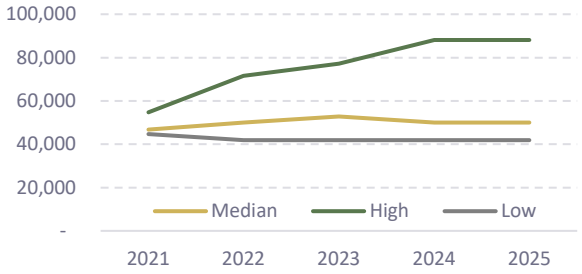
Use in strategic downstream industries: Cobalt is used in several strategic and growing sectors, including aerospace and defence, mobility and automotive, renewable energy, and electronics industries.[7]

Geopolitical factors: 63% of the cobalt reserves are concentrated in DRC. According to World Bank Governance indicators, the country is ranked fourth last (211th out of 214 countries) in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] Additionally, most of the cobalt mined in DRC is processed in China.

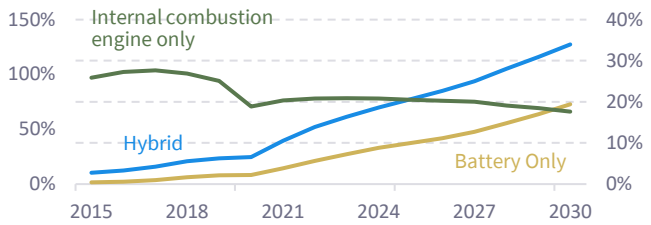
Market Outlook

- Price outlook: Based on the median forecast, the cobalt commodity price is expected to stay relatively flat at USD$50,000 per tonne, but could exceed USD$80,000 per tonne in a high price scenario.
- Downstream industry demand outlook: One of the major factors driving the demand for cobalt is adoption of EVs, as cobalt is a key raw material for EV batteries. The global share of EVs is expected to increase rapidly in the next ten years, which may lead to cobalt shortages.

Cobalt Price Forecast (USD$/tonne)[3]



Share of Total Light Vehicle Sales by Vehicle Type, Global[4]



Key Takeaways

Supply chain risks

- The reserves of cobalt are highly concentrated in DRC, a politically unstable country, and most of the cobalt is processed in China
- Therefore, given the increasing demand from electrical equipment, automotive, and aerospace industries, European countries and the US may experience cobalt supply chain disruptions
- As cobalt is produced in Canada, including mines and refineries in Ontario, supply chain risk for Ontario may be lower than on the global scale; based on analysis of quantitative data, supply risk is estimated to be moderate

Opportunities for Ontario

- Ontario is a net exporter of cobalt, with the mineral being both produced and processed within the province
- Domestically, the supply of cobalt may be at a relatively low risk as new exploration projects take place and downstream industries can access local supplies
- On a global scale, Ontario may play an important role in supplying refined cobalt, especially to countries that seek to source it from politically stable jurisdictions

Sources: [1] BGS [2] S&P Global Market Intelligence [3] S&P Global Market Intelligence [4] LMC Automotive [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Fluorspar

Low — Economic importance

Low — Supply risk

Status in Ontario: Exploration Potential

Description and Key Facts

Fluorspar is the commercial name of the mineral fluorine, which is a colourful, widely occurring mineral. Large quantities of fluorine are present in phosphate rock.[1]

- Ontario does not currently produce fluorspar. However, the mineral is produced in Newfoundland. Major projects include Canada Fluorspar Inc.'s St. Lawrence Fluorspar Mine, NL.
- Fluorspar has a wide variety of end uses, with coatings, insulation, and air conditioning among the most common applications.
- Ontario is a net importer of fluorspar; Mexico is its top import partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Acid grade • Metallurgical grade	• Hydrogen fluoride • Cryolite and aluminum fluoride	• Solid fluoropolymers • Fluorocarbons • Fluoroaromatics	• Cookware coating and cable insulation • Refrigeration and air conditioning • Nuclear energy • Aluminum, steel, iron making

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

No Canadian production in 2020[3]

Fluorspar has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Kenora
- Sudbury

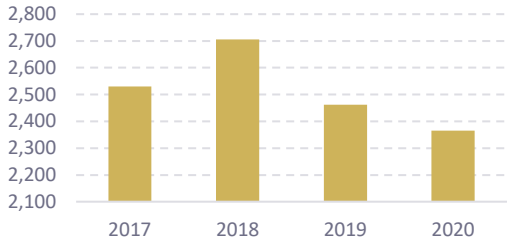
Ontario's Trade Balance: Importer

Top Import Partner: Mexico (16%)

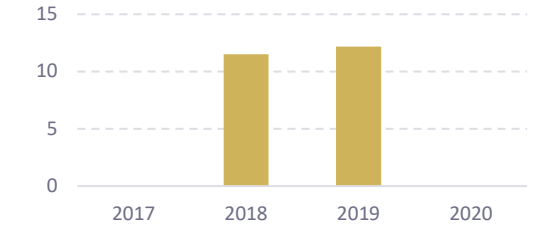
Top Export Partner: Korea Republic (51%)

Note: Trade balance total across years 2017-2020

Fluorspar Imports (CAD$, thousands)[5]



Fluorspar Exports (CAD$, thousands)[6]



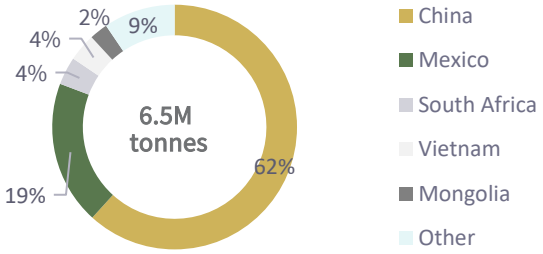
Note: HS codes include 252921, 252922

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Mexico	68M
2. China	42M
3. South Africa	41M
4. Mongolia	22M
5. Spain	10M
6. Vietnam	5M
Total*	320M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Calcium Fluoride	
1. Mongolia (699.4K)	4. South Africa (102.2K)
2. Mexico (398K)	5. Morocco (65.3K)
3. China (374.1K)	6. Italy (53.7K)

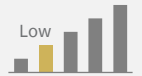
Top Importers (2019, tonnes)[11]

Calcium Fluoride	
1. China (567.5K)	4. India (243.4K)
2. USA (424.5K)	5. Russia (185.8K)
3. Italy (263.3K)	6. Germany (178.4K)

Sources: [1] USGS, [2] NRCAN, [3] USGS, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS [9] BGS, [10,11] UN Comtrade Database

Fluorspar

Economic importance



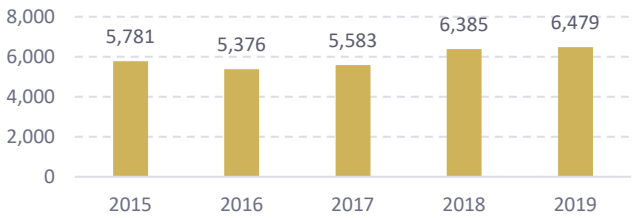
Supply risk

Status in Ontario: Exploration Potential

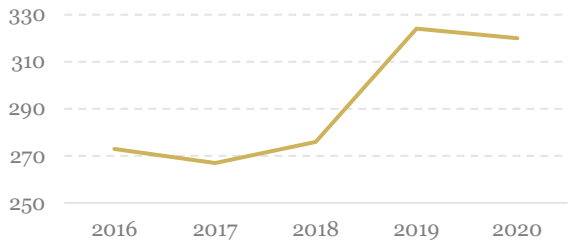
Market Conditions

- Price: Price of fluorspar has ranged from ~USD$260-320 per tonne over the past five years. The uptick in recent years are likely driven by increased demand in the downstream industries, including hydrofluoric acid production, aluminium and steelmaking.[1]
- Production: Continued ramp-up of new mines in Canada and South Africa have contributed to the increased production in recent years.[2]

Global Fluorspar Mining Production (kilo-tonnes)[2]



Fluorspar Price, Acid Grade (USD$/tonne)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Fluorspar is on the critical mineral list of four major jurisdictions: EU, US, UK, and Canada.[5]

Substitution (High): Substitutes exist for fluorspar, and include calcium chloride, iron oxides, manganese ore, and silica sand.[6]

Use in strategic downstream industries: Fluorspar is primarily used in the metallurgical, ceramics, and chemical industries.[7]

Geopolitical factors: The majority of reserves and production occurs in China and Mexico, countries that are ranked towards the bottom of the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	↗	↗
Increased supply from new mines is expected to stabilize prices. Tightening regulations on the use of fluorocarbon in Europe and North America may impact prices in the near-term.	The future demand for fluorspar will highly depend on the development and use of fluorocarbon substitutes and additional supplies.	With demand for fluorocarbon staying stable, strong growth in the production and consumption of hydrofluoroolefins (a substitute for fluorocarbon) will drive the demand for fluorspar.	Fluorocarbon substitutes will prop up demand for fluorspar. Demand for aluminum, which uses fluorspar as an input, is also expected to grow, contributing to a positive medium-to-long term outlook.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

- China currently dominates fluorspar production, which in the case of supply chain disruptions may impact other jurisdictions, including the EU, the UK and the US that list fluorspar on their critical minerals lists
- Ontario's top export partner is Mexico and Canadian production takes place in Newfoundland
- As the province has access to domestic and North American supply of fluorspar, the risk of supply chain disruptions for Ontario is relatively low

Opportunities for Ontario

- Ontario's endowment with fluorspar deposits in several regions provides a potential opportunity for mining companies in the province to engage in exploration activity and provides steady supply for domestic use as well as exports, primarily to the US and the EU countries

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Graphite

Moderate — Economic importance

Moderate — Supply risk

Status in Ontario: Advanced Mineral Projects

Description and Key Facts

Graphite is a grey-black mineral; it is a good thermal and electrical conductor and has a high melting point. Due to its high thermal resistance, corrosion resistance and chemical inertness, it has a wide range of uses.[1]

- Ontario has not reported significant graphite production in the past five years. However, several advanced mineral projects are ongoing in the province, including Northern Graphite's Bissett Creek and ZEN Graphene Solutions' Albany Graphite.
- The leading global producer is China, making up over 60% of global supply.
- Graphite is an important input in a number of applications, with a particularly strong demand in electrical products/activities.
- Ontario is a net importer of graphite and the US is the top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Graphite powder and flakes	• Purified graphite powder • Expandable graphite • Spheroidal graphite • Foil graphite	• Products for foundries • Powder metallurgy products • Battery cells • Lubricants	• Electronics and other technology products, including batteries and FCs • Casting of base metals • Iron and steel making

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

11,937 tonnes
Canadian production in 2020[3]

Graphite has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Thunder Bay North
- Kenora
- Sudbury
- Kenora
- Timmins

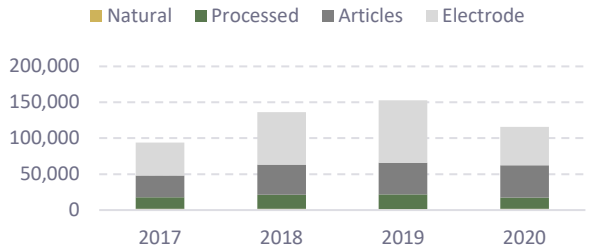
Ontario's Trade Balance: Importer

Top Import Partner: United States (66%)

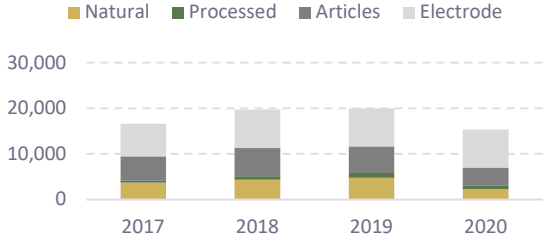
Top Export Partner: United States (97%)

Note: Trade balance total across years 2017-2020

Graphite Imports (CAD$, thousands)[5]



Graphite Exports (CAD$, thousands)[6]



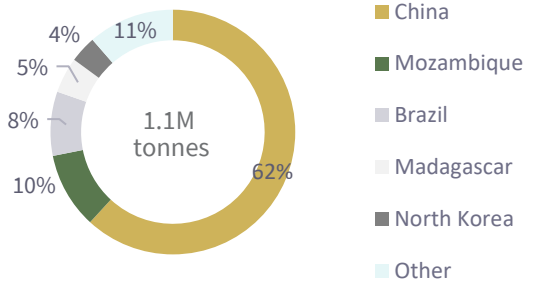
Note: HS codes include 250410, 250490, 380110, 380120, 380190, 681510, 690310, 854511, 854519, 854520, 854590

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Turkey	90M
2. China	73M
3. Brazil	70M
4. Madagascar	26M
5. Mozambique	25M
6. Tanzania	17M
Total*	320M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

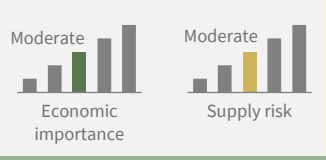
Graphite	
1. China (641.6K)	4. USA (48K)
2. Germany (87.7K)	5. France (44.3K)
3. Japan (53.3K)	6. Spain (32.1K)

Top Importers (2019, tonnes)[11]

Graphite	
1. Malaysia (393.4K)	4. USA (159.7K)
2. China (249.9K)	5. Germany (134.9K)
3. Japan (212.4K)	6. India (97.1K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Graphite

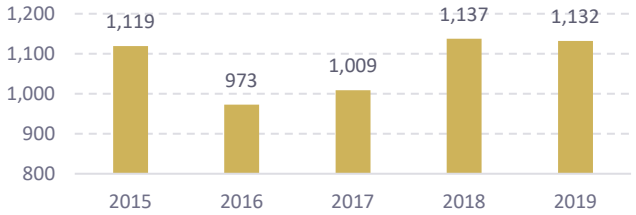


Status in Ontario: Advanced Mineral Projects

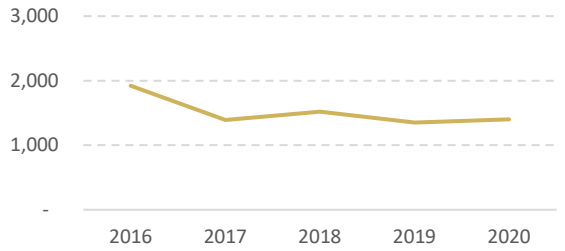
Market Conditions

- Price: Graphite prices have declined in recent years, likely driven by oversupply from new producers such as Mozambique.[1]
- Production: China is the world's largest graphite producer, producing nearly two-thirds of total world output. The COVID-19 pandemic had limited impact on graphite supply as Chinese producers quickly increased production once restrictions were lifted in 2020.[2]

Global Graphite Ore Production (kilo-tonnes)[2]



Graphite Price, Flake (USD$/tonne)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Graphite is on the critical mineral list of five major jurisdictions: US, UK, Canada, Japan, and Australia.[5]

Substitution (Moderate): Within the steel and iron industry, there are substitutes that compete for use, such as calcined petroleum coke. Additionally, molybdenum disulfide can compete as a dry lubricant, but is more sensitive to oxidizing conditions.[6]

Use in strategic downstream industries: The steel and manufacturing industries are the biggest users of graphite. It is a key component in lithium-ion batteries.[7]

Geopolitical factors: The majority of reserves and production occurs in countries that are ranked towards the bottom of the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	↗	↗
Price of graphite may remain subject to downward pressure as Chinese producers increase their production to fill the supply gap caused by the COVID-19 pandemic in other countries.	Despite higher anticipated demand from lithium-ion batteries and numerous high-technology applications, ample production capacity means price may remain stable.	Accelerated electrification in the automotive industry has created strong demand for lithium-ion batteries, in which spherical graphite is used as anode material.	In addition to strong demand derived from EVs, innovative refining techniques have made the use of graphite possible in many high-tech applications, which may drive long term demand.

Legend: → Neutral; ↗ Positive; ↘ Negative

Key Takeaways

Supply chain risks

- China currently dominates the supply of graphite, which may result in unfavourable market conditions and supply chain disruptions in Western economies
- Graphite is a key component in lithium-ion batteries; therefore, the demand from the transportation and renewable energy industries may lead to competition for secure and reliable supply
- Based on analysis, the supply chain risk for Ontario's industries is moderate

Opportunities for Ontario

- With advanced mineral projects underway in Ontario, the province can secure domestic sources of graphite, thereby mitigating potential supply chain disruptions in the future
- Moreover, Ontario may be in a position to supply graphite to other major jurisdictions that include it on their critical minerals lists, including the US and the UK

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Indium

Moderate — Economic importance

Moderate — Supply risk

Status in Ontario: Produced

Description and Key Facts

Indium is a very soft, ductile and malleable silvery metal. It is produced mainly from residues generated during zinc ore processing.[1]

- Ontario produced around CAD$2.3 million worth of indium in 2020. The mineral is most commonly recovered as a by-product of zinc sulfide processing. Glencore's Kidd Creek mine in the Timmins region produces indium.[2]
- Production of indium tin oxide (ITO) continued to account for most of global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel displays— most commonly liquid crystal displays (LCDs).
- Ontario is a net exporter of indium and the US is its top import and export partner.

Value Chain[8]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite • Other ores containing indium are copper and lead	• Indium metal	• Indium tin oxide • Indium chemical compounds • Indium alloys • Semi-conductors	• Electrical and electronic equipment • Batteries • LEDs • Photovoltaic panels

Ontario Production and Trade Statistics

6.3 tonnes produced in Ontario in 2020[3]

$2.3M production value in 2020[4]

Indium has been discovered in the following districts:[5]

- Southeastern Ontario
- Thunder Bay South
- Thunder Bay North
- Kenora
- Sudbury
- Kenora
- Timmins

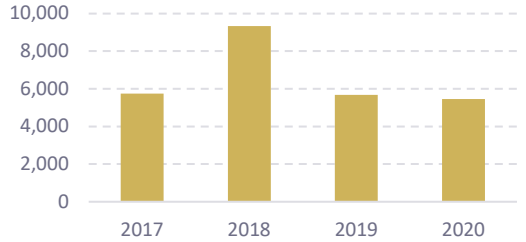
Ontario's Trade Balance: Exporter

Top Import Partner: United States (38%)

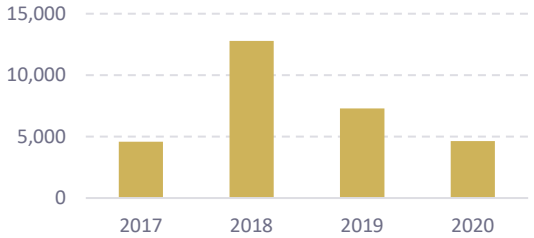
Top Export Partner: United States (78%)

Note: Trade balance total across years 2017-2020

Indium Imports (CAD$, thousands)[6]



Indium Exports (CAD$, thousands)[7]



Note: HS codes include 811292, 811299

Global Production and Trade Statistics

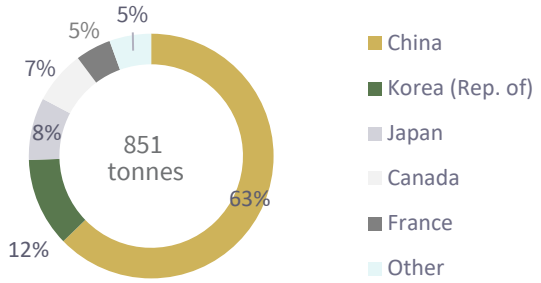
Reserves[9]

Quantitative estimates are not available, as indium is produced from other ore bodies, primarily zinc sphalerite.

The content of indium in zinc deposits ranges from 1 part per million to 100 parts per million.

Most deposits of other base metal sulphides are subeconomic for indium recovery.

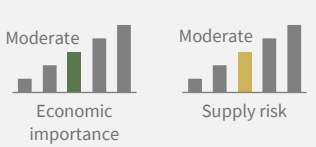
Refinery Production (2019)[10]



Top Exporters (2019, tonnes)[11]	Top Importers (2019, tonnes)[12]
Metal	Metal
China	USA
Canada	S. Korea
S. Korea	Japan

Sources: [1] USGS, [2] Ontario Mining Exploration Directory, 2021 [3,4] NRCAN, [5] Ontario Mineral Deposit Inventory, [6,7] Statistics Canada, [8] USGS & EU: Critical Minerals Study, [9] USGS, [10] BGS, [11,12] UN Comtrade Database

Indium

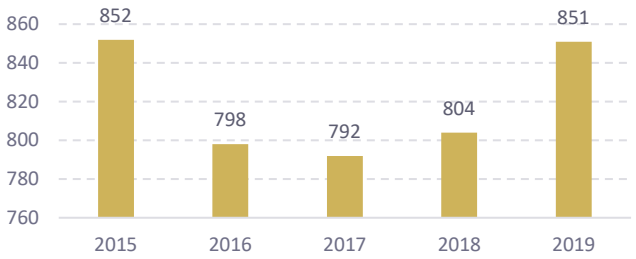


Status in Ontario: Produced

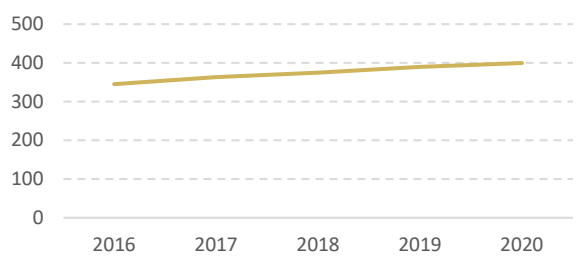
Market Conditions

- Price: The price of indium has recovered gradually from its downturn caused by the collapse of the Fanya Metals Exchange in China.[1]
- Production: China and South Korea are two of the largest producers of refined indium. Global production level has been stable over the last five years at around 800 tonnes per annum.[2]

Global Indium Production (tonnes)[2]



Indium Price (USD$/kg)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Indium is on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Low): Few non-critical mineral substitutes exist. For example, in soldering applications, tin-bismuth alloys can replace tin-indium alloys for low temperature bonding.[6]

Use in strategic downstream industries: Indium is a key input in the manufacturing process, especially in electronic, optical, and computer equipment.[7]

Geopolitical factors: 61% of the refinery production is concentrated in China. According to World Bank Governance indicators, the country is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	↗	↗	→
Ample supply from China is likely to stabilize indium price over the near-term. Without new applications, price may level off in the near-term.	Price of indium over the medium-to-long term is highly dependent on global supply, which is largely controlled by China. Several substitutes may displace indium and in turn decrease price.	The primarily application of indium is in flat screens, including LCD and OLED. Elevated consumer demand may likely push up demand for indium in the near-term.	As technology continues to improve, the use of indium in flat display may slightly decrease over the medium-to-long term. New applications such as batteries may create new demand.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

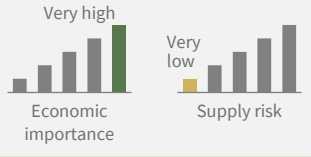
- China currently dominates more than 60% of the global indium production; in case of increasing demand for the mineral, downstream industries in major jurisdictions may face supply disruptions
- Six major jurisdictions include indium on their critical minerals list, indicating its strategic importance
- Indium supply chain disruption risk is moderately high, but Ontario is a producer and exporter of the mineral; thus, supply chain risk for Ontario's industries seems to be moderate

Opportunities for Ontario

- As Ontario is currently a producer of indium, the province may have a competitive advantage in supplying the mineral to other jurisdictions, including the US, the EU, and the UK
- Ontario's indium production may offer a competitive advantage to downstream industries, in particular, electrical and computer manufacturing companies located in the province

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Lithium



Status in Ontario: Advanced Mineral Projects

Description and Key Facts

Lithium is a silver-white to grey alkali metal. It has high electrical conductivity and the highest electrochemical potential of all metals, which makes it ideal for use in batteries. Lithium supply security has become an important priority for technology and automotive companies.[1]

- Ontario does not currently produce lithium. Canadian production has historically occurred in Quebec and Manitoba. Notable projects include Nemaska Lithium's Whabouchi Lithium in Quebec.
- Lithium advanced mineral projects in Ontario include Frontier Lithium (PAK), Avalon Advanced Materials (Separation Rapids), and Rock Tech Lithium (Georgia Lake).
- The leading global producer is Australia, making up 85% of global production.
- Ontario is a net importer of lithium, and the US is both its top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• At the extraction stage, lithium is produced in the form of lithium concentrated	• Initially, lithium is processed into carbonate, hydroxide, or chloride • Then, lithium chemicals are produced, including cathodes and metal	• Batteries • Glass and ceramics • Lubricants • Rubber and plastics	• Electronics and electrical equipment • EVs • Chemicals • Pharmaceuticals • Steel and aluminum production

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

No Canadian production in 2020[3]

Lithium has been discovered in the following districts:[4]

- Thunder Bay South
- Thunder Bay North
- Kenora
- Red Lake
- Timmins
- Kirkland Lake

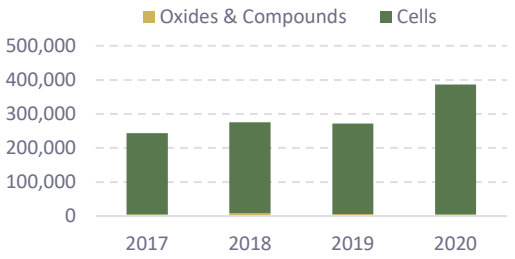
Ontario's Trade Balance: Importer

Top Import Partner: United States (45%)

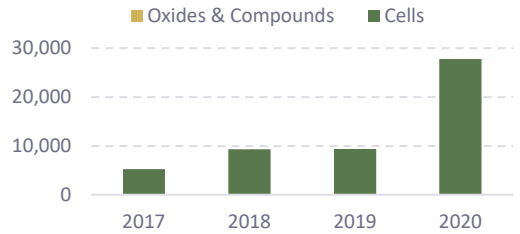
Top Export Partner: United States (81%)

Note: Trade balance total across years 2017-2020

Lithium Imports (CAD$, thousands)[5]



Lithium Exports (CAD$, thousands)[6]



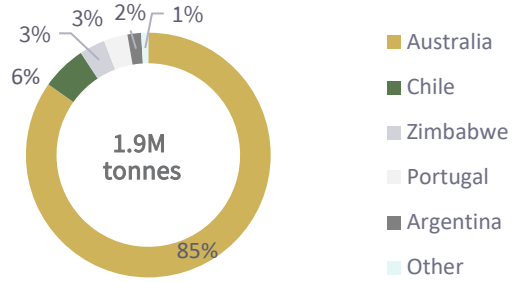
Note: HS codes include 282520, 283691, 290433, 850650, 850760

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Chile	9.2M
2. Australia	4.7M
3. Argentina	1.9M
4. China	1.5M
5. USA	0.75M
6. Canada	0.53M
Total*	21M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

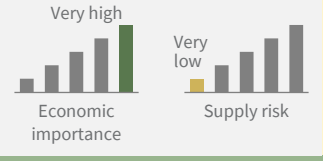
Carbonates	Oxide & Hydroxide
Chile (82.5K)	China (49.3K)
China (12.9K)	Canada (41.3K)
Belgium (6.9K)	USA (9.4K)

Top Importers (2019, tonnes)[11]

Carbonates	Oxide & Hydroxide
S. Korea (38.6K)	Japan (37.3K)
China (29.3K)	S. Korea (23.5K)
Japan (23.6K)	France (6.9K)

Sources: [1] USGS, [2] NRCAN, [3] USGS [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Lithium

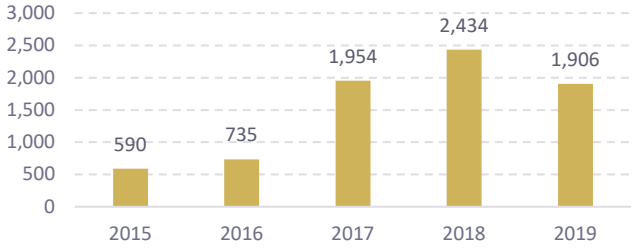


Status in Ontario:
Advanced Mineral Projects

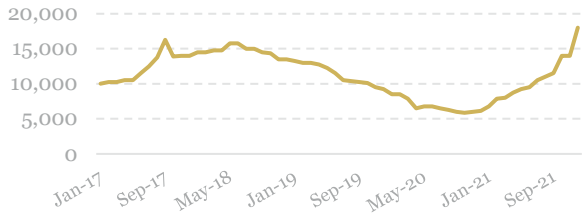
Market Conditions

- Price: Lithium prices have risen significantly in 2021. Record lithium prices have been driven by strong demand from the EV market.[1]
- Production: Australia dominates the lithium market, accounting for nearly half of global supply.[2] Strong lithium price momentum over the past 12 months has stimulated miners to accelerate projects amid increasing market tightness.[1]

Global Lithium Ore Production (kilo-tonnes)[2]



Lithium Carbonate Price, Global Average (USD$/tonne)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Lithium is on the critical mineral list of five major jurisdictions: EU, US, Canada, Japan, Australia.[5]

Substitution (Moderate): While substitutes do exist in many applications, such as batteries, glass, and ceramics, there is little incentive to use them because lithium is cheap and has a stable supply source.[6]

Use in strategic downstream industries: Lithium is a key input in the manufacturing of electric automobiles as such vehicles are energized by lithium-ion batteries.[7]

Geopolitical factors: 85% of production currently takes place in Australia, which according to the World Bank Governance indicators is ranked 11th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness while almost 45% of reserves are in Chile, which is also ranked high on the same measure (27th out of 214 countries).[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Price is set to climb resulting from accelerated adoption of EVs in many parts of the world. Prices may respond swiftly to any signs of supply shortages.	Price is expected to remain high and stabilize over time with lithium miners pressing ahead with new projects to meet growing demand.	The electrification of vehicles and the ramp-up of the related battery production will lead to significantly higher demand for lithium.	Policy levers aiming to reduce carbon emissions will continue to drive demand for lithium. Li-ion battery substitutes like solid-state batteries may curtail demand over the long run.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

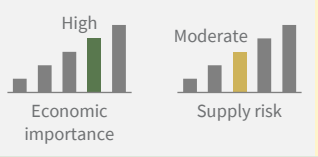
- Australia, which supplies 85% of lithium, is considered a politically stable supplier of the mineral; therefore, supply chain risk is considered to be very low
- With increasing demand for lithium from battery manufacturers and limited substitutability, lithium has very high economic importance
- Ontario's lithium imports have increased significantly since 2017, indicating the demand from downstream industries

Opportunities for Ontario

- With advanced mineral projects underway in Ontario, the province can secure a domestic source of lithium, thereby mitigating potential supply chain disruptions
- Domestic supply of lithium can contribute to the strengthening of Ontario's automotive and mobility sector and other low-carbon economy industries

Sources: [1] S&P Global Market Intelligence, [2] BGS [3] S&P Global Market Intelligence [4] LMC Automotive [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Magnesium



Status in Ontario: Advanced Mineral Projects

Description and Key Facts

Magnesium is the eighth most abundant element in Earth's crust and the third most abundant in solution in seawater. It does not occur in its elemental form in nature but is formed in different forms in other minerals.[1]

- No significant magnesium production has been reported in Ontario over the past five years.
- China is the top producer of magnesium, accounting for over 90% of global production.
- Magnesium is used in products that benefit from being lightweight. Common applications are found in the automotive and transportation, packaging, and construction industries.
- Ontario is a net importer of magnesium. China is the top import partner, representing 67% of provincial imports.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Magnesium is extracted from dolomite, magnesite, and carnallite minerals and from seawater and brines	• Magnesium metal • Magnesium alloys	• Aluminum alloys • Die casting • Steel desulphurisation	• Automotive and transportation • Packaging • Construction

Ontario Production and Trade Statistics

No Magnesium production in Ontario in 2020[2]

No Canadian production in 2020[3]

Magnesium has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Timmins
- Sault Ste. Marie
- Sudbury

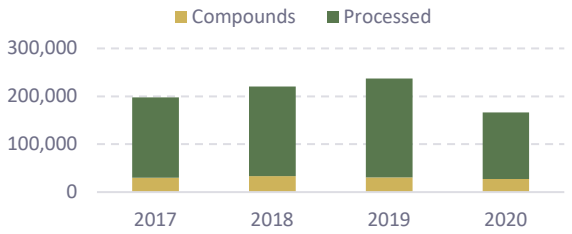
Ontario's Trade Balance: Importer

Top Import Partner: China (67%)

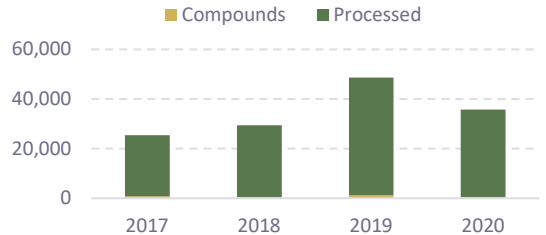
Top Export Partner: United States (99%)

Note: Trade balance total across years 2017-2020

Magnesium Imports (CAD$, thousands)[5]



Magnesium Exports (CAD$, thousands)[6]



Note: HS codes include 251990, 253020, 282731, 283321, 810411, 810419, 810490, 251910, 281610, 810420, 810430

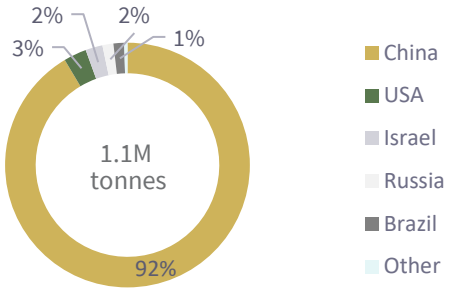
Global Production and Trade Statistics

Reserves[8]

Quantitative estimates of the reserves are not available.

The reserves for this metal are sufficient to supply current and future requirements.

Mine Production (2019)[9]



Top Exporters (2019, tonnes)[10]

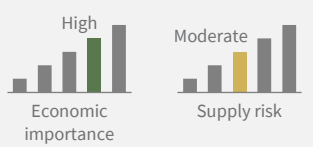
Refined Metal	Chemicals*
China (455.6K)	China (4.2M)
Germany (22.6K)	Germany (834.4K)
Canada (14.8K)	Turkey (361.2K)

Top Importers (2019, tonnes)[11]

Refined Metal	Chemicals*
Canada (74.3K)	Japan (751.6K)
Germany (69.4K)	USA (654.9K)
USA (45.4K)	Germany (598.1K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Magnesium

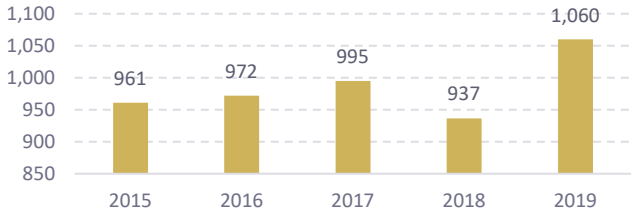


Status in Ontario:
Advanced Mineral Projects

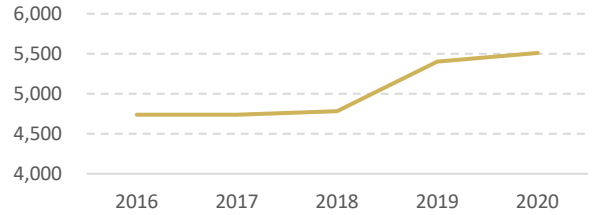
Market Conditions

- Price: Magnesium prices have gradually increased in recent years. Stable supply from major producers has contributed to a relatively stable market.[1]
- Production: China dominates the global magnesium metal production. Increase in supply is attributed to several new projects in China and abroad.[2]

Global Magnesium Production (kilo-tonnes)[2]



Magnesium Price, US spot Western (USD$/tonne)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Magnesium is on the critical mineral list of five major jurisdictions: EU, US, UK, Canada, Japan.[5]

Substitution (High): Substitution is possible in casting and wrought products using aluminum. Calcium carbide can also be used for iron and steel desulfurization.[6]

Use in strategic downstream industries: While the major use of magnesium is in the transportation/automotive industry, it is also used in construction and in packaging.[7]

Geopolitical factors: 92% of production occurs in China, which in the World Bank Governance indicators is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	↗	↗	↗
No major fluctuations are expected assuming continuation of stable supply from China and new projects in other countries ramping up production.	While demand for magnesium in the automotive industries is expected to increase, several new projects under development are expected to increase global supply and stabilize price.	The use of magnesium in automobile parts continues to rise as OEMs look to decrease the weight of the vehicles in order to improve fuel efficiency and react to tightening emission standards.	New technologies could result in stronger demand, including magnesium-ion rechargeable batteries, 3D printing applications. Magnesium alloys' low density may prove valuable in EVs too.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

- The supply chain risk for magnesium is anticipated to be moderate since most production occurs in China
- Canada is the largest importer of refined metal, largely dependent on supply from China
- Magnesium is an important input to Ontario's manufacturing industries, including automotive and transportation

Opportunities for Ontario

- With advanced mineral projects underway in Ontario, the province can secure a domestic source of magnesium, thereby mitigating potential supply chain disruptions
- Domestic supply of magnesium can generate competitive advantage for Ontario's advanced manufacturing industries using magnesium in aluminum alloys, including in the automotive and transportation industries

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Manganese

Status in Ontario: Exploration Potential

Description and Key Facts

Manganese is widely used in iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. World manganese resources are relatively large.[1]

- No significant manganese production in Ontario has been reported in the past five years.
- South Africa is the leading global producer of the mineral, accounting for 30% of global production in 2019.
- Manganese is often alloyed with steel. Applications can be found in the construction, machinery, and transportation industries.
- Ontario is a net importer of manganese, and the US is its top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Manganese ore production	• Manganese dioxide • Manganese metal • Ferroalloys, consisting of various grades of ferromanganese and silicomanganese	• Iron and steel production • Dry cell batteries • Brick colorant	• Construction • Machinery • Transportation • Agriculture (plant fertilizers, animal feed)

Ontario Production and Trade Statistics

No Manganese production in Ontario in 2020[2]

No Canadian production in 2020[3]

Manganese has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay South
- Timmins
- Sault Ste. Marie
- Sudbury

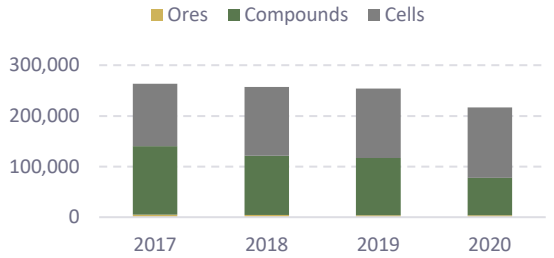
Ontario's Trade Balance: Importer

Top Import Partner: United States (67%)

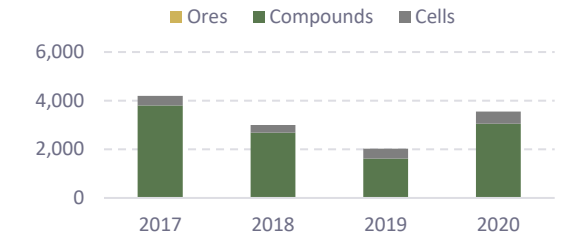
Top Export Partner: United States (95%)

Note: Trade balance total across years 2017-2020

Manganese Imports (CAD$, thousands)[5]



Manganese Exports (CAD$, thousands)[6]



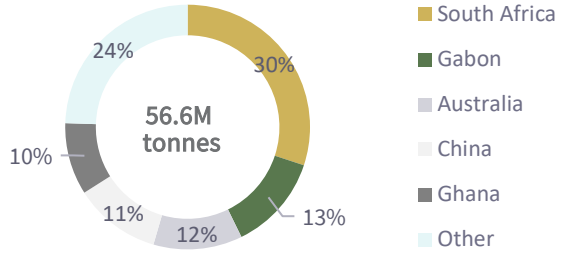
Note: HS codes include 260200, 282010, 282090, 720211. 720219, 720230, 722720, 811100, 850610

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. South Africa	520M
2. Brazil	270M
3. Australia	230M
4. Ukraine	140M
5. China	54M
6. India	34M
Total	1,300M

Mine Production (2019)[9]



Top Exporters (2019, tonnes)[10]

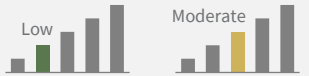
Ores	Refined Metal	Oxides
S. Africa (19.5M)	India (972.6K)	Myanmar (63K)
Ghana (4.9M)	China (743.1K)	China (58.9K)
Brazil (3.8M)	Ukraine (714K)	S. Africa (49K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal	Oxides
India (2.9M)	USA (756.7K)	USA (22K)
Norway (1.2M)	Japan (470.3K)	India (20.5K)
Ukraine (1.2M)	Germany (451K)	Indonesia (20K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9] BGS, [10,11] UN Comtrade Database

Manganese

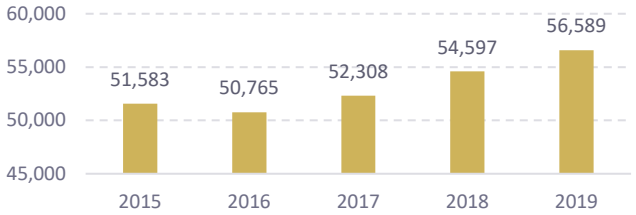


Status in Ontario: Exploration Potential

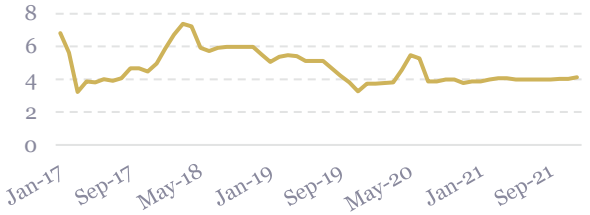
Market Conditions

- Price: Lower steel production (the leading use of manganese) caused by the COVID-19 pandemic has resulted in lower manganese prices in 2020.[1]
- Production: Production level has gradually increased over the last few years, largely owing to producers responding to a growing demand.[2]

Global Manganese Mining Production (kilo-tonnes)[2]



Manganese Price, Ore, 38% FOB S.A. (USD$/tonne)[3]



Economic and Strategic Importance

Importance in other jurisdictions: Manganese is on the critical mineral list of four major jurisdictions: US, Canada, Japan, and Australia.[6]

Substitution (Low): There are no satisfactory substitutes for any of manganese's major applications.[6]

Use in strategic downstream industries: While upwards of 90% of manganese is used in the steel making industry, it also has applications in construction, transportation, textiles, medicine, and agriculture.[7]

Geopolitical factors: Approximately 61% of reserves are found in South Africa or Brazil, which, according to the World Bank Governance indicators, are 82nd and 98th (out of 214 countries), respectively, in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook[4]		Demand outlook[5]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Strong demand for steel will likely lead to recovery in manganese prices over the near-term. Price may stabilize once demand begins to level off.	Price in the medium- to long-term will largely depend on global steel production. Price may fluctuate as major steel producers look for ways to reduce pollution and emissions.	Strong investment in infrastructure and construction in China and the US as part of the COVID revival plan is expected to result in a strong demand for steel and, by extension, manganese.	Long-term demand will be primarily driven by infrastructure investment and population growth (new housing construction), which will likely trend upwards.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

- Overall, manganese is relatively abundant with production taking place in more than 20 different countries[9]
- No manganese production occurs in Canada, therefore, Ontario is dependent on manganese imports from the US
- Based on the combination of supply risk factors with no satisfactory substitutes, the supply chain risk for Ontario is estimated to be moderate

Opportunities for Ontario

- Ontario's manganese exploration potential in several regions may provide an opportunity for the province to supply the mineral to the local downstream industries, and to other jurisdictions, including current top global importers

Sources: [1] USGS, [2] BGS [3] S&P Global Market Intelligence [4,5,7] EU critical raw materials factsheets and USGS [6] Critical mineral lists of major jurisdictions [8] World Bank

Molybdenum

Moderate — Economic importance

Low — Supply risk

Status in Ontario: Exploration Potential

Description and Key Facts

Molybdenum is produced both as a primary product as well as a by-product of copper extraction. It is a refractory metallic element used primarily as an alloying agent in steel, cast iron, and super alloys. It has the key desired metallurgical properties: hardenability, strength, toughness, and wear and corrosion resistance.[1]

- No significant production of molybdenum has been reported in Ontario. However, molybdenum is produced in BC. For example, Avanti Mining's Kitsault Molybdenum Mine is one of major BC's projects.
- China is the top producer, accounting for 38% of global production in 2019.
- Molybdenum is an input in the heavy construction, chemical processing and automotive sectors.
- Ontario is a net importer of molybdenum, and the US is its top import partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Molybdenum ores and concentrates	• Molybdic oxide • Ferromolybdenum • Molybdenum metals • Molybdenum chemicals	• Metallurgical applications in alloy metals: iron, nickel, chromium • Chemical applications as catalysts, lubricants, pigments	• Heavy construction • Food handling and chemical processing equipment • Automotive parts (steel alloys)

Ontario Production and Trade Statistics

No Molybdenum production in Ontario in 2020[2]

2,655 tonnes
Canadian production volume in 2020[3]

Molybdenum has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Kirkland Lake
- Sault Ste. Marie
- Kenora
- Sudbury
- Red Lake
- Timmins

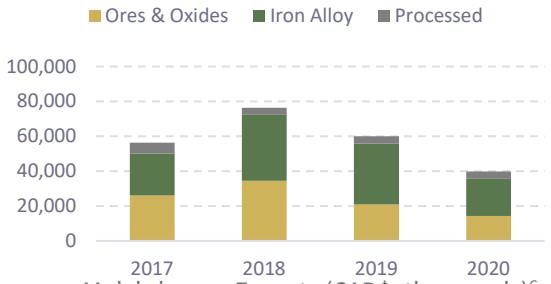
Ontario's Trade Balance: Importer

Top Import Partner: United States (45%)

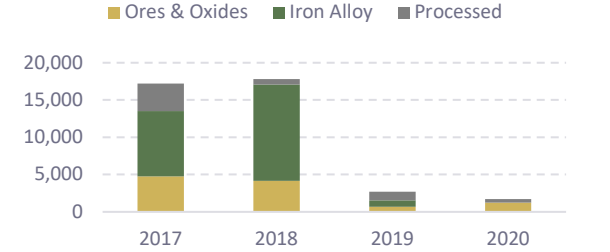
Top Export Partner: United States (99%)

Note: Trade balance total across years 2017-2020

Molybdenum Imports (CAD$, thousands)[5]



Molybdenum Exports (CAD$, thousands)[6]



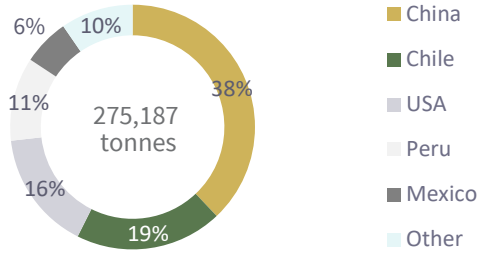
Note: HS codes include 261310, 261390, 282570, 720270, 810210, 810294, 810295, 810296, 810297, 810299

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	8.3M
2. Peru	2.8M
3. USA	2.7M
4. Chile	1.4M
5. Russia	1.0M
6. Turkey	0.8M
Total*	18M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

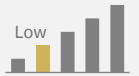
Ores	Refined Metal	Oxides
Chile (96.3K)	S. Korea (24.7K)	Chile (9.8K)
USA (64.2K)	UK (13.9K)	Netherlands (7K)
Peru (55.7K)	Malaysia (11.7K)	China (3.9K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal	Oxides
Netherlands (50K)	Germany (15.2K)	India (9K)
S. Korea (41.9K)	USA (13.4K)	USA (4.3K)
USA (40.8K)	Belgium (5.8K)	Japan (2.6K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9] BGS, [10,11] UN Comtrade Database

Molybdenum

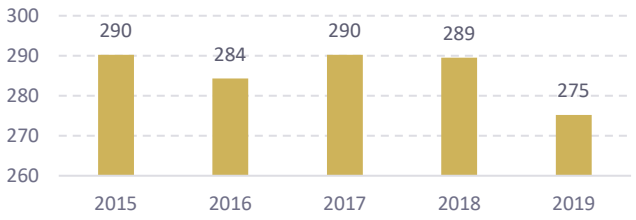


Status in Ontario: Exploration Potential

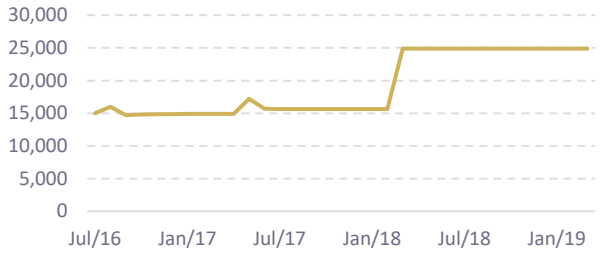
Market Conditions

- Price: Price of molybdenum remained elevated before the COVID-19 pandemic; however, its price declined by nearly 25%, due to the lower anticipated demand for steel.[1]
- Production: China is the largest producer of molybdenum. The environmental policy aiming to reduce mining-related pollution was implemented in China in 2018, which has resulted in a temporary shut-down of many mining operations. Production was resumed in 2020.[2]

Global Molybdenum Mining Production (kilo-tonnes)[2]



Molybdenum Price, Cash (USD$/tonne)[3]



Economic and Strategic Importance

Importance in other jurisdictions: Molybdenum is on the critical mineral list of two major jurisdictions: Canada and Australia.[5]

Substitution (Low): In steel and cast iron applications, substitution is limited, but potential substitutes include boron, chromium, niobium, and vanadium, in addition to others.[6]

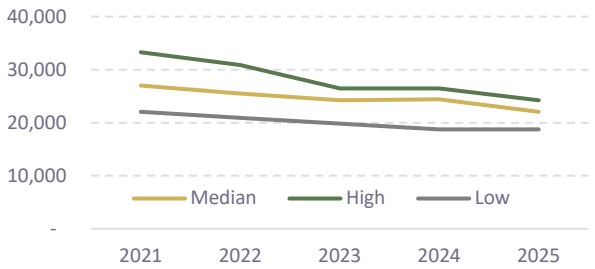
Use in strategic downstream industries: Molybdenum's primary downstream use is in manufacturing, as it improves the strength of steel at high temperatures.[7]

Geopolitical factors: Approximately 62% of reserves are found in China or Peru, which, according to the World Bank Governance indicators, are 144th and 110th out of 214 countries, respectively, in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

- Price outlook: Based on market consensus, the molybdenum price is expected to trend downwards starting in 2021. Additional supply from new projects is likely to be the main contributor of a more conservative price outlook.

Molybdenum Price Forecast (USD$/tonne)[3]



Demand outlook[4]

Near-term	Medium-to-long term
Several countries have indicated strong investment intention in infrastructure, which is expected to translate into strong demand for steel, and therefore, molybdenum.	There is little substitution for molybdenum in its major application in steels and cast irons. New materials are being developed due to its unique alloying properties, adding to future demand.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

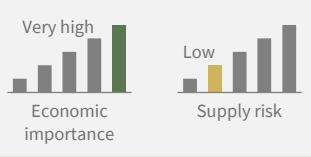
- Molybdenum is on the critical mineral list of only two major countries, including Canada
- It is produced in a number of different countries, with a relatively high concentration of reserves
- As molybdenum has few substitute and is an important input into steel and cast iron, the impact of supply chain disruptions may be relatively high globally; however, for Ontario, the supply chain risk is low since the mineral is produced in Canada

Opportunities for Ontario

- Ontario's endowment with molybdenum deposits in several regions provides an opportunity for mining companies in the province to engage in exploration activity and provide steady supply for domestic use, as well as export markets, primarily to the US and the EU countries

Sources: [1] USGS, [2] BGS [3] S&P Market Intelligence, [4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Nickel



Status in Ontario: Produced/Processed

Description and Key Facts

Nickel is a lustrous, silver-white metal, which is hard, ductile, malleable, and can take a high polish. Nickel-bearing alloys are valued for their corrosion resistance, high melting point, ductility, and magnetic properties.[1]

- Ontario is a major producer of nickel. In 2020, Ontario accounted for 40% of Canada's production.
- Around CAD$2.6 billion of processed nickel was exported from Ontario in 2020, with Norway as the top export partner.
- In 2021, nickel producing mines were Vale (Sudbury Operations), Glencore (SINO), KGHM International Ltd (McCreedy West Mine), and Impala Platinum Holdings Ltd (Lac des Iles Mine).

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Nickel is produced from sulphide and lateritic ores	• Ferronickel • Unwrought nickel • Nickel powders	• Stainless and alloy steels • Nonferrous alloys and superalloys • Catalysts and chemicals	• Aerospace & defence • Electronics • Oil and gas • Automotive

Ontario Production and Trade Statistics

63,370 tonnes produced in Ontario in 2020[2]

$1.05B production value in 2020[3]

Nickel has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Kirkland Lake
- Sault Ste. Marie
- Kenora
- Sudbury
- Red Lake
- Timmins

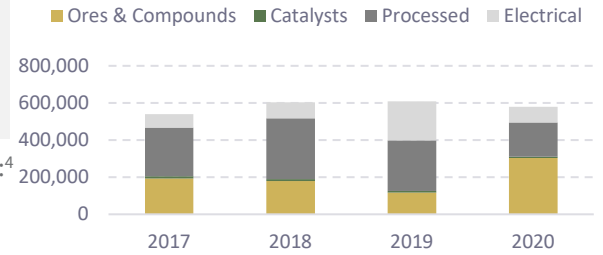
Ontario's Trade Balance: Exporter

Top Import Partner: United States (61%)

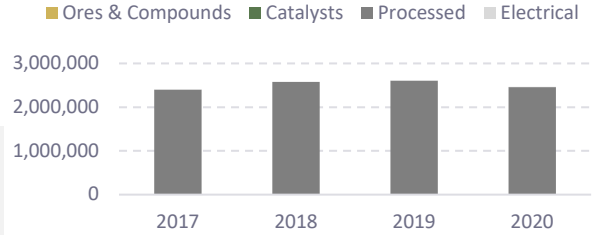
Top Export Partner: Norway (42%)

Note: Trade balance total across years 2017-2020

Nickel Imports (CAD$, thousands)[5]



Nickel Exports (CAD$, thousands)[6]



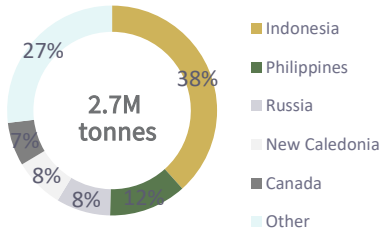
Note: HS codes include 282540, 282735, 283324, 381511, 741122, 750210, 750220, 750300, 750400, 750522, 750712, 750720, 750810, 750890, 850730 etc.

Global Production and Trade Statistics

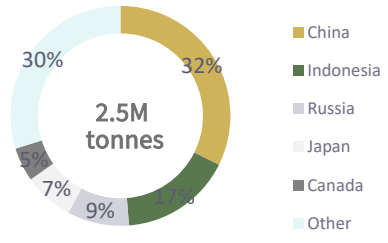
Reserves[8]

Country	Tonnes
1. Indonesia	21M
2. Australia	20M
3. Brazil	16M
4. Russia	6.9M
5. Cuba	5.5M
6. Philippines	4.8M
Total*	94M

Mine Production (2019)[9]



Refined & Smelted Production (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

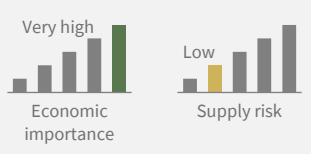
Ores	Refined Metal
Philippines (32.6M)	Indonesia (1.6M)
Indonesia (32.4M)	Japan (231.6K)
Ivory Coast (912.3K)	Brazil (181.6K)

Top Importers (2019, tonnes)[12]

Ores	Refined Metal
China (56.1M)	China (2.2M)
Japan (3.8M)	USA (219.6K)
S. Korea (3.2M)	S. Korea (190.4K)

Sources: [1] USGS [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7,8] USGS, [9,10] BGS, [11,12] UN Comtrade Database

Nickel

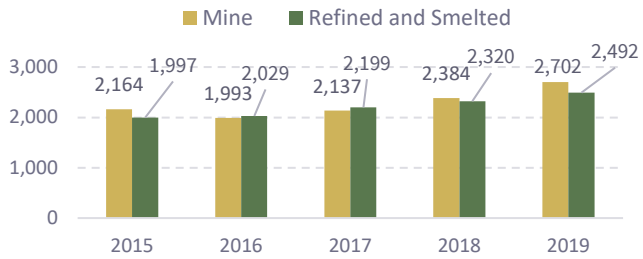


Status in Ontario: Produced/Processed

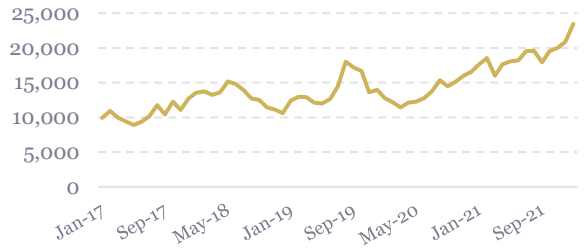
Market Conditions

- Price: Price of nickel fluctuates depending on demand for stainless and alloy steels. After an initial dip at the beginning of the pandemic, nickel prices saw a strong recovery as demand picked up in China and the US.[1]
- Production: Gradual expansion of production capacity was observed in major producing countries. Numerous idled facilities and delayed development projects resumed activity in anticipation of growing demand for nickel in EV batteries.[2]

Global Nickel Production (kilo-tonnes)[2]



Nickel Price, Cash (USD$/tonne)[3]



Economic and Strategic Importance

Importance in other jurisdictions: Nickel is on the critical mineral list of three major jurisdictions: Canada, Australia, and the US.[5]

Substitution (High): In construction, ultrahigh-chromium stainless steels have been substituted for austenitic grades in construction. Other critical minerals can also be substitutes for nickel, including titanium alloys in corrosive chemical environments.[6]

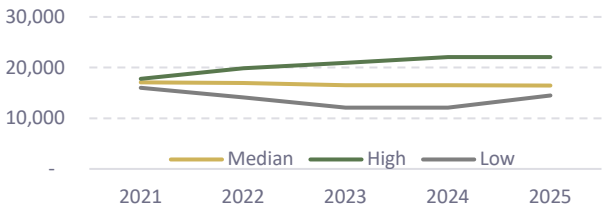
Use in strategic downstream industries: Nickel alloys are used by end-use industries such as aerospace & defence, chemical, electrical & electronics, oil & gas, and energy/power.[7]

Geopolitical factors: With the exception of Australia, where 21% of reserves are found, the majority of reserves are found in countries that are ranked towards the bottom half of the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness. For example, Indonesia, which owns the single largest quantity of reserves of nickel in the world, is ranked 128th out of 214 countries.[8]

Market Outlook

- Price outlook: Consensus suggests that the market expects the nickel price to trend upwards over the next few years, primarily driven by a growing demand for nickel in EV batteries, return of aviation demand and supply deficit.

Nickel Price Forecast (USD$/tonne)[3]



Demand outlook[4]

Near-term	Medium-to-long term
Demand is expected to pick up as electrification of vehicles continues to advance. In addition, return of air travel is expected to boost demand for aircrafts, which use nickel alloys for turbine engines.	Positive long-term outlook in anticipated, mainly derived by demand for EV batteries. New nickel-containing battery technology is being developed for uses in energy storage systems.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

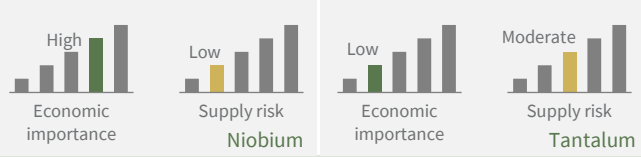
- Nickel has a high economic importance, as nickel alloys are inputs to a number of strategic downstream industries
- Overall, supply chain risks are at a relatively low risk, because the mineral is produced in many different countries
- Ontario has established nickel-producing mines and is a net exporter
- While there is currently no company producing battery-grade nickel, several junior mining companies indicated intention to produce nickel of such grades.

Opportunities for Ontario

- Ontario's endowment with nickel resources and the presence of major nickel producers provides an opportunity for the province to supply the mineral to local downstream industries, as well as to international markets
- Nickel is included on the critical minerals lists of three major jurisdictions, and the demand is expected to trend upwards; therefore, Ontario can leverage its competitive position to supply nickel to the international market

Sources: [1] USGS, [2] BGS [3] S&P Market Intelligence, [4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Niobium and Tantalum



Status in Ontario:

Niobium: Advanced Mineral Projects

Tantalum: Exploration Potential

Description and Key Facts

Niobium and tantalum are transition metals with very similar physical and chemical properties, and are commonly grouped together. The unique properties of niobium and tantalum include superconductivity, corrosion resistance, heat resistance, share-memory properties, and biocompatibility.[1]

- Ontario has no niobium or tantalum production as of 2020. In 2021, Niobay Metals' James Bay niobium project was at the advanced minerals project stage.
- Canadian niobium production takes place in Quebec. Canada is the second largest niobium producer after Brazil, accounting for 7% of global production in 2019.
- No signification production of tantalum has been reported in Canada in the past five years.
- Globally, niobium and tantalum production was highly concentrated, with Brazil producing more that 50% of niobium and tantalum ores in 2019.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Niobium ores and concentrates • Tantalum ores and concentrates	• Ferroniobium, niobium chemicals, niobium metal • Tantalum oxides, tantalum fluorides	• Steel • Superalloys • Superconductors	• Metal products • Motor vehicles and other transport equipment • Electronics • Chemical products

Ontario Production and Trade Statistics

No Niobium or Tantalum production in Ontario in 2020[2]

6,800 tonnes Canadian Niobium production in 2019[3]

Niobium and Tantalum have been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Kirkland Lake
- Sault Ste. Marie
- Kenora
- Sudbury
- Red Lake
- Timmins

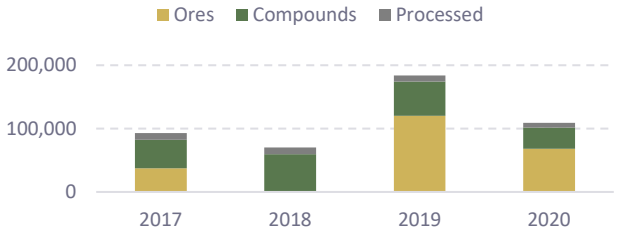
Ontario's Trade Balance: Exporter

Top Import Partner: Brazil (92%)

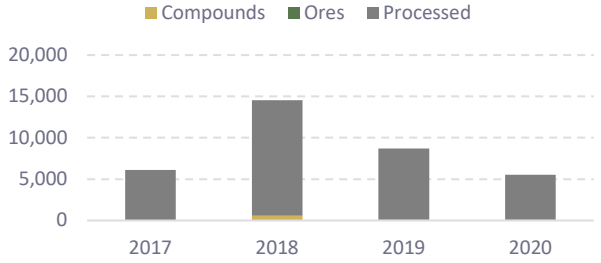
Top Export Partner: Norway (78%)

Note: Trade balance total across years 2017-2020

Niobium & Tantalum Imports (CAD$, thousands)[5]



Niobium & Tantalum Exports (CAD$, thousands)[6]



Note: HS codes include 261590, 720293, 8210320, 810330, 810390, 853221

Global Production and Trade Statistics

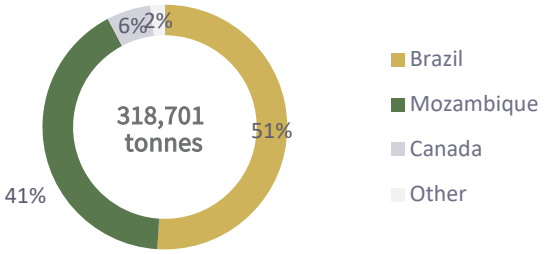
Niobium Reserves[8]

Country	Tonnes
1. Brazil	16M
2. Canada	1.6M
3. USA	0.17M
Total	>17M

Tantalum Reserves[9]

Country	Tonnes
1. USA	99,000
2. Brazil	40,000

Mine Production, Tantalum & Niobium (2019)[10]



Top Exporters (2019, tonnes)[11]

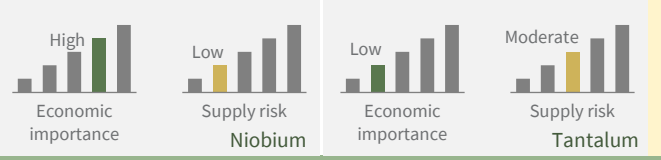
Niobium – Metal	Tantalum – Metal
Brazil (105.9K)	USA (0.5K)
Canada (9.7K)	China (0.5K)
Singapore (7K)	Indonesia (0.2K)

Top Importers (2019, tonnes)[12]

Niobium – Metal	Tantalum – Metal
China (46.7K)	USA (1.2K)
USA (13.2K)	UK (0.2K)
Singapore (9.3K)	Germany (0.2K)

Sources: [1] USGS, [2] NRCAN, [3] USGS [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study [8,9] USGS, [10] BGS, [11,12] UN Comtrade Database

Niobium and Tantalum



Status in Ontario:

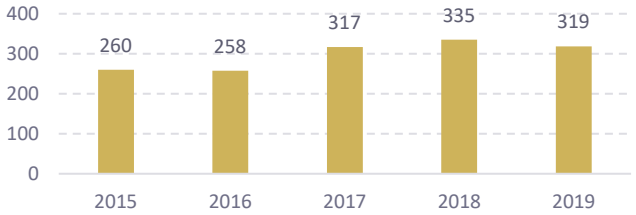
Niobium: Advanced Mineral Projects

Tantalum: Exploration Potential

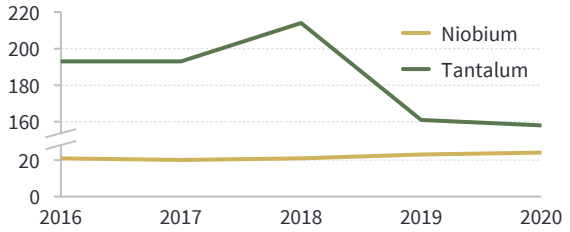
Market Conditions

- Price: Niobium price has remained stable in recent years. Tantalum price has dropped considerably after its recent peak in 2018, largely due to a lower demand and oversupply.[1]
- Production: Global production of tantalum peaked in 2018 and declined in 2019 due to weaker demand signals. Niobium production, however, has remained stable in recent years.[2]

Global Tantalum and Niobium Production (kilo-tonnes)[2]



Niobium and Tantalum Prices (USD$/kg)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Niobium and tantalum are on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Moderate): While substitutes exist, they are often associated with a price and penalty, and in general, there appears to be little economic or technical incentive to make any substitutions in these minerals' principal applications.[6]

Use in strategic downstream industries: Both critical minerals are used widely in electronics, metallurgy, steel, chemical, aerospace, and medical industries.[7]

Geopolitical factors: Just under 95% of reserves of niobium are found in Brazil, which, according to World Bank Governance indicators, is ranked 98th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] The US has the largest reserves of tantalum and is ranked 23rd on the same measure. Additionally, 92% of production occurs in either Brazil or Mozambique.

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	↗	→	↗
Price of niobium can be negatively impacted due to a lower demand for high-strength low-alloy (HSLA) in the automotive industry. Price of tantalum depends on the return of aerospace demand.	Long-term price of niobium depends on steel demand and price of its substitutes (e.g., vanadium). Tantalum price may increase given its important role in smartphone capacitors.	Demand for niobium is likely to decrease as chip shortages cause automakers to pull back production. Tantalum demand is expected to remain stable in the near-term.	Long-term outlook for niobium depends on new applications as demand for HSLA is expected to decline in the oil and gas sector. Superalloys and smart phones may result in higher tantalum demand.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

- Niobium and tantalum are generally considered to be high supply chain risk minerals due to highly concentrated production and reserves[9]
- Moreover, any substitution for niobium leads to inferior product quality
- Canada is the world's third largest producer of niobium and tantalum; therefore, access to domestic supply may mitigate supply disruptions in the downstream industries
- For Ontario, supply risk is estimated to be low for niobium and moderate for tantalum

Opportunities for Ontario

- Ontario's endowment with niobium and tantalum deposits in several regions provides an opportunity for the mining companies in the province to engage in exploration activity and provide steady supply for domestic use, as well as exports, primarily to the US and the EU countries
- With Niobay Metals' James Bay niobium project currently at an advanced mineral stage, Ontario may be able to compete with Quebec and strengthen Canada's opportunity to provide a reliable supply of niobium

Sources: [1,9] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Phosphate

Status in Ontario: Exploration Potential

Description and Key Facts

Phosphate rock is a mineral from which phosphorus is produced. Phosphorous is an essential element for plant and animal nutrition. It is a principal component in nitrogen-phosphorus-potassium fertilizers used throughout the world.[1]

- There has been no phosphate production in Canada in the past five years.
- China is the leading global producer of phosphate rock, making up 41% of global output in 2019.
- Phosphate's primary use is in fertilizer and other agricultural sector products.
- Ontario is a net importer of phosphate, and the US is the top import partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Phosphate rock	• Elemental phosphorous • Fertilizer based minerals	• Fertilizer chemicals • Phosphorous compound for industrial applications	• Agricultural chemicals (fertilizer) • Animal feed • Food additives

Ontario Production and Trade Statistics

No production in Ontario in 2020[2]

No Canadian production in 2020[3]

Phosphate has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Timmins

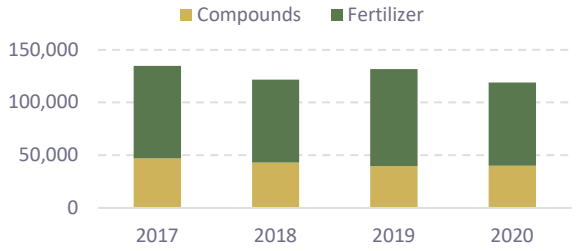
Ontario's Trade Balance: Importer

Top Import Partner: United States (72%)

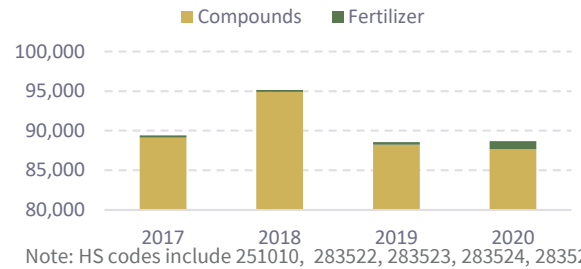
Top Export Partner: United States (92%)

Note: Trade balance total across years 2017-2020

Phosphate Imports (CAD$, thousands)[5]



Phosphate Exports (CAD$, thousands)[6]



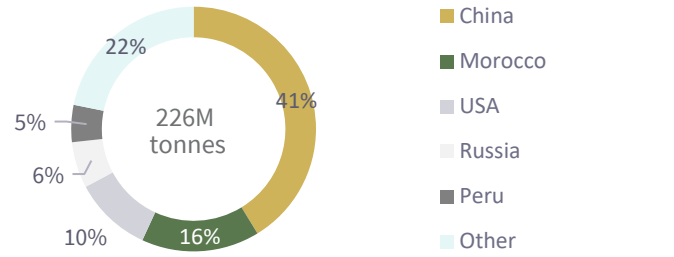
Note: HS codes include 251010, 283522, 283523, 283524, 283525, 283526, 283529, 283531, 283539, 291910, 310311, 310319, 310530, 310540, 310550 etc.

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Morocco	50B
2. China	3.2B
3. Egypt	2.8B
4. Algeria	2.2B
5. Syria	1.8B
6. Brazil	1.6B
Total*	71B

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

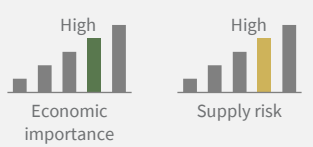
Ores	
1. Morocco (9.5M)	4. Russia (3M)
2. Jordan (4.9M)	5. China (1.5M)
3. Egypt (3.1M)	6. Togo (1M)

Top Importers (2019, tonnes)[11]

Ores	
1. India (7.5M)	4. Poland (1.5M)
2. Brazil (2.4M)	5. Serbia (671K)
3. USA (2.2M)	6. Belarus (643K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Phosphate

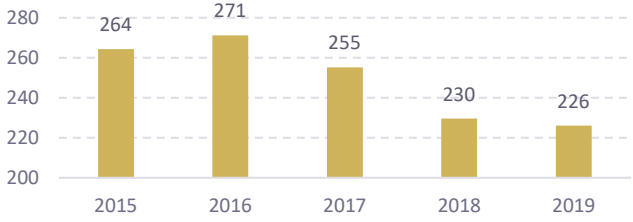


Status in Ontario: Exploration Potential

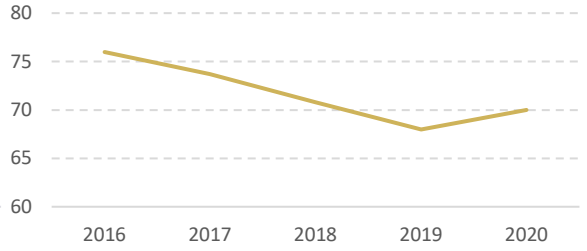
Market Conditions

- Price: Between 2016 and 2019 the average annual price of phosphate rock fell by over 10%, from USD$77 to USD$68 per tonne, before rising to USD$70 per tonne as of 2020.[1]
- Production: China is the main global producer of phosphate rock, although large reserves exist in Morocco and Western Sahara. Global phosphate rock production fell by nearly 20% between 2016 and 2019 due in part to Chinese government interventions to protect reserve levels.[2]

Global Phosphate Rock Production (million tonnes)[2]



Phosphate Price (USD$/tonne)[1]



Economic and Strategic Importance

Importance in other jurisdictions: Phosphate is on the critical mineral list of the EU.[5]

Substitution (Low): There are no substitutes for phosphate rock for the production of fertilisers.[6]

Use in strategic downstream industries: The agricultural industry primarily uses phosphates in fertilizer and feeds, with the remaining consumption occurring in downstream industries, such as personal hygiene and construction.[7]

Geopolitical factors: Morocco is where by far the largest reserves of phosphate are found, with approximately 70% of the global total. According to World Bank Governance indicators. Morocco is ranked 127th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] Additionally, 57% of production occurs in China and Morocco, the former which is ranked 144th on the same index.

Market Outlook

Price outlook[3]		Demand outlook[4]	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	↗	→
Price of phosphate rock may remain stable in the near-term as both supply and demand are less affected by the pandemic.	New supply takes years to build up, thus, supply deficit may occur in the long-term. However, reliance on phosphate for fertilizer is decreasing. Long-term price may stay flat.	Over 90% of phosphate rock is used in fertilizer production globally. Demand will rise in the near-term as global population growth drives agricultural production.[3]	Demand is primarily driven by population growth. However, environmental considerations mean several secondary sources of phosphorus are being developed, which may displace phosphate.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

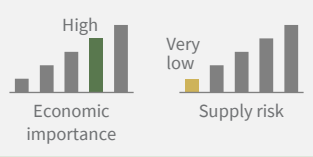
- As there are no substitutes for phosphate in agricultural fertilizer applications, it has a high economic important for the agriculture industry
- The majority of the reserves are controlled by Morocco and production is dominated by China; this may indicate that phosphate's supply chain risks may be relatively high
- There is no current phosphate rock production in Ontario; the province relies on the US imports for its supplies of phosphate fertilizer and compounds

Opportunities for Ontario

- Ontario's endowment with phosphate rock deposits in several regions provides an opportunity for mining companies in the province to engage in exploration activity and provide steady supply of the mineral for domestic use as well as export markets, such as the EU countries
- Access to domestic supply of phosphate fertilizer could contribute to strengthening Ontario's agricultural industry, and its export potential, and mitigate supply chain risks

Sources: [1] USGS, [2] BGS [3,4,7] EU critical raw materials factsheets and USGS [5] Critical mineral lists of major jurisdictions [6] EU Critical Minerals Study [8] World Bank

Platinum Group Elements



Status in Ontario: Produced/Processed

Description and Key Facts

PGEs comprise of six elements: platinum, palladium, rhodium, ruthenium, iridium, and osmium. Many of PGEs' properties, including strong catalytic properties, high resistance to corrosion and oxidation, high melting point, high density, electrical conductivity and non-toxicity make them suitable for industrial applications.[1]

- In 2020, Ontario produced approximately CAD$1.4 billion in PGEs; the province contributes significantly to the global market. North American Palladium Ltd.'s Lac des Iles mine is a major PGE-producing mine in the province.
- Platinum group metals are valuable and are often found in jewelry. Other uses are observed in the automotive and chemical manufacturing sector.
- Ontario is a net exporter of platinum group metals. Switzerland is the top import partner and Norway is the top export partner of Ontario.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Composite PGE ore concentrates • By-products from base metals mining	• Unwrought or powder	• Metals in semi-manufactured forms • Auto-catalysts • Process catalysts	• Automotive • Chemical manufacturing • Jewelry • Electronics • Medical instruments

Ontario Production and Trade Statistics

22.86 tonnes produced in Ontario in 2020[2]

$1.4B production value in 2020[3]

PGEs have been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Sudbury
- Timmins
- Kirkland Lake

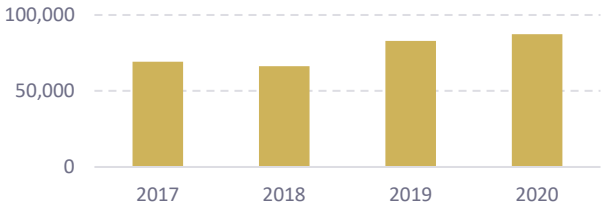
Ontario's Trade Balance: Exporter

Top Import Partner: Switzerland (51%)

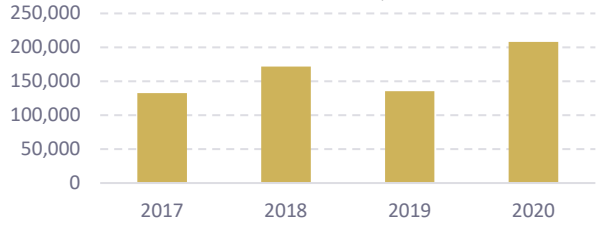
Top Export Partner: Norway (49%)

Note: Trade balance total across years 2017-2020

Platinum Group Element Imports (CAD$, thousands)[5]



Platinum Group Element Exports (CAD$, thousands)[6]



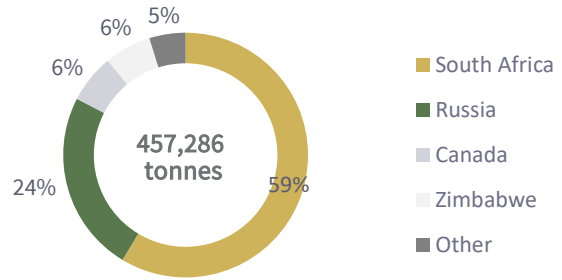
Note: HS codes include 711011, 711019, 711510, 711292

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. South Africa	63M
2. Russia	3.9M
3. Zimbabwe	1.2M
4. USA	0.9M
5. Canada	0.3M
Total*	69M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

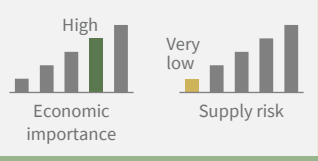
Ores	
1. Germany (6.7K)	4. Canada (2.2K)
2. UK (3.2K)	5. Mexico (1.1K)
3. Japan (3.0K)	6. USA (1.0K)

Top Importers (2019, tonnes)[11]

Ores	
1. Belgium (23.3K)	4. S. Africa (6.5K)
2. Japan (11.7K)	5. USA (5.6K)
3. Germany (8.7K)	6. S. Korea (3.5K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Platinum Group Elements

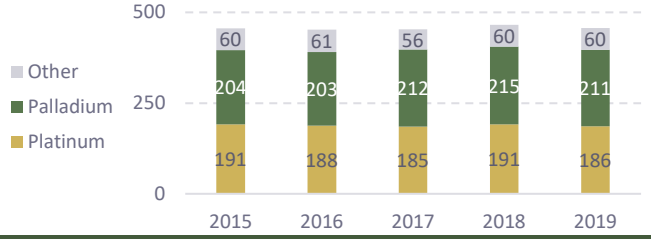


Status in Ontario: Produced/Processed

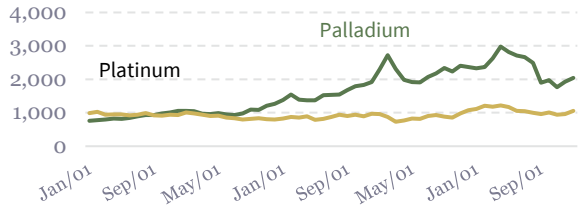
Market Conditions

- Price: PGEs have limited availability, resulting in high prices and short-term volatility. Since 2016, platinum prices have been in the range of ~USD$1,000 per ounce, while palladium has seen prices reach as high as ~USD$3,000 per ounce.[2]
- Production: The largest primary suppliers of PGEs are South Africa (platinum) and Russia (palladium). PGEs are scare resources that are typically produced in low volumes; global production remained flat at approximately 450 kilo-tonnes in each year between 2015 and 2019. Due to their high prices, PGEs are frequently recycled in order to meet global demand.[3]

Global PGE Production (kilo-tonnes)[1]



PGE Prices (USD$/oz)[2]



Economic and Strategic Importance

Importance in other jurisdictions: PGEs are on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Moderate): While various substitutes exist, for the most part, they tend to replace one platinum group metal for another.[6]

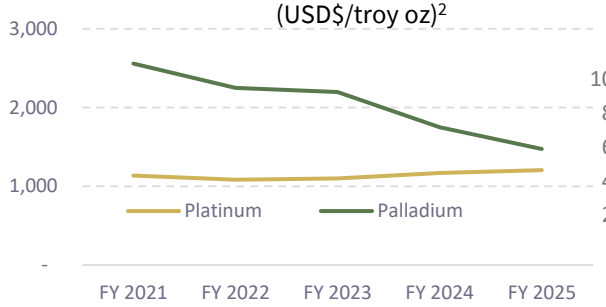
Use in strategic downstream industries: PGEs are used in automotive industry, medical industry as an important chemotherapy drugs in treating cancer. The electronic industry also uses them for computer hard disks and thermocouples.[7]

Geopolitical factors: South Africa is both the country which holds the largest quantity of reserves globally (91%) and the greatest amount of production (59%). According to World Bank Governance indicators, the country is ranked 82nd out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

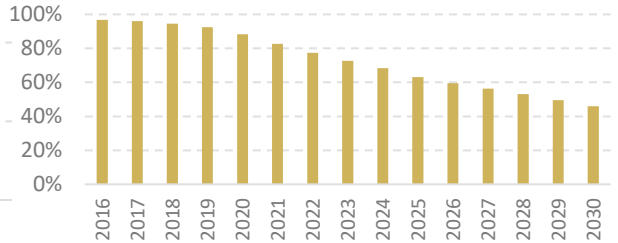
Market Outlook

- Price outlook: Based on the median forecast the price of palladium is expected to decline rapidly to ~USD$1,500 per ounce by 2025, while the price of platinum rises modestly to ~USD$1,200.
- Downstream industries demand outlook: The primary use of platinum and palladium is as automotive catalysts for emission control in internal combustion engine (ICE) vehicles. While demand may rise in the near-term due to stricter emission standards, the projected declining trend for ICE vehicle market share will cause demand to fall over the next decade and beyond. [3]

Platinum Group Elements Price Forecasts (USD$/troy oz)[2]



ICE Vehicle Share of Total Light Vehicle Market, Global[4]



Key Takeaways

Supply chain risks

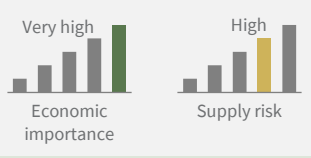
- With over 80% of mine production occurring in South Africa and Russia, and the majority of reserves concentrate in South Africa, supply chain risks at a global scale may be relatively high
- As Ontario is currently a producer, processor, and net exporter of PGEs, the risk of supply chain disruption for downstream industries in the province is likely very low

Opportunities for Ontario

- Given Ontario's endowment and current production status, the province has an opportunity to provide a reliable supply of the mineral to local downstream manufacturers, including medical equipment and electronics sectors
- Ontario can be a reliable and geopolitically stable source of PGE imports for other major jurisdictions; currently, PGEs are included on six major jurisdictions critical mineral lists

Sources: [1] BGS [2] S&P Global Market Intelligence [3] European Commission [4] LMC Automotive [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Rare Earth Elements



Status in Ontario: Exploration Potential

Description and Key Facts

Rare earth elements (REEs) are a group of 15 elements referred to as the lanthanide series in the periodic table of elements. Scandium and yttrium, while not true REEs, are also included in this categorization because they exhibit similar properties to the lanthanides and are found in the same ore bodies. RREs are used in a variety of industrial applications, including electronics, clean energy, aerospace, automotive and defence.[1]

- There hasn't been REEs production in Ontario to date. Elsewhere in Canada, the Nechalacho mine near Yellowknife, Northwest Territories, Canada's first rare earth mining project, began production of REEs in mid-2021.
- China is the world's largest producer of REEs, accounting for over 60% of global annual production in 2019. The manufacturing of permanent magnets represents the single largest and most important end use for REEs, accounting for 38% of total forecasted demand.[2]
- Ontario is a net importer of REEs, and the US is its top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• REE occur in other minerals deposits • The most important REEs in ore deposits are bastnäsite and monazite	• Oxides • REE metals	• Chemical catalysts • Ceramics and glass • Metallurgy and alloys	• Electronics • Automotive • Aerospace and defence • Lighting • Renewable energy • Ceramics and pigments

Ontario Production and Trade Statistics

No production in Ontario[2]

First Canadian project began in mid-2021[3]

REEs have been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Sudbury
- Timmins
- Red Lake
- Kenora

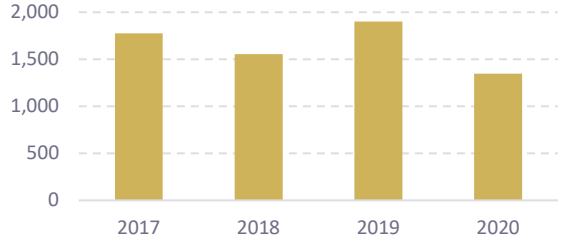
Ontario's Trade Balance: Importer

Top Import Partner: United States (62%)

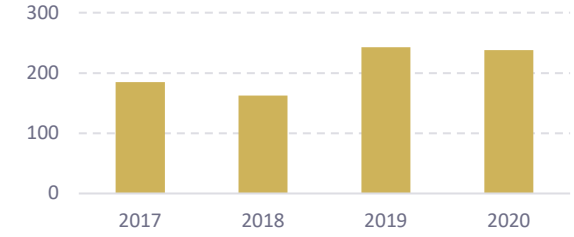
Top Export Partner: United States (89%)

Note: Trade balance total across years 2017-2020

Rare Earth Element Imports (CAD$, thousands)[5]



Rare Earth Element Exports (CAD$, thousands)[6]



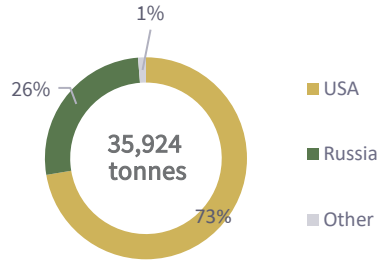
Note: HS codes include 284610, 284690, 280530

Global Production and Trade Statistics

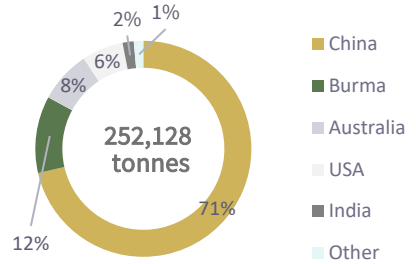
Reserves[8]

Country	Tonnes
1. China	44M
2. Vietnam	22M
3. Brazil	21M
4. Russia	12M
5. India	6.9M
6. Australia	4.1M
Total*	120M

Rare Earth Minerals (2019)[9]



Rare Earth Oxides (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

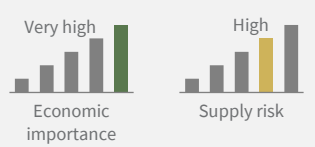
Metals	Chemicals
China (6.9K)	USA (46.6K)
Philippines (0.9K)	China (30.6K)
Thailand (0.6K)	Malaysia (21.4K)

Top Importers (2019, tonnes)[12]

Metals	Chemicals
Malaysia (26.2K)	China (35.6K)
Japan (8.3K)	Benin (27.5K)
Thailand (0.7K)	USA (16.9K)

Sources: [1] USGS [2] NRCAN [3] CBC [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study [8] USGS, [9,10] BGS, [11,12] UN Comtrade Database

Rare Earth Elements

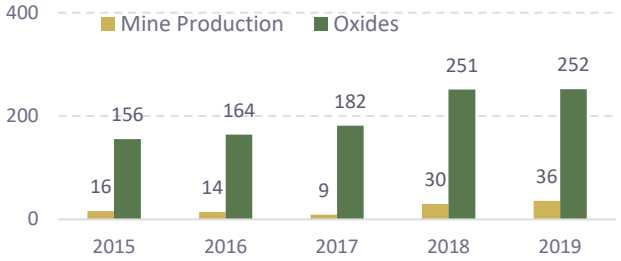


Status in Ontario: Exploration Potential

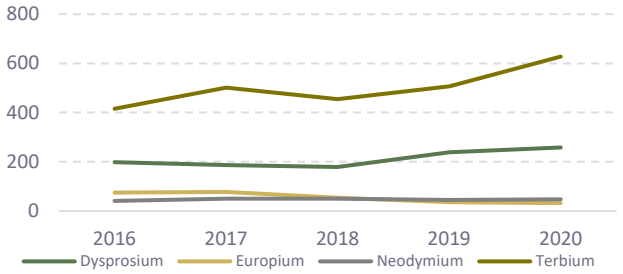
Market Conditions

- Price: Recent price trends for major REEs vary from healthy growth (for terbium, dysprosium), to stable (for neodymium), and decline in price (for europium).[2]
- Production: China is the world's largest producer of REEs, accounting for over 60% of annual global production. Total mineral production more than doubled and oxide production grew by over 60% between 2015 and 2019, reflecting the growing use of rare earth permanent magnets in electronics.[4]

Global Rare Earth Elements Production (kilo-tonnes)[1]



Rare Earth Elements Prices (USD$/kg)[2]



Economic and Strategic Importance

Importance in other jurisdictions: REEs are on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Moderate): Depending on the rare earth element, some substitutability is possible.[6]

Use in strategic downstream industries: REEs are used in the manufacturing industry as steel alloys as well as components in high technology devices.[7]

Geopolitical factors: Just over 95% of reserves are found in countries that, according to the World Bank Governance indicators, rank towards the bottom in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8] However, almost three quarters of production occurs in the US (ranked 23rd). Additionally, over 70% of rare earth oxide rare earth metal production occurs in China, ranked 144th.

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
China maintains strict control (e.g., quotas) over its REE production that creates a limited and unstable supply for the rest of the world. This could result in an overall rise in prices in the near-term.[3]	REEs are found in minable concentrations less often than other minerals and have limited recycling input rates, meaning prices may remain high overall in the medium- to-long term.[2]	The largest source of demand of REEs is for the production of permanent magnets, which are used in a wide variety of industrial applications and will drive strong demand in the near-term. [3]	REEs have strong potential for clean technology applications, particularly in EV motors, which should keep demand high over the medium- to-long term as they gain market share.[3]

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

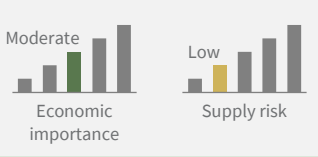
- REE are considered one of the highest supply chain risk commodities, because they have diverse and highly useful properties[9]
- Supply of REEs plays an important role in high-tech applications, as well as green technologies
- As no REE production takes place in Canada, it may pose a relatively high supply chain risk for Ontario's industries
- Rare earth oxide market is dominated by China, which may pose supply chain risks to other countries relying on REE supply in high-tech manufacturing

Opportunities for Ontario

- Ontario's REE exploration potential in several regions may provide an opportunity for the province to supply the mineral to local downstream industries, and to other jurisdictions, including current top global importers
- Given REEs importance in major manufacturing jurisdictions, Ontario's geological endowment can materialize in export opportunities

Sources: [1] BGS [2] USGS [3] European Commission [4] NRCAN [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank [9] Geoscience Australia "Critical commodities for a high-tech world: Australia's potential to supply global demand"

Selenium



Status in Ontario: Produced/Processed

Description and Key Facts

Selenium is a non-metal chemical element, occurring in organic and non-organic forms. Its usage has been driven by the development of applications in rubber compounding, steel alloying and selenium rectifiers.[1]

- Ontario currently produces selenium, with production mostly occurring in the Sudbury Basin.
- Currently, China is the leading producer globally, making up 32% of global supply in 2019.
- Selenium is used in fertilizer, cosmetics and solar cells among other applications.
- Ontario is a net exporter of selenium. The province's top import partner is Germany and the top export partner is the US .

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Selenium is extracted as a by-product of copper or nickel	• Selenium metal • Selenium dioxide	• Copper, lead, steel alloys • Rubber compounding chemicals • Pigments • Plating solutions • Dietary supplements	• Agricultural fertilizers • Cosmetics • Solar cells • Photocopying • Rubber products

Ontario Production and Trade Statistics

53.5 tonnes produced in Ontario in 2020[2]

$2.6M production value in 2020[3]

Selenium has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Timmins

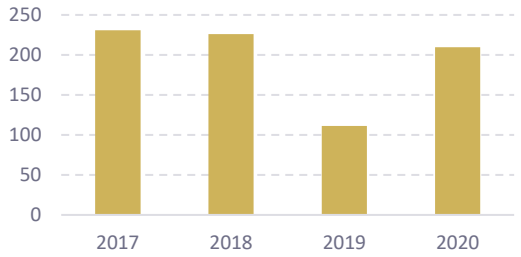
Ontario's Trade Balance: Exporter

Top Import Partner: Germany (33%)

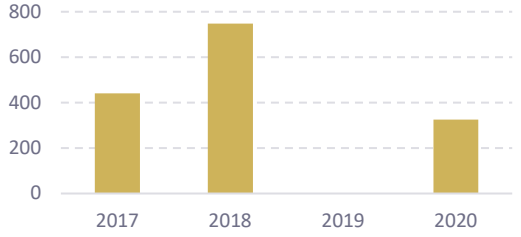
Top Export Partner: United States (73%)

Note: Trade balance total across years 2017-2020

Selenium Imports (CAD$, thousands)[5]



Selenium Exports (CAD$, thousands)[6]



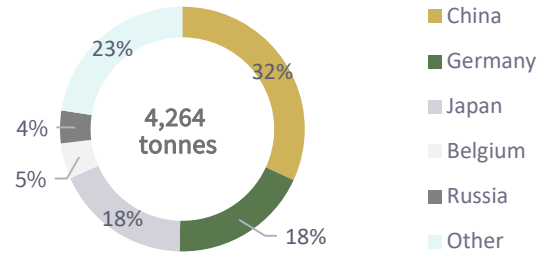
Note: HS codes include 280490

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	26,000
2. Russia	20,000
3. Peru	13,000
4. USA	10,000
5. Canada	6,000
6. Poland	3,000
Total*	100,000

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

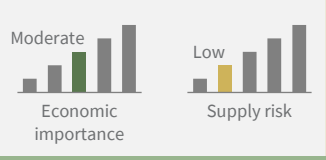
Metals	
1. Hong Kong (1.3K)	4. China (0.5K)
2. Japan (0.6K)	5. S. Korea (0.4K)
3. Canada (0.6K)	6. USA (0.4K)

Top Importers (2019, tonnes)[11]

Metals	
1. Hong Kong (1.4K)	4. USA (0.5K)
2. China (1.3K)	5. India (0.5K)
3. Germany (1.3K)	6. UK (0.3K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9] BGS, [10,11] UN Comtrade Database

Selenium

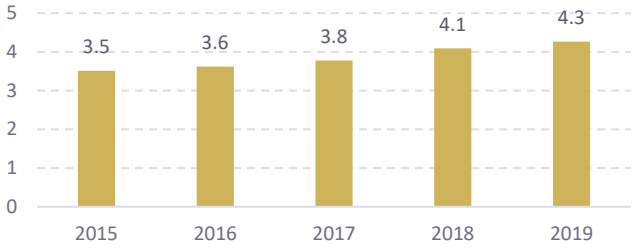


Status in Ontario: Produced/Processed

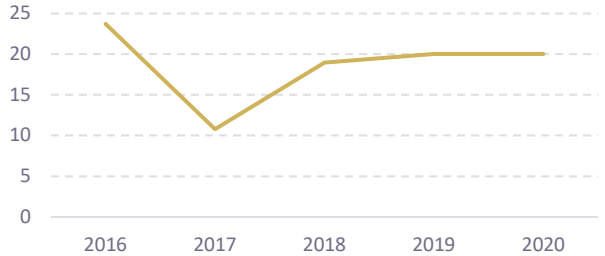
Market Conditions

- Price: Selenium prices saw a short-lived dip in 2017, followed by a partial recovery in 2018. The average annual price of selenium has remained stable at USD$20 per pound since late 2018.[2]
- Production: China is the world's leading producer of refined selenium, with significant production also coming from Germany and Japan. Global production levels have been steadily increasing since 2015, rising by over 20% to 4.3 kilo-tonnes as of 2019.[2]

Global Selenium Production (kilo-tonnes)[1]



Selenium Price, 99.5% (USD$/lb)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Selenium is included on the Australia's critical mineral list.[3]

Substitution (Moderate): The major substitute in low- and medium-voltage rectifiers is silicon, and organic pigments can be used for cadmium sulfoselenide pigments. Additionally, sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese.[4]

Use in strategic downstream industries: Selenium is primarily used in the glassmaking and pigments industries.[5]

Geopolitical factors: While about 60% of reserves are found in countries that are ranked towards the bottom half of the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality and government effectiveness (e.g., China, Russia), the other 40% are in countries that rank in the upper half, including the US, Poland and Canada.[6]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	→	↗
The price of selenium has been steady since late 2018 despite the impact of the COVID-19 pandemic on the global economy. Barring unforeseen changes, the price should remain stable in the near-term.	Most selenium is produced as a by-product of other metals, primarily copper. Increases in metal refining activities are expected to create additional supply, resulting in a neutral price outlook.	China's selenium market has slowed due to reduced demand from downstream industries (e.g., glass manufacturers), resulting in a neutral outlook in the near-term.[2]	Selenium's usage as a fertilizer additive should increase its demand over the medium- to long-term, as global population growth results in a greater need for agricultural production.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

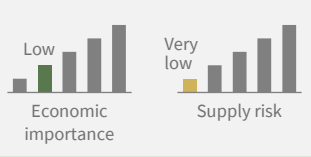
- Small quantities of selenium are produced globally in a number of different countries, indicating a slowing and stable demand from downstream industries
- Australia is the only jurisdiction that includes selenium on its critical minerals list
- Selenium supply chain disruption risk is likely relatively low

Opportunities for Ontario

- Ontario can leverage its endowment and production capacity of selenium to provide a stable supply for domestic downstream industries and exports to the US
- In the medium- to long-term, the demand for selenium may increase, which may offer an opportunity for Ontario's producers to strengthen a competitive export position

Sources: [1] BGS [2] USGS [3] Critical mineral lists of major jurisdictions,[4],[5] USGS,[6] World Bank

Tellurium



Status in Ontario: Produced/Processed

Description and Key Facts

Tellurium is a relatively rare element in the same chemical family as oxygen, sulfur and selenium. It has the properties of both metals and non-metals. It is most widely used in thermoelectric and alloying applications.[1]

- Ontario is a producer of tellurium.
- China is the global production leader, making up nearly 75% of total tellurium production.
- Tellurium is used in photocopying and printers, along with solar cells and a number of other uses.
- Ontario is a net importer of tellurium. The US is the top import partner and China is the top export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Produced as a by-product of copper processing	• Tellurium powder • Tellurium dioxide • Tellurium compounds	• Alloying additive in steel, copper, lead • Rubber • Pigment for glass and ceramics • Semi-conductors	• Photocopying and laser printers • Solar cells • Thermoelectric devices • Healthcare

Ontario Production and Trade Statistics

7.67 tonnes produced in Ontario in 2020[2]

$790,000 production value in 2020[3]

Tellurium has been discovered in the following districts:[4]

- Thunder Bay South

Note:
For the purposes of tracking trade flows, boron and tellurium are grouped together. This makes it difficult to parse out the two elements. Most imports under this code may be boron, while most exports may be tellurium as it is produced in Ontario.

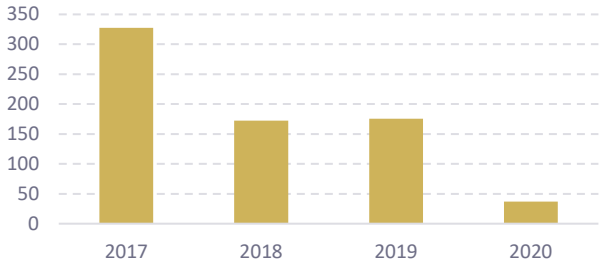
Ontario's Trade Balance: Exporter

Top Import Partner: United States (98%)

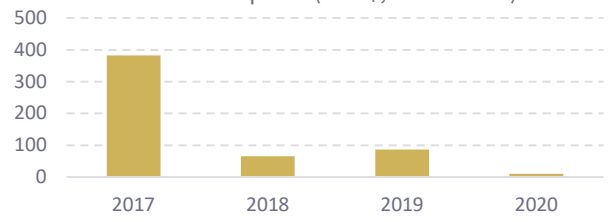
Top Export Partner: China (52%)

Note: Trade balance total across years 2017-2020

Tellurium Imports (CAD$, thousands)[5]



Tellurium Exports (CAD$, thousands)[6]



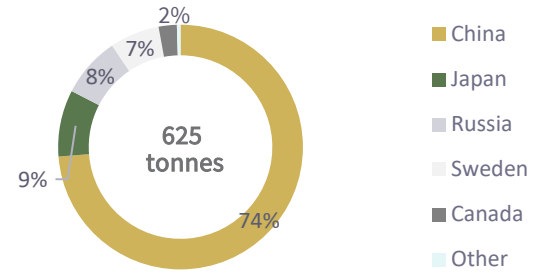
Note: Trade data groups boron and tellurium together under a single commodity code (280450)

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	6,600
2. USA	3,500
3. Canada	800
4. Sweden	670
Other	19,000
Total	31,000

Mine Production (2019)[9]



Top Exporters (2019, tonnes)[10]

Metals	
1. China (1.8K)	4. S. Korea (0.3K)
2. Hong Kong (1.1K)	5. Philippines (0.3K)
3. Canada (0.3K)	6. Germany (0.1K)

Top Importers (2019, tonnes)[11]

Metals	
1. USA (1.2K)	4. China (0.2K)
2. UK (0.2K)	5. S. Korea (0.1K)
3. Germany (0.2K)	6. Czechia (0.1K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9] BGS, [10,11] UN Comtrade Database

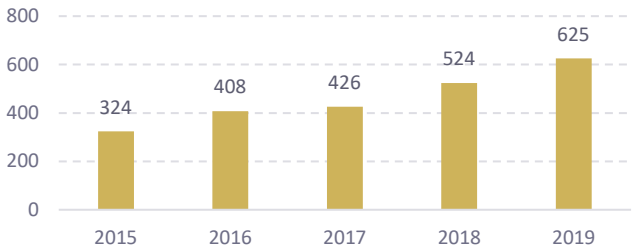
Tellurium

Status in Ontario: Produced/Processed

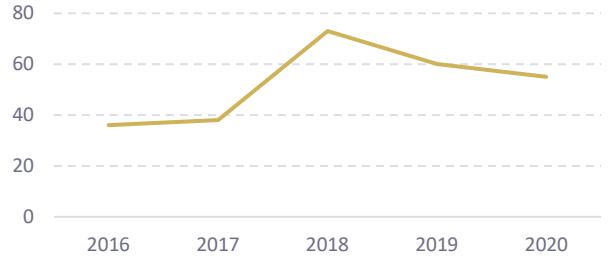
Market Conditions

- Price: The average price of tellurium increased significantly between 2016 and 2018 but has since declined in consecutive years, falling to USD$55 per kilogram in 2020.[2]
- Production: China is the leading global producer of tellurium, accounting for over 70% of annual production. Global production rose by 20% in 2019 mostly due to increases in output from Chinese firms and tellurium auctions in Yunnan province.[2]

Global Tellurium Production (tonnes)[1]



Tellurium Price, 99.95% (USD$/kg)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Tellurium is on the critical mineral list of two major jurisdictions: US and Canada.[3]

Substitution (Moderate): While several materials can replace tellurium in most of its uses, it is usually coupled with losses in efficiency or product characteristics. For example, calcium and lead can be used in place of tellurium in many free-machining steels.[4]

Use in strategic downstream industries: Tellurium is used as a catalyst in the oil refining industry, in cooling and energy generation and as an alloying additive to improve machining characteristics.[5]

Geopolitical factors: China is where the largest quantity of reserves are found (about 21%) and is where the majority of production occurs (74%). According to the World Bank Governance indicators, the country is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality and government effectiveness.[6]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Tellurium prices began recovering from the impact of COVID-19 pandemic on global demand towards the end of 2020. This trend is expected to continue, resulting in a positive price outlook. [2]	Like selenium, tellurium is mostly produced as a by-product of other metals. Additional supply of these metals means the price outlook will remain neutral over the medium- to long-term.	Tellurium is used in the production of PV solar cells. Demand for replacement cells is expected to be moderate in the near-term as many in use currently are still relatively new. [2]	Adoption of solar panels and thermoelectric generators is expected to increase over the medium- to long-term, leading to growth in the demand for tellurium.

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

- Tellurium is a rare element, with just over 600 tonnes produced in 2019, its economic significance is likely limited.
- Canada and the US are the two major jurisdictions that include it on their critical minerals lists.
- With domestic production taking place in Ontario, supply chain disruptions risk is relatively low.

Opportunities for Ontario

- Ontario's tellurium exploration potential (e.g., occurs in association with some gold deposits) and existing production capacity may provide an opportunity for the province to supply the mineral to the local downstream industries, and to other jurisdictions, including current top global importers.
- Since the largest quantity of the reserves and the majority of production is dominated by China, Ontario may have an opportunity to expand its exports.

Sources: [1] BGS [2] USGS [3] Critical mineral lists of major jurisdictions , [4,5] USGS, [6] World Bank

Tin

Low — Economic importance

Moderate — Supply risk

Status in Ontario: Exploration Potential

Description and Key Facts

Tin is a chemical element from the carbon family, it is soft silvery-white metal. Tin is most widely used for plating cans used as food containers. It is one of the earliest minerals known and used on all continents, but is relatively scarce.[1]

- There has been no tin production in Canada in the past five years.
- The top global producer of both mined and smelted tin is China.
- Tin is used in canning, electrical products and lighting among others.
- Ontario is a net importer of tin, and the US is both the top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Most of the tin in the world is produced from placer deposits • Recovered from old and new scrap	• Smelted tin	• Chemicals • Solder • Alloys • Brass and bronze, tinning • Tin plating • Grass	• Canned food • Electrical products • Lighting • Eyeglasses, lenses • Metal consumer products • Plastics

Ontario Production and Trade Statistics

No tin production in Ontario in 2020[2]

No Canadian production in 2020[3]

Tin has been discovered in the following districts:[4]

- Thunder Bay North
- Kenora
- Timmins

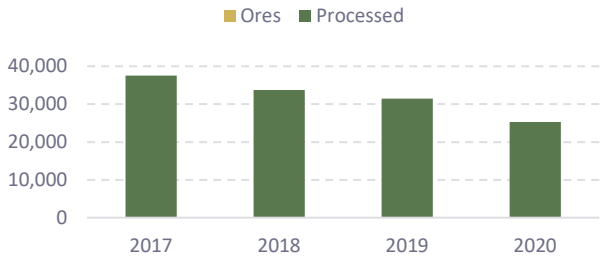
Ontario's Trade Balance: Importer

Top Import Partner: United States (37%)

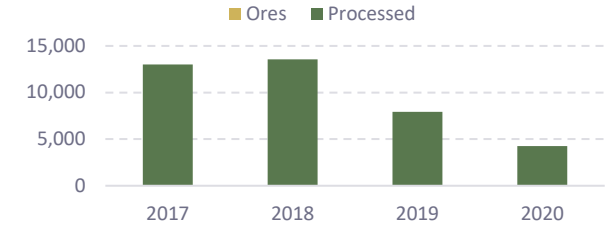
Top Export Partner: United States (99%)

Note: Trade balance total across years 2017-2020

Tin Imports (CAD$, thousands)[5]



Tin Exports (CAD$, thousands)[6]



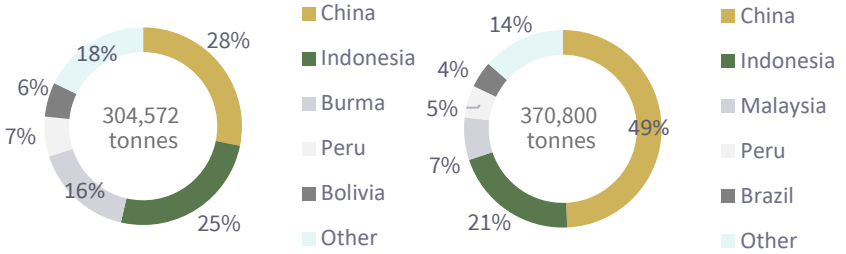
Note: HS Codes 800110, 800120, 800200, 800300, 800700, 260900

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	1,100,000
2. Indonesia	800,000
3. Australia	430,000
4. Brazil	420,000
5. Bolivia	400,000
6. Russia	280,000
Total*	4,300,000

Mine Production (2019)[9]



Smelted Production (2019)[10]

*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

Ores	Refined Metal
Myanmar (33.1K)	Indonesia (69.3K)
Australia (14.5K)	Malaysia (32.1K)
DRC (4.5K)	Canada (31.0K)

Top Importers (2019, tonnes)[12]

Ores	Refined Metal
China (178.2K)	USA (69.6K)
Malaysia (32.7K)	Japan (25.3K)
Thailand (10.8K)	Germany (21.9K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9,10] BGS, [10,11] UN Comtrade Database

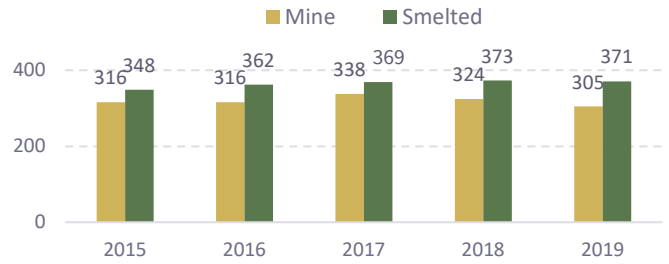
Tin

Status in Ontario: Exploration Potential

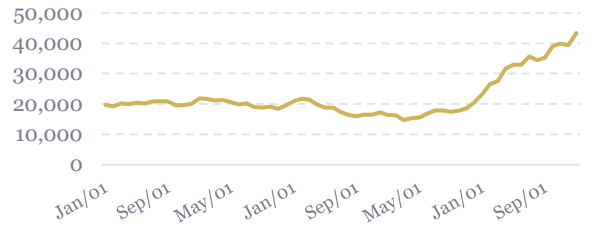
Market Conditions

- Price: The price of tin was stable at ~USD$20,000 per tonne before declining to ~USD$15,000 per tonne beginning in mid-2019. Prices have surged in 2021 due to a combination of the pandemic supply disruptions, voluntary production cuts and political unrest in producing nations.[4]
- Production: The world's top producers of mined tin are China and Indonesia, with additional production supplied by Burma and Peru. Global tin mine production has declined modestly since 2017, while tin smelter output has remained relatively stable.[3]

Global Tin Production (kilo-tonnes)[1]



Tin Price, 99.85%, Cash (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Tin is on the critical mineral list of three major jurisdictions: US, Canada, and Australia.[4]

Substitution (High): Aluminium, glass, paper, plastic or tin-free steel substitute can serve as substitutes for use in containers. Other materials include epoxy resins for solder, aluminum alloys for bronze and plastics for bearing materials that contain tin.[5]

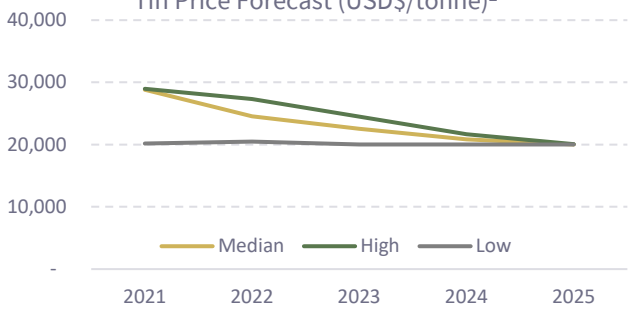
Use in strategic downstream industries: Tin is used in a variety of industries, including aerospace, construction and home décor, electronics, jewelry manufacturing and telecommunications.[6]

Geopolitical factors: With the exception of Australia, where 10% of reserves are found, the majority of reserves are found in countries that are ranked towards the bottom half of the World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality and government effectiveness. For example, China which owns the single largest quantity of reserves of tin in the world, is ranked 144th out of 214 countries.[5] China is also the biggest producer and smelter of tin globally.[7]

Market Outlook

Price outlook: Based on the median forecast, tin commodity price is expected to decline to ~USD$20,000 per tonne by 2025. This price is also expected in both the low and high forecast scenarios despite different price outlooks in the intervening years.

Tin Price Forecast (USD$/tonne)[2]



Demand outlook

Near-term	Medium-to-long term
The largest global use of tin is in alloys, such as solder. A return to pre-pandemic levels of global demand for durable goods will result in a positive near-term outlook for tin demand.[3]	The outlook for tin demand is positive over the medium- to long-term, due to its use in electronics with strong commercial potential, including semi-conductors and lithium-ion batteries.[4]

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

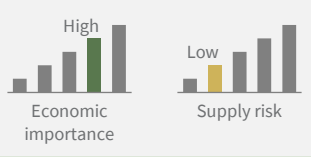
- Tin has a wide range of applications and is produced in a number of different countries; however, China dominates the production of ore and smelted tin
- With no current production in Ontario, provincial downstream industries depend on import supplies of tin, primarily from the US
- As the demand for tin may continue to rise, supply chain risks may be moderate

Opportunities for Ontario

- Ontario's tin exploration potential in several regions may provide an opportunity for the province to supply the mineral to the local downstream industries and to other jurisdictions, including current top global importers
- Additionally, tin production in Ontario could strengthen the mining sector's export potential

Sources: [1] BGS [2] S&P Global Market Intelligence [3] USGS [4] Critical mineral lists of major jurisdictions , [5,6] USGS, [7] World Bank

Titanium



Status in Ontario: Exploration Potential

Description and Key Facts

Titanium is primarily extracted from ilmenite, leucoxene and rutile minerals. The majority of titanium is consumed in the form of titanium dioxide, but titanium metal and metal powders have applications in manufacturing due to its superior corrosion resistance and strength-to-weight ratio.[1]

- Titanium is not currently produced in Ontario, although titanium oxide is produced in Quebec at the Rio Tinto's Lac Tio titanium mine.
- China is the global leader in titanium production, making up ~30% of total production.
- Titanium is used in paints and pigments, along with aerospace and defence and other types of equipment.
- Ontario is a net importer of titanium, and the US is Ontario's top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Titanium ores and concentrates	• Titanium metal • Titanium oxides	• Metal bats, rods, profiles, sheets, pipes • Pigments • Titanium alloys	• Paints • Aerospace and defence parts • Medical equipment • Automotive parts

Ontario Production and Trade Statistics

No Titanium production in Ontario in 2020[2]

2M tonnes
Canadian production in 2019[3]

Titanium has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Kenora
- Sault Ste. Marie
- Sudbury
- Timmins
- Kirkland Lake

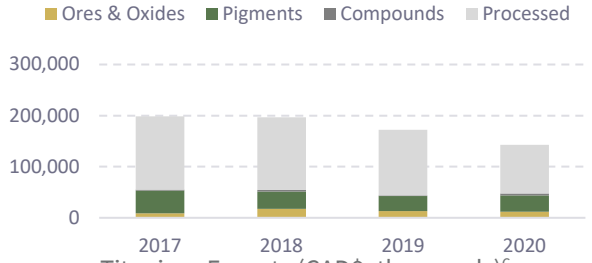
Ontario's Trade Balance: Importer

Top Import Partner: United States (75%)

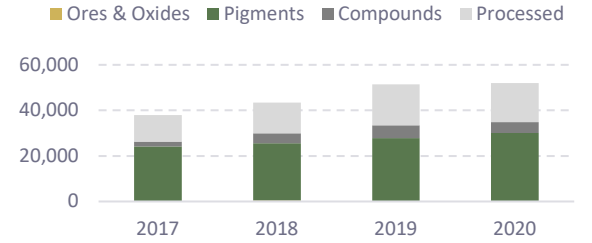
Top Export Partner: United States (82%)

Note: Trade balance total across years 2017-2020

Titanium Imports (CAD$, thousands)[5]



Titanium Exports (CAD$, thousands)[6]



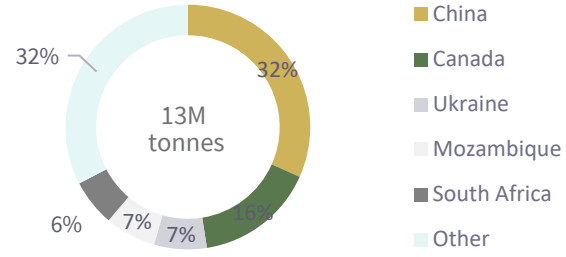
Note: HS Codes 261400, 282300, 320619, 720291, 810820, 810830, 810890

Global Production and Trade Statistics

Reserves (Ilmenite)[8]

Country	Tonnes
1. China	230M
2. Australia	150M
3. India	85M
4. Brazil	43M
5. Norway	37M
6. South Africa	35M
Total*	700M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

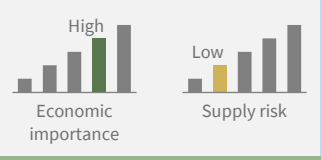
Ores	Refined Metal	Oxides
S. Africa (1M)	Japan (53.5K)	China (78.5K)
Ukraine (621K)	USA (49.6K)	Germany (72.2K)
Senegal (526K)	Russia (49.4K)	India (69.7K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal	Oxides
China (2.6M)	USA (76.7K)	Germany (75.4K)
USA (1.1M)	Germany (41.1K)	Belgium (50K)
Germany (693K)	UK (29.8K)	Italy (30.2K)

Sources: [1] USGS, [2] NRCAN, [3] BGS [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

Titanium

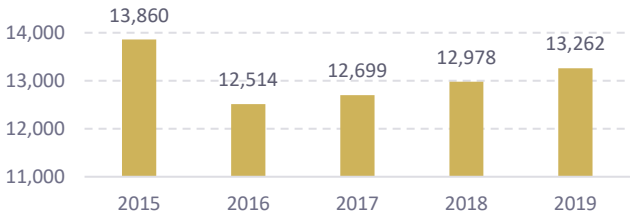


Status in Ontario: Exploration Potential

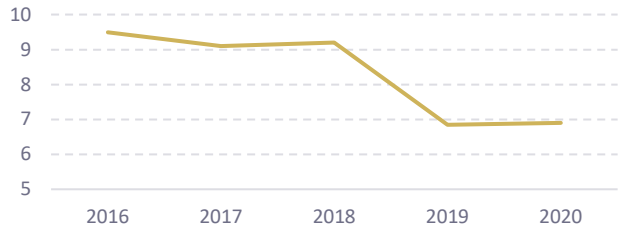
Market Conditions

- Price: While titanium remains expensive, its price has declined in recent years. Titanium metal price fell from USD$9.5 per kilogram in 2016 to USD$6.9 per kilogram in 2020. This downward trend began in 2006.[2]
- Production: Global titanium production has seen consistent growth totaling 6% between 2016 and 2019. The world's top producers of titanium metal include China, Russia, and Japan, while ores and concentrates come primarily from Canada, China, Ukraine, and South Africa.[3]

Global Titanium Minerals Production (kilo-tonnes)[1]



Titanium Price, Sponge Metal (USD$/kg)[3]



Economic and Strategic Importance

Importance in other jurisdictions: Titanium is on the critical mineral list of five major jurisdictions: EU, US, Canada, Japan, and Australia.[5]

Substitution (Moderate): While there are substitutes that do exist for titanium, due to its outstanding properties, very few materials can compete with its strength-to-weight ratio and corrosion resistance.[6]

Use in strategic downstream industries: Titanium is used widely in manufacturing industries, such as aerospace, automotive, aerospace, chemicals, power generation and metallurgy.[7]

Geopolitical factors: China owns the single largest quantity of reserves of titanium in the world (33% of global quantity) and is the biggest producer of titanium (32%). However, Canada is the second biggest producer with 16% of global production. According to the World Bank Governance indicators, the countries are ranked 144th and 9th out of 214 respectively, in a composite measure of political stability, rule of law, control of corruption, regulatory quality and government effectiveness.[8]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	↗	↗	↗
Titanium consumption decreased globally in 2020 due to the pandemic, resulting in a market surplus that is expected to keep prices stable in the near-term until demand fully recovers.[3]	Prices are expected to rise over the medium-to-long term as a result of increasing demand for titanium from the commercial aviation and industrial sectors.[4]	Titanium is most often used as a pigment or as a metal with aerospace and automotive applications. Near term demand will be positive as it recovers following COVID-19 pandemic.[3]	Titanium has many applications for high-end civil and military technologies. Demand for titanium will keep rising over the medium-to long-term, as a result of global technological advancement.

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

- Titanium is a relatively abundant mineral and is produced in many different countries
- It has a relatively high economic importance, especially in the metallurgy (e.g., titanium alloys) and downstream automotive, aerospace, and chemical industries
- With increasing demand, titanium supply chain disruptions may be at a moderate risk level
- Ontario's downstream industries can currently benefit from access to titanium produced in Quebec

Opportunities for Ontario

- Ontario's endowment with titanium deposits provides an opportunity for mining companies in the province to engage in exploration activity and provide steady supply for domestic advanced manufacturing industries, as well as strengthen export potential
- Given the positive demand outlook for the mineral, titanium exploration could contribute to Ontario's manufacturing industries' competitiveness

Sources: [1] BGS [2] Metalary [3] USGS [4] European Commission [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Tungsten

Status in Ontario: Exploration Potential

Description and Key Facts

Tungsten is a hard, rare metal with outstanding robustness and had the highest melting point of all elements. The hardness and high density of this metal make it a unique material with no substitutes.[1]

- There was no tungsten production observed in Canada in 2020.
- The global production leader is China, which accounts for over 80% of global output.
- Tungsten has many uses, including applications in mining, construction, lighting, and aerospace. A potential use might also be found in the construction of nuclear fusion reactors.
- Ontario is a net importer of tungsten and the US is Ontario's top import and export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Tungsten ores and concentrates	• Tungsten oxides • Tungsten carbides • Ferrotungsten • Tungsten powders	• Alloys • Chemical compounds • Catalysts and pigments • Mill and cutting tools	• Mining and construction • Lighting and electronic uses • Aerospace • Energy generation

Ontario Production and Trade Statistics

No Tungsten production in Ontario in 2020[2]

No Canadian production in 2020[3]

Tungsten has been discovered in the following districts:[4]

- Red Lake
- Sault Ste. Marie
- Kenora
- Kirkland Lake
- Sudbury

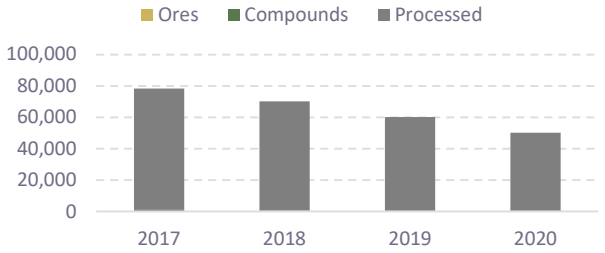
Ontario's Trade Balance: Importer

Top Import Partner: United States (30%)

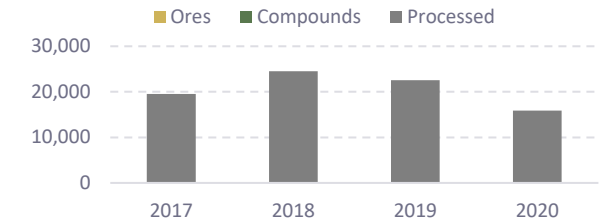
Top Export Partner: United States (75%)

Note: Trade balance total across years 2017-2020

Tungsten Imports (CAD$, thousand)[5]



Tungsten Exports (CAD$, thousand)[6]



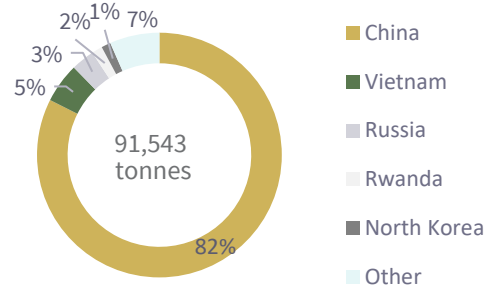
Note: HS Codes include 261100, 720280, 810110, 810194, 810196, 810197, 810199, 853921

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	1,900,000
2. Russia	400,000
3. Vietnam	95,000
4. Spain	54,000
5. North Korea	29,000
6. Austria	10,000
Total*	3,400,000

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Ores	Refined Metal
Russia (2.6K)	China (7.3K)
Rwanda (1.9K)	Germany (5.4K)
Bolivia (1.8K)	USA (2.9K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal
USA (4.7K)	Malaysia (33.6K)
S. Korea (1K)	Philippines (8.9K)
Singapore (0.6K)	USA (7.2K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

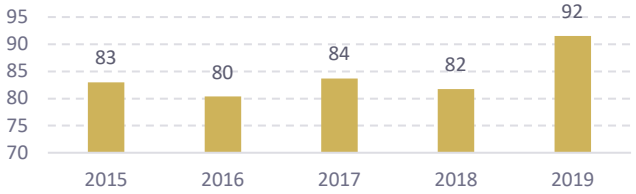
Tungsten

Status in Ontario: Exploration Potential

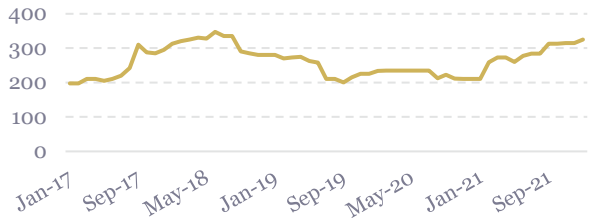
Market Conditions

- Price: The price of tungsten has typically ranged between ~USD$200 and ~USD$300 per tonne over the past five years. The price has been rising in recent months as demand returns to pre-pandemic levels.[3]
- Production: China is the global leader in both production and consumption of tungsten. The Chinese Government regulates the supply of tungsten through quotas and licensing limits. While global production rose by 12% in 2019, the impact of the pandemic likely decreased tungsten output in 2020.[1]

Global Tungsten Minerals Production (kilo-tonnes)[1]



Tungstate Price, APT CIF (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Tungsten is on the critical mineral list of six major jurisdictions: EU, US, UK, Canada, Japan, and Australia.[5]

Substitution (Low): Existing substitutes lack in functional properties. R&D is currently under way on substitution using nanostructured nickel-alloys, however, such developments are at least ten years away from commercialization.[6]

Use in strategic downstream industries: The automobile, jewelry, medical, and mining industries all rely on the tungsten.[7]

Geopolitical factors: 80% of tungsten reserves and over 90% of production occurs in countries ranked towards the bottom of World Bank Governance indicators in a composite measure of political stability, rule of law, control of corruption, regulatory quality and government effectiveness. For example, China where most reserves and production is found, is ranked 144th out of 214 countries.[8]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Tungsten price is expected to be elevated in the near-term as demand from several sectors, including automotive manufacturing and oil & gas, rebounds following the pandemic.[3]	The Chinese Government's regulation of its tungsten production is expected to limit global supply going forward. As a result, the price outlook is expected to remain elevated.[4]	Tungsten is a key component of the construction, manufacturing, mining, and oil drilling sectors. Near-term demand from these sectors will be high as activity returns to pre-pandemic levels.[3]	In addition to tungsten's widespread use across industrial sectors, it is also a metal without viable substitutes, meaning demand will likely remain high over the medium- to long-term.[4]

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

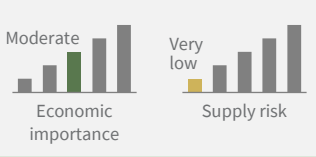
- With over 80% of the world production dominated by China, tungsten supply chains, particularly in the US and the EU, may be at a high risk, given that this mineral is also currently included on critical mineral list of six major jurisdictions
- Ontario may also be at a high risk of supply chain disruption since no production occurs in Canada

Opportunities for Ontario

- Ontario's endowment with tungsten deposits in several regions provides an opportunity for the mining companies in the province to engage in exploration activity and provide steady supply for domestic use, as well as exports, primarily to the US and EU countries

Sources: [1] BGS [2] S&P Global Market Intelligence [3] USGS [4] European Commission [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Uranium



Status in Ontario: Processed Only

Description and Key Facts

Uranium is a dense, hard metallic element that is silvery white in colour, and is radioactive. As a result of its radioactive properties, uranium plays a key role in nuclear energy generation.[1]

- There is no uranium mine production in Ontario. Cameco's refining operations in Blind River, Ontario, is Canada's only uranium refining facility in Canada; it is the largest facility in the world, with 24 million kilograms of annual uranium oxide production capacity.[2]
- Kazakhstan is the leading global producer of uranium ore, accounting for 43% of global production in 2019; the country is also Ontario's top import partner.
- Ontario's exports of processed uranium have been increasing steadily from 2017 to 2019, but have dropped significantly in 2020 due to the COVID-19 pandemic.

Value Chain[8]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Uranium ore mining and milling	• Uranium oxide is converted to uranium hexafluoride	• Nuclear fuel fabrication	• Nuclear power generation • Nuclear science technology

Ontario Production and Trade Statistics

Ontario is home to Canada's only uranium refinery[3]

4,121 tonnes Canadian mine production in 2020[4]

Uranium has been discovered in the following districts:[5]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Sault Ste. Marie
- Sudbury
- Kenora
- Red Lake
- Kirkland Lake
- Timmins

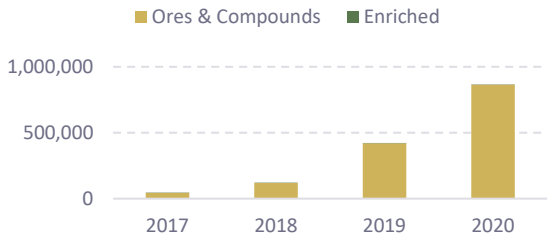
Ontario's Trade Balance: Exporter

Top Import Partner: Kazakhstan (30%)

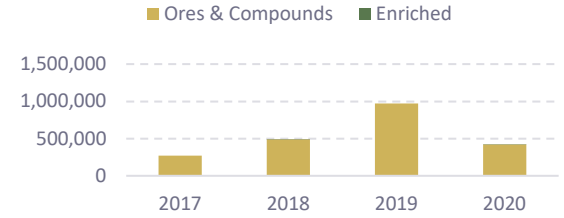
Top Export Partner: Germany (21%)

Note: Trade balance total across years 2017-2020

Uranium Imports (CAD$, thousands)[6]



Uranium Exports (CAD$, thousands)[7]



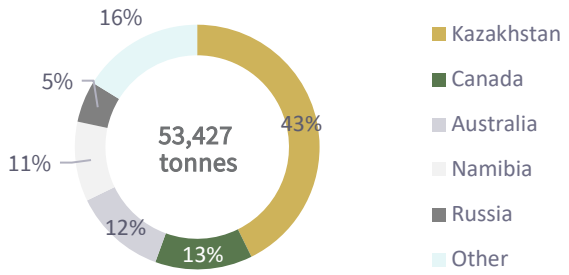
Note: HS Codes 261210, 284410, 284420, 284430

Global Production and Trade Statistics

Reserves[9]

Country	Tonnes
1. Australia	1,700,000
2. Kazakhstan	900,000
3. Canada	565,000
4. Russia	486,000
5. Namibia	448,000
6. South Africa	321,000
Total*	6,150,000

Mine Production (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

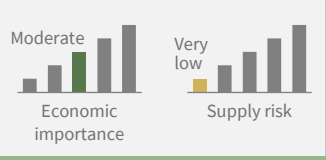
Ores	
1. Kazakhstan (27.5K)	4. USA (1.7K)
2. Germany (12.6K)	5. Netherlands (1.2K)
3. France (5.2K)	6. Ukraine (1.1K)

Top Importers (2019, tonnes)[12]

Ores	
1. Russia (20.1K)	4. USA (9.2K)
2. China (12.8K)	5. Germany (6.1K)
3. Canada (11.8K)	6. France (3.1K)

Sources: [1] RSC, [2,3] Cameco, [4] NRCAN, [5] Ontario Mineral Deposit Inventory, [6,7] Statistics Canada, [8,9] World Nuclear Association, [10] BGS, [11,12] UN Comtrade Database

Uranium

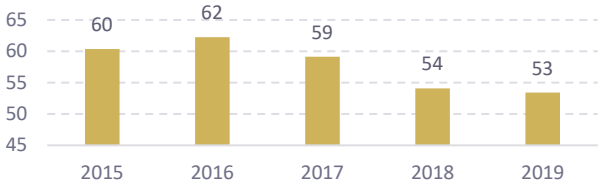


Status in Ontario: Processed Only

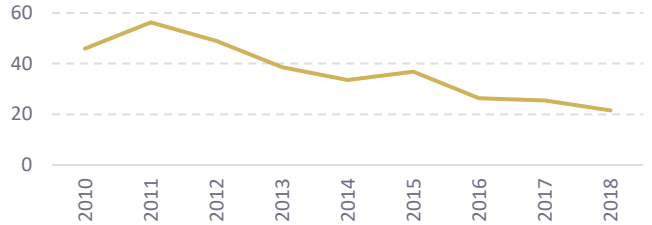
Market Conditions

- Price: Prices for uranium have been trending downwards over much of the past decade, falling by over 60% between 2011 and 2018. Price drops were initially caused by the closure of nuclear facilities globally causing a decline in uranium demand. As of 2020 the price of uranium was just under USD$30 per pound.
- Production: Global uranium production fell by approximately 11% between 2015 and 2019. After a slight uptick in 2016, production levels saw a steady decline in each subsequent year through 2019.

Global Uranium Production (kilo-tonnes)[1]



Uranium Price (USD$/lb)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Uranium is on the critical mineral list of two major jurisdictions: US and Canada.[4]

Substitution (Moderate): Thorium can be used as a fuel in the nuclear cycle as an alternative to uranium. The technology to achieve this has been around since the 1960s.[5]

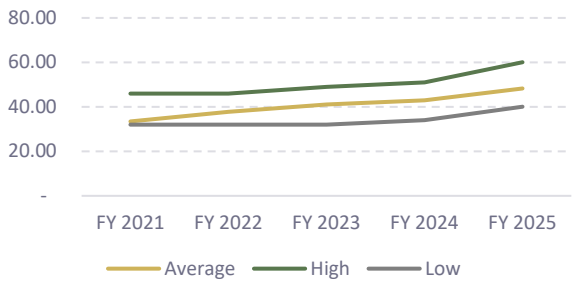
Use in strategic downstream industries: Uranium is primarily used as a fuel in nuclear power reactors for electricity generation.[6]

Geopolitical factors: Australia owns the single largest quantity of reserves of uranium in the world (28% of global quantity) but has limited production (12%). The biggest uranium ore producer (and with the second most reserves) is Kazakhstan. Canada is the second biggest ore producer with 13% of the global production. According to the World Bank Governance indicators, Australia is ranked 11th, Canada is ranked 9th, and Kazakhstan is ranked 145th in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[7]

Market Outlook

Price outlook: Based on the average forecast, the price of uranium is expected to rise from USD$30 per pound as of 2020 to USD$48 per pound by 2025, but could range between USD$40 in a low price scenario and USD$60 per pound in a high price scenario.

Uranium Price Forecast (USD$/lb)[3]



Demand outlook

Near-term	Medium-to-long term
The global uranium market saw a deficit in 2020 due to reduced and suspended operations resulting from the COVID-19 pandemic. Demand is expected to continue outpacing supply in the near-term.[3]	Uranium's main use is for principal fuel for nuclear reactors. As China recommits to nuclear power development, demand for uranium is expected to continue to rise in the medium- to long-term.[3]

Legend: Neutral | Positive | Negative

Key Takeaways

Supply chain risks

- Uranium is an important input to the nuclear energy sector; however, it is only considered a critical mineral by Canada and the US
- Canada is the second leading uranium ore producer, and Ontario is home to the only refining facility in the country
- Ontario currently is a net exporter of processed uranium; and provincial supply seems to be at a very low disruption risk

Opportunities for Ontario

- With substantial uranium processing capacity, Ontario can maintain its position as an exporter of uranium compounds to the countries that utilize nuclear power reactors

Sources: [1] BGS [2] Metalary [3] S&P Global Market Intelligence [4] Critical mineral lists of major jurisdictions , [5,6] RSC, [7] World Bank

Vanadium

Status in Ontario: Exploration Potential

Description and Key Facts

Vanadium is a steel-grey, bluish, shimmering, and ductile metallic element. It has corrosion resistance properties, and is primarily used in steel and titanium alloys to improve their corrosion resistance and strength.[1]

- There has been no production of vanadium across Canada in the past five years, although deposits have been found in Manitoba, Ontario, and Quebec.
- China is currently the leading producer of vanadium, and possesses 43% of the known reserves.
- Vanadium is used in multiple mechanical applications, primarily as a steel and titanium alloy component.
- As no vanadium is produced in Ontario, the province is a net importer.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Vanadium is typically recovered as a by-product or co-products from production of steel.	• Ferrovanadium • Vanadium oxides and hydroxides • Unwrought vanadium	• Paints and basic polymers • Catalysts • Tubes and pipes • Chassis parts	• Ships and aircrafts • Household appliances • Turbines and electromotors

Ontario Production and Trade Statistics

No Vanadium production in Ontario in 2020[2]

No Canadian production in 2020[3]

Vanadium has been discovered in the following districts:[4]

- Southeastern Ontario
- Thunder Bay North
- Thunder Bay South
- Timmins
- Sudbury
- Kenora

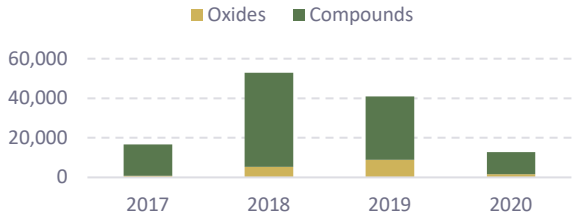
Ontario's Trade Balance: Importer

Top Import Partner: Czech Republic (45%)

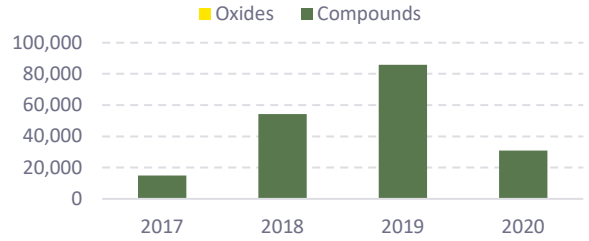
Top Export Partner: United States (99%)

Note: Trade balance total across years 2017-2020

Vanadium Imports (CAD$, thousand)[5]



Vanadium Exports (CAD$, thousand)[6]



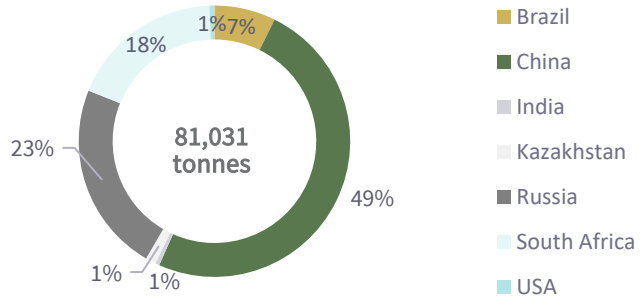
Note: HS Codes 261590 (niobium, tantalum, and vanadium ores), 282530, 720292. As no vanadium is produced in Ontario, it is understood that the province is a net importer.

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. China	9,500,000
2. Russia	5,000,000
3. Australia	4,000,000
4. South Africa	3,500,000
5. Brazil	120,000
6. USA	45,000
Total*	22,000,000

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Refined Metal	Oxides
New Zealand (13.1K)	Brazil (9.9K)
Iceland (7.2K)	Russia (9.7K)
Czechia (6.7K)	S. Africa (6.3K)

Top Importers (2019, tonnes)[11]

Refined Metal	Oxides
USA (7.6K)	Czechia (10.4K)
Germany (5.0K)	India (6.1K)
Japan (4.7K)	S. Korea (4.5K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7] USGS & EU: Critical Minerals Study, [8] USGS, [9] BGS, [10,11] UN Comtrade Database

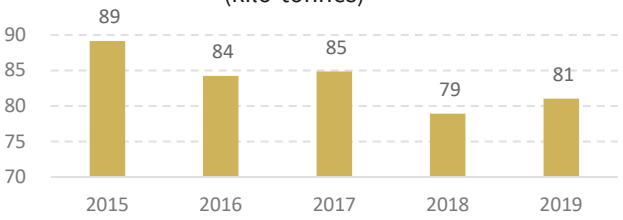
Vanadium

Status in Ontario: Exploration Potential

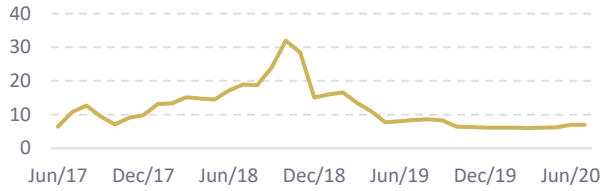
Market Conditions

- Price: Prices for vanadium have experienced two distinct trends in recent years. Prices rose rapidly between mid-2017 to late 2018, from USD$6 to USD$32 per pound. However, the inverse trend was observed from 2019 through to mid-2020 as prices fell back to USD$7 per pound.
- Production: Major global producers of vanadium include China, Russia, and South Africa. Global vanadium mining production fell by nearly 12% between 2015 and 2018 but saw a partial recovery with 3% growth in 2019.

Global Vanadium Mining Production (kilo-tonnes)[1]



Vanadium Price (USD$/lb)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Vanadium is on the critical mineral list of 4 major jurisdictions: EU, US, Canada, and Japan.[5]

Substitution (Moderate): In steel alloys, vanadium can be substituted by certain elements, such as manganese, molybdenum, niobium, titanium, and tungsten. However, currently, there is no acceptable substitute for vanadium in aerospace titanium alloys.[6]

Use in strategic downstream industries: Vanadium is widely used in the tool making industry, aerospace manufacturing, and in nuclear reactors.[7]

Geopolitical factors: China owns the single largest quantity of reserves of vanadium in the world (43% of global quantity) and is the biggest producer of titanium ore (49%). According to World Bank Governance indicators, China is ranked 144th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[8]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
→	→	↗	↗
While some global vanadium producers were limited due to the pandemic disruptions, others were able to expand production in new facilities. As a result, prices are expected to remain neutral.[3]	Vanadium experiences one of the highest degrees of price volatility of any material. The balance of price increases and decreases means the outlook will be neutral over the medium-to-long term.[4]	Vanadium is mainly used in steel production, including HSLA and special steels. Near-term demand will be driven by increased steel production.[4]	Vanadium demand is expected to increase in the medium-to-long term due to its application in redox batteries, which can be used for mass storage of energy from alternative sources (solar, wind).[4]

Legend: → Neutral ↗ Positive ↘ Negative

Key Takeaways

Supply chain risks

- China dominates the market and the production of vanadium, most of which appears to be consumed by its domestic industries (based on top exporters figures)
- This may indicate that supply chain disruptions are possible in the event of increased demand from downstream industries, in particular, steel alloys
- As no vanadium production takes place in Canada, it may pose a relatively high supply chain risk for Ontario's industries

Opportunities for Ontario

- Ontario's exploration potential for vanadium ores in several regions provides an opportunity for mining companies in the province to supply the mineral to local downstream industries, and to other jurisdictions, including current top importers

Sources: [1] BGS [2] S&P Global Market Intelligence [3] USGS [4] European Commission [5] Critical mineral lists of major jurisdictions , [6] EU: Critical Minerals Study, [7] USGS, [8] World Bank

Zinc

High — Economic importance

Low — Supply risk

Status in Ontario: Produced

Description and Key Facts

Zinc is the fourth most widely used metal in the modern world after iron, aluminum, and copper. The primary use of zinc is in galvanizing, which protects iron and steel from rusting. It is also widely used in other metal alloys.[1]

- In terms of production value in 2019, zinc was the 5th mineral produced in Ontario. Glencore's Kidd Creek Mine site is a major producer of zinc.
- Ontario is the net exporter of zinc, with 92% of the mineral exported to the US.
- Globally, zinc production occurs in many different countries; the top three leading producers are China, Peru, and Australia.
- China is the leading processor of zinc, making up 47% of the refined zinc production in 2019.
- Top importers of the refined zinc are China, the US, and Germany.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Zinc ores and concentrates	• Zinc metal • Zinc oxide	• Galvanizing • Brass and bronze • Alloys • Metal manufacturing • Chemicals	• Fertilizers • Consumer and commercial metal products

Ontario Production and Trade Statistics

Confidential
Production volume in Ontario in 2020[2]

184,846 tonnes
Canadian production in 2020[3]

Zinc has been discovered in the following districts:[4]

- Southeastern Ontario
- Southwestern Ontario
- Thunder Bay North
- Thunder Bay South
- Sault Ste. Marie
- Kenora
- Red Lake
- Kirkland Lake
- Timmins
- Sudbury

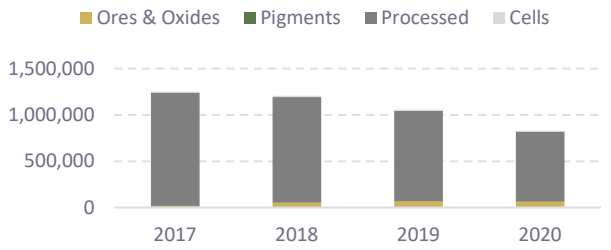
Ontario's Trade Balance: Exporter

Top Import Partner: United States (82%)

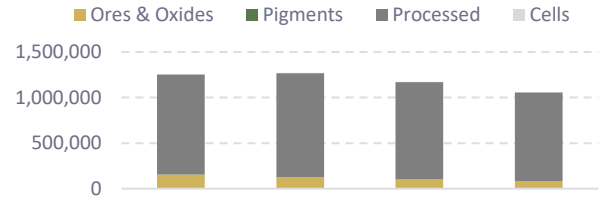
Top Export Partner: United States (92%)

Note: Trade balance total across years 2017-2020

Zinc Imports (CAD$, thousands)[5]



Zinc Exports (CAD$, thousands)[6]



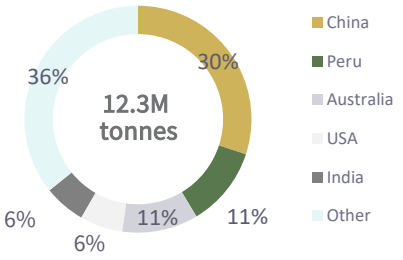
Note: HS Codes 281700, 320642, 721030, 721041, 721049, 721061, 721220, 721230, 740721, 740929, 741121, 790111, 790112, 790310, 790400, 790500, 790700, 740321 etc.

Global Production and Trade Statistics

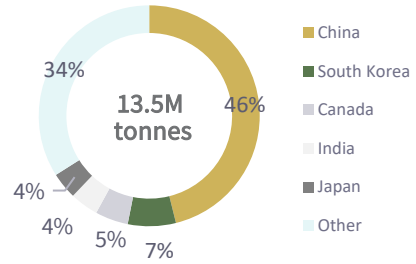
Reserves[8]

Country	Tonnes
1. Australia	68M
2. China	44M
3. Mexico	22M
4. Russia	22M
5. Peru	20M
6. Kazakhstan	12M
Total*	250M

Mine Production (2019)[9]



Smelted Production (2019)[10]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[11]

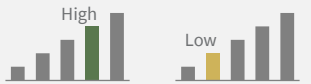
Ores	Refined Metal	Oxides
Australia (2.3M)	S. Korea (568K)	Netherlands (115K)
Peru (2.0M)	Spain (539K)	S. Korea (63K)
USA (889K)	Netherlands (389K)	Belgium (48.6K)

Top Importers (2019, tonnes)[12]

Ores	Refined Metal	Oxides
S. Korea (2.1M)	China (687K)	Germany (34.6K)
Japan (834K)	USA (534K)	Netherlands (30K)
Netherlands (397K)	Germany (406K)	Vietnam (25.4K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory, [5,6] Statistics Canada, [7,8] USGS, [9,10] BGS, [11,12] UN Comtrade Database

Zinc

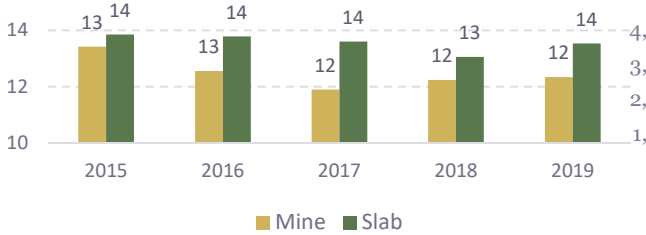


Status in Ontario: Produced

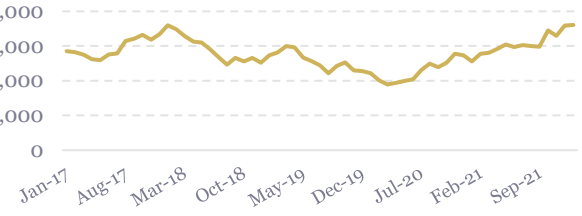
Market Conditions

- Price: Over the past five years, the price of zinc has ranged between USD$2,000 and USD$3,500 per tonne. The highest prices during the period were seen in early 2018, however this was followed by a relatively steady decline, culminating in the lowest prices in Spring 2020 due to the COVID-19 pandemic. The price has increased significantly in 2021.
- Production: Global zinc production (including mine and slab sub-commodities) has decreased by 5% between 2015 and 2019. 2019 production represented a modest increase from 2018 levels.

Global Zinc Production (million tonnes)[1]



Zinc Price, 99.995%, Cash (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Zinc is on the critical mineral list of two major jurisdictions: Canada and the US.[4]

Substitution (High): Substitutes exist as aluminum and plastics substitute for galvanized sheet in automobiles, and aluminum-and magnesium-base alloys are major competitors for zinc-base diecasting alloys.[5]

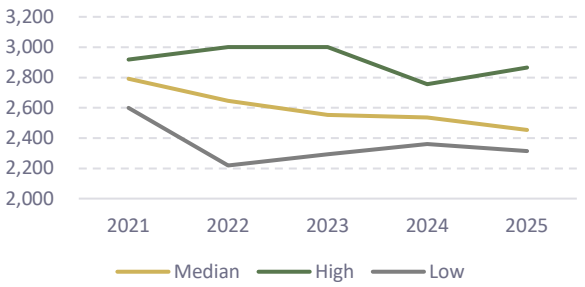
Use in strategic downstream industries: Zinc has applications in the paints, pharmaceuticals, and manufacturing industries (e.g., electrical equipment).[6]

Geopolitical factors: Australia is where the largest quantity of reserves are found (about 27%) while China is the biggest producer (30%). According to the World Bank Governance indicators, these countries are ranked 9th and 144th out of 214 countries, respectively, in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[7]

Market Outlook

Price outlook: Based on the median price forecast, the commodity price for zinc is expected to decline to approximately USD$2,500 per tonne, but could reach nearly USD$2,900 in a high price scenario.

Zinc Price Forecast (USD$/tonne)[3]



Demand outlook

Near-term	Medium-to-long term
Zinc's primary application is galvanizing iron and steel. Near-term growth is expected due to robust demand for infrastructure and consumer durables (e.g., vehicles).[4]	The demand outlook may be neutral over the medium-to-long term as Chinese infrastructure demand is expected to taper due to a scaling back of stimulus measures related to the COVID-19 pandemic.[4]

Legend: Neutral Positive Negative

Key Takeaways

Supply chain risks

- Zinc is produced in many different counties and is widely used in the manufacturing industries
- Zinc is considered to be a critical mineral by the US (based on 2021 US Administration review) and Canada
- Ontario is currently a producer and net exporter of zinc; therefore, the supply chain risk for downstream industries in the province is relatively low

Opportunities for Ontario

- Access to local supply of zinc may offer an advantage for Ontario's downstream industries and help avoid supply chain challenges
- The majority (92%) of Ontario's exports are to the US; the province's exports value has stayed relatively stable in 2017-2019 with only a slight decline in 2020 due to the COVID-19 pandemic

Sources: [1] BGS [2] S&P Global Market Intelligence [3] S&P Global Market Intelligence [4] Critical mineral lists of major jurisdictions , [5,6] USGS, [7] World Bank

Zirconium

Low — Economic importance

Low — Supply risk

Status in Ontario: Exploration Potential

Description and Key Facts

Zirconium is a very strong, malleable, ductile, lustrous silver-gray metal. Its chemical and physical properties are similar to those of titanium.[1]

- Zirconium has not been produced in Canada in the past five years; the leading producers are Australia, South Africa, and the US.
- Zirconium and associated products can be found in nuclear energy, heat exchangers and ceramics.
- Ontario is a net importer of zirconium. The US is Ontario's top import partner and China is the top export partner.

Value Chain[7]

Extraction	Processing	Manufacturing	Use in downstream sectors
• Zirconium ores and concentrates usually mined as a coproduct of heavy-mineral sands for the titanium minerals, ilmenite and rutile, or tin minerals.	• Oxide • Cubic zirconia	• Abrasives and chemicals • Nuclear control rods • Nickel-based superalloys	• Nuclear energy • Heat exchangers • Ceramics • Medical

Ontario Production and Trade Statistics

No Zirconium production in Ontario in 2020[2]

No Canadian production in 2020[3]

Zirconium has been discovered in the following districts:[4]

- Thunder Bay South

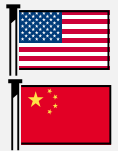
Importance for the Nuclear Industry

A report prepared by NRCAN indicated that a reliable supply of zirconium alloys is critical to Canada's nuclear energy industry

Ontario's Trade Balance: Importer

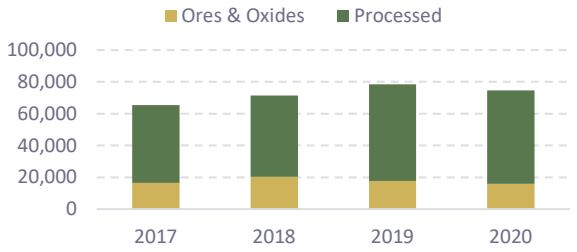
Top Import Partner: United States (91%)

Top Export Partner: China (26%)

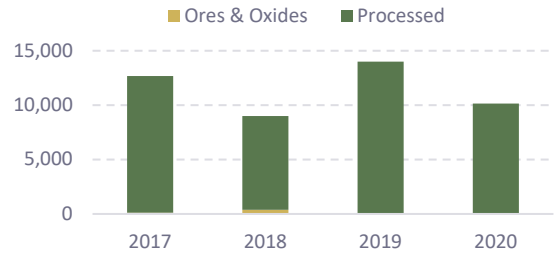


Note: Trade balance total across years 2017-2020

Zirconium Imports (CAD$, thousand)[5]



Zirconium Exports (CAD$, thousand)[6]



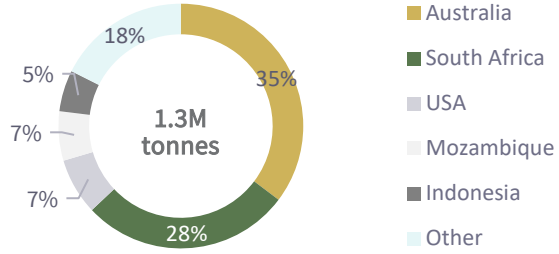
Note: HS Codes include 261510, 282560, 810920 810930, 810990

Global Production and Trade Statistics

Reserves[8]

Country	Tonnes
1. Australia	43M
2. South Africa	6.7M
3. Mozambique	1.8M
4. USA	0.5M
5. China	0.5M
6. Kenya	0.05M
Total*	64M

Mine Production (2019)[9]



*Note: Total is for all countries, values in table may not add up.

Top Exporters (2019, tonnes)[10]

Ores	Refined Metal	Oxides
S. Africa (342K)	S. Africa (13.9K)	China (15.9K)
Senegal (89K)	USA (1.8K)	France (4K)
Indonesia (73K)	Germany (0.5K)	USA (3.5K)

Top Importers (2019, tonnes)[11]

Ores	Refined Metal	Oxides
China (1.2M)	USA (2.4K)	Spain (5.7K)
India (57.1K)	Germany (0.7K)	Japan (5.5K)
USA (34.8K)	China (0.6K)	France (4.3K)

Sources: [1] USGS, [2,3] NRCAN, [4] Ontario Mineral Deposit Inventory [5,6] Statistics Canada, [7,8] USGS, [9] BGS, [10,11] UN Comtrade Database

Zirconium

Low
Economic importance

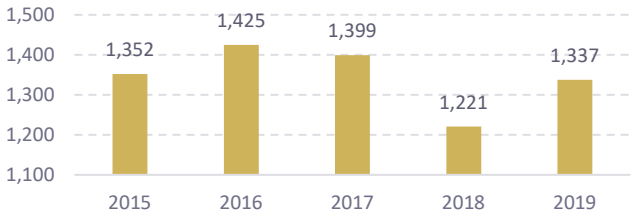
Low
Supply risk

Status in Ontario: Exploration Potential

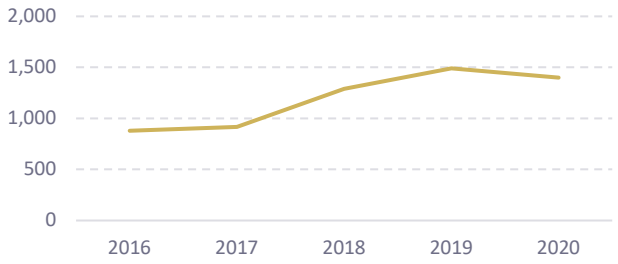
Market Conditions

- Price: The price of zirconium has seen moderate growth overall, with prices increasing in recent years before declining in 2020 to approximately USD$1,400 per tonne.
- Production: Global zirconium production grew by 5% in 2016 before declining by 14% through 2018. However, production experienced a strong recovery in 2019, growing by 10% to return to 2015 levels. Leading zirconium producers globally include Australia, South Africa, and the US.

Global Zirconium Minerals Production (kilo-tonnes)[1]



Zirconium Price (USD$/tonne)[2]



Economic and Strategic Importance

Importance in other jurisdictions: Zirconium is on the critical mineral list of three major jurisdictions: US, Japan, and Australia.[4]

Substitution (Moderate): There are moderate substitute options for zirconium. For example, chromite and olivine can be used instead of zircon for some foundry applications. Zirconium can be used interchangeably with hafnium in certain superalloys.[5]

Use in strategic downstream industries: Zirconium is used in the manufacturing, construction, medical, and energy industries.[6]

Geopolitical factors: Australia owns the single largest quantity of reserves of zirconium in the world (67% of global quantity) and is the global leader in production (35% of global production). According to World Bank Governance indicators, Australia is ranked 11th out of 214 countries in a composite measure of political stability, rule of law, control of corruption, regulatory quality, and government effectiveness.[7]

Market Outlook

Price outlook		Demand outlook	
Near-term	Medium-to-long term	Near-term	Medium-to-long term
Global zirconium production decreased in 2020 due to power, labour issues, and the impact of the COVID-19 pandemic. Prices are expected to rise in the near-term as a result of the supply constraints.[2]	Several large mining projects containing zirconium were in development during 2020. These projects are expected to increase supply over the medium-to-long term, resulting in a neutral price outlook.[2]	Major end uses of zirconium include high-temperature applications, such as ceramic opacification and foundry sands. A return to pre-pandemic production globally may boost near-term demand. [2]	Over the medium-to-long term, zirconium is expected to continue rising due to its use in the production of nuclear control rods, which are a key component of nuclear reactors. [3]

Legend: Neutral; Positive; Negative

Key Takeaways

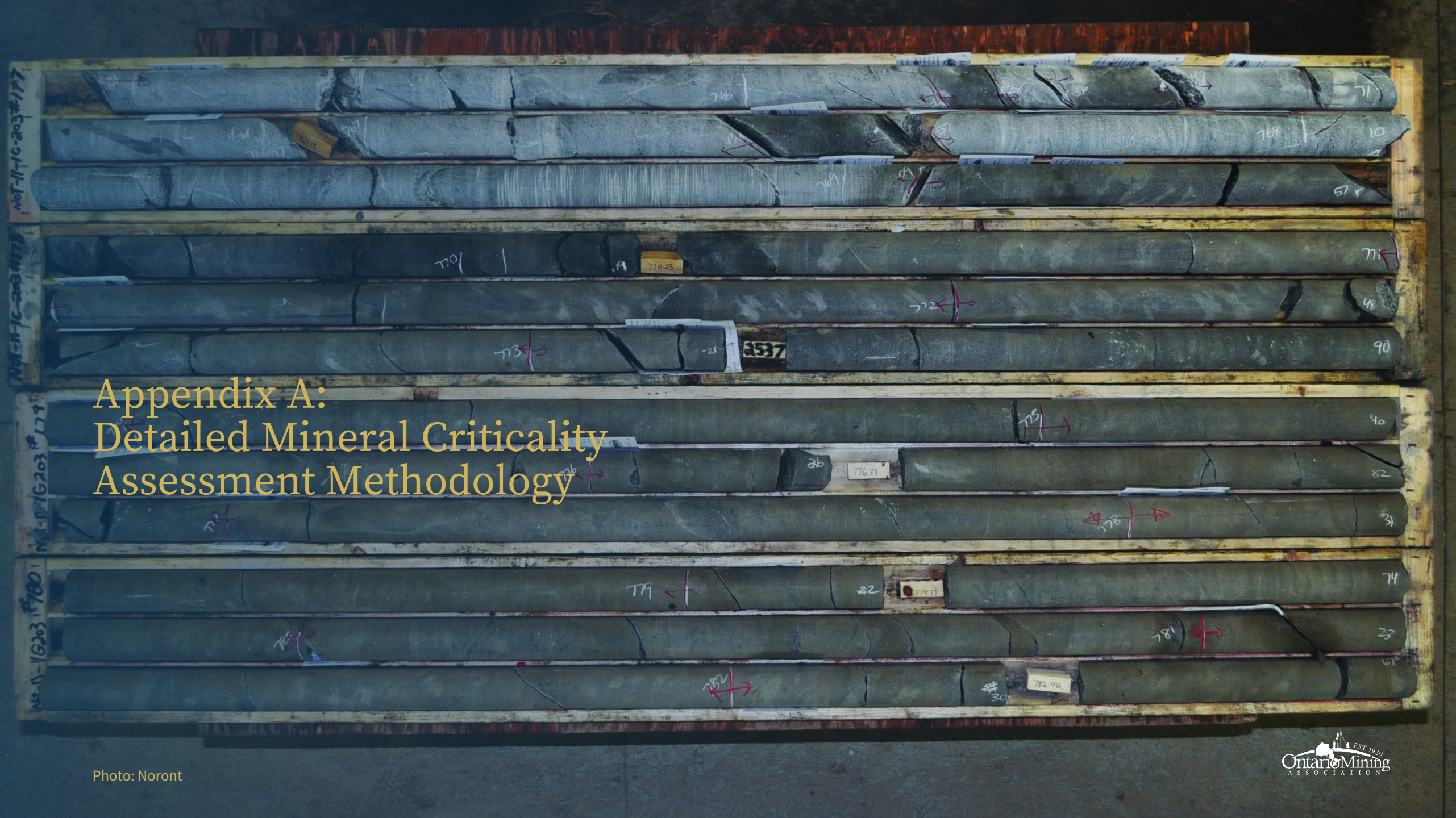
Supply chain risks

- Zirconium production and reserves are concentrated in only four countries, but the supply chain risk is likely relatively low for major jurisdictions, as Australia and the US are current producers
- Zirconium is on the critical minerals list of three major jurisdictions. Even though the mineral is not produced in Canada, it is not included in the critical mineral list in Canada
- Substitute options do exist for zirconium; therefore, supply chain risks for Ontario's industries may be moderate

Opportunities for Ontario

- Ontario's zirconium exploration potential in several regions may provide an opportunity for the province to supply the mineral to local downstream industries, and to other jurisdictions, including current top global importers

Sources: [1] BGS [2] USGS [3] European Commission [4] Critical mineral lists of major jurisdictions , [5,6] USGS, [7] World Bank



Appendix A: Detailed Mineral Criticality Assessment Methodology

Photo: Noront

Mineral Criticality Assessment Methodology

Criticality Assessment Methodology

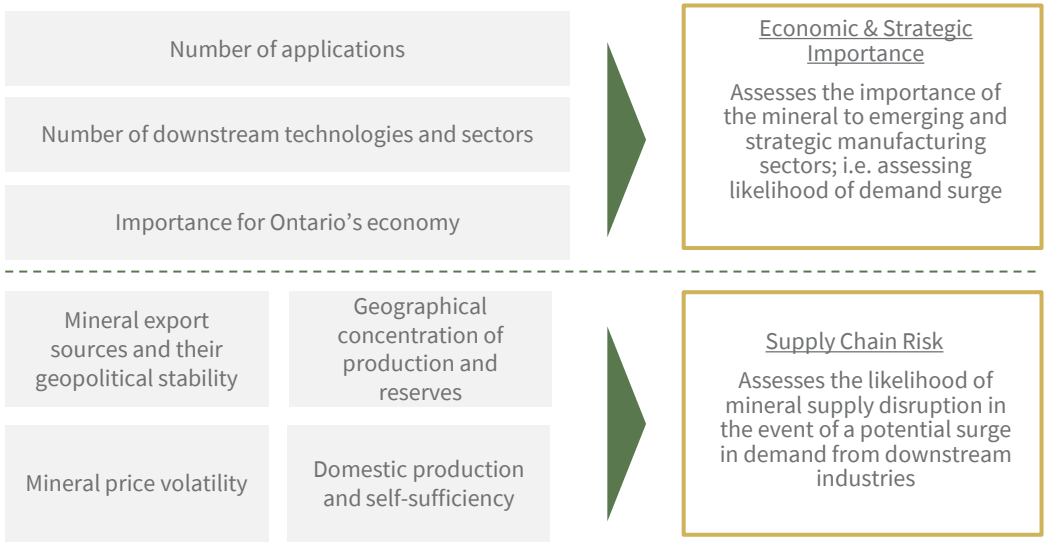
A criticality assessment was conducted for each of the minerals included in the Ontario's preliminary critical minerals list.

The concept of criticality is measured on a two-dimensional scale of supply chain risk and economic and strategic importance.

Using publicly available data and information, a quantitative score for each scale was developed:

- Supply chain risk metric incorporates the data on (1) diversity of mineral export suppliers and their geopolitical stability ranking; (2) concentration of ore production, processing and reserves; (3) mineral historical price volatility; and (4) presence of domestic mineral production and trade balance.
- Economic and strategic importance metric assigns a score based on (1) the number of applications for each mineral; (2) number of priority technologies and sectors where each mineral is used; and (3) sectoral importance to Ontario's economy (GDP).

Illustration of Criticality Assessment Methodology

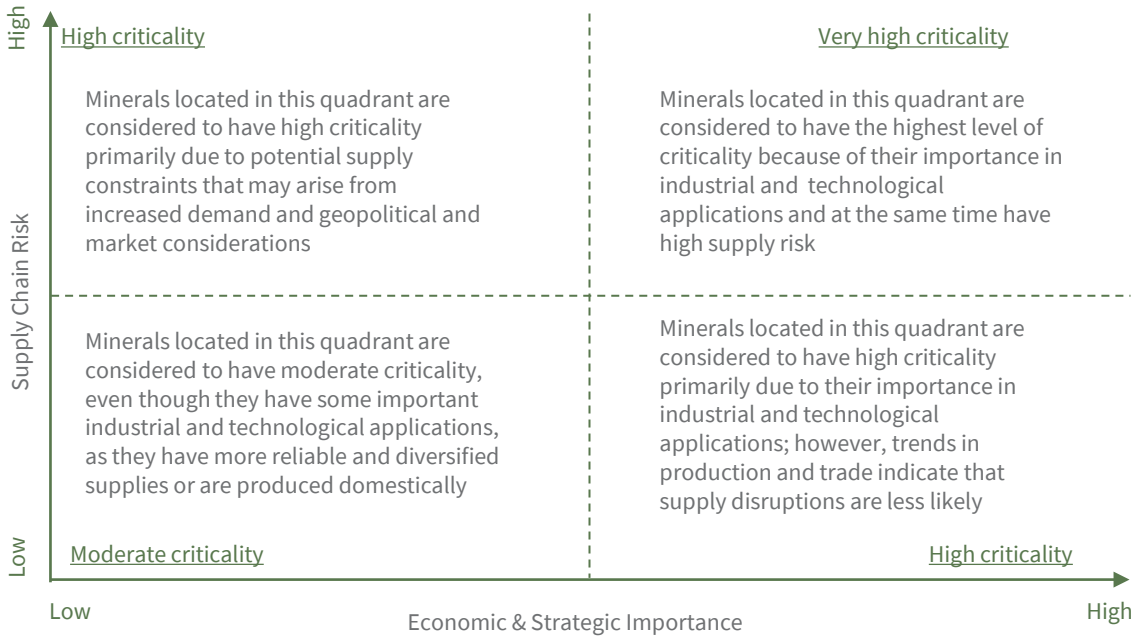


Mineral Criticality Matrix

The mineral criticality matrix summarizes the results of the criticality assessment, which aims to quantify the economic importance and supply chain risk associated with each critical mineral in Ontario.

The positioning of a mineral on the matrix indicates its level of criticality. Minerals with higher levels of economic importance and that are more susceptible to supply chain disruptions have the highest level of criticality (top right). Conversely, minerals that are associated with lower value-added activities and have abundant and diversified supplies (or produced domestically) have the lowest level of criticality (bottom left). These minerals are still considered to have moderate criticality as they are included in Ontario's list due to their technological and industrial applications. Minerals in between have moderate to high criticality.

Mineral Criticality Matrix Interpretation



Mineral Criticality Assessment Methodology

HS Codes Included in the Analysis

Mineral	HS codes included
Antimony	261710, 282580, 811010, 811020, 811090
Barite	251110, 251120, 283327, 283660
Beryllium	811212, 811213, 811219
Bismuth	810600
Chromite	6851591
Copper	260300, 283325, 74
Cobalt	282200, 810520, 810530, 810590
Fluorspar	252921, 252922
Graphite	250410, 250490, 380110, 380120, 380190, 681510, 690310, 854511, 854519, 854520, 854590
Indium	811292, 811299
Lithium	282520, 283691, 290433, 850650, 850760
Magnesium	251990, 253020, 282731, 283321, 810411, 810419, 810490, 251910, 281610, 810420, 810430
Manganese	260200, 282010, 282090, 720211. 720219, 720230, 722720, 811100, 850610
Molybdenum	261310, 261390, 282570, 720270, 810210, 810294, 810295, 810296, 810297, 810299

Mineral	HS codes included
Nickel	282540, 282735, 283324, 381511, 741122, 75
Niobium/Tantalum	261590, 720293, 8210320, 810330, 810390, 853221
Phosphate	251010, 283522, 283523, 283524, 283525, 283526, 283529, 283531, 283539, 291910, 310311, 310319, 310530, 310540, 310550
PGE	711011, 711019, 711510, 711292
REE	284610, 284690, 280530
Selenium	280490
Tellurium	280450
Tin	800110, 800120, 800200, 800300, 800700, 260900
Titanium	261400, 282300, 320619, 720291, 810820, 810830, 810890
Tungsten	261100, 720280, 810110, 810194, 810196, 810197, 810199, 853921
Uranium	261210, 284410, 284420, 284430
Vanadium	261590, 282530, 720292
Zinc	281700, 320642, 721030, 721041, 721049, 721061, 721220, 721230, 740721, 740929, 741121, 79
Zirconium	261510, 282560, 810920 810930, 810990

Appendix B: Critical Mineral Lists of Comparable Jurisdictions

Photo: Avalon Advanced Materials

Critical Mineral Lists of Comparable Jurisdictions

USA (Total: 37)

Critical Minerals list developed in 2018 includes:

- Aluminum
- Antimony
- Arsenic
- Barite
- Beryllium
- Bismuth
- Cesium
- Chromium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite (natural)
- Hafnium
- Helium
- Indium
- Lithium
- Magnesium
- Manganese
- Nickel
- Niobium
- PGEs
- Potash
- REEs
- Rhenium
- Rubidium
- Scandium
- Strontium
- Tantalum
- Tellurium
- Tin
- Titanium
- Tungsten
- Uranium
- Vanadium
- Zirconium
- Zinc

Nickel and zinc were added to the US Critical Minerals List based on the 2021 US Administration review.

Canada (Total: 31)

Critical Minerals list includes:

- Aluminum
- Antimony
- Bismuth
- Cesium
- Chromium
- Cobalt
- Copper
- Fluorspar
- Gallium
- Germanium
- Graphite (natural)
- Hafnium
- Helium
- Indium
- Lithium
- Magnesium
- Manganese
- Molybdenum
- Nickel
- Niobium
- PGEs
- Potash
- REEs
- Scandium
- Tantalum
- Tellurium
- Tin
- Titanium
- Tungsten
- Uranium
- Vanadium
- Zinc

EU (Total: 30)

2020 Critical Raw Materials list includes:

- Antimony
- Barite
- Beryllium
- Bismuth
- Borate
- Cobalt
- Coking coal
- Fluorspar
- Gallium
- Germanium
- Hafnium
- Graphite
- Indium
- Magnesium
- Niobium
- PGEs
- Phosphate Rock
- Phosphorus
- REEs
- Scandium
- Silicon metal
- Tantalum
- Tungsten
- Vanadium
- Bauxite
- Lithium
- Titanium
- Strontium

Sources: USGS, NRCAN, European Commission

Critical Mineral Lists of Comparable Jurisdictions

Australia (Total: 23)

Critical Minerals list includes:

- Antimony
- Beryllium
- Bismuth
- Chromium
- Cobalt
- Copper
- Graphite
- Helium
- Indium
- Lithium
- Manganese
- Molybdenum
- Nickel
- Niobium
- PGEs
- REEs
- Selenium
- Tantalum
- Thorium
- Tin
- Titanium
- Tungsten
- Zirconium

Japan (Total: 20)

Critical Minerals list includes:

- Antimony
- Chromite
- Cobalt
- Gallium
- Germanium
- Graphite
- Indium
- Lithium
- Magnesium
- Manganese
- Niobium
- PGEs
- REEs
- Rhenium
- Scandium
- Tantalum
- Titanium
- Tungsten
- Vanadium
- Zirconium

UK (Total: 14)

Critical raw materials lists includes:

- Antimony
- Beryllium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite
- Indium
- Magnesium
- Niobium
- PGEs
- REEs
- Tantalum
- Tungsten

Sources: Geoscience Australia, Japanese Ministry of Economy, BGS

Appendix C: Detailed Competitiveness Analysis Results

Photo: Vale, Totten Mine

C.1 Critical Mineral In-Situ Value: Reserves & Resources

Mineral	Ontario	Quebec	USA	Australia
	USD$, million			
Nickel	24,601	44,302	4,601	141,683
PGE	16,173	3,221	29,660	2,450
Copper	9,425	2,811	379,031	162,002
Cobalt	1,317	4,125	1,182	21,418
Zinc	1,096	2,871	19,954	53,199
Graphite	466	2,004	-	4,011
Uranium	252	356	999	21,517
Chromite	-	-	1,487	-
Phosphate	-	52,487	58,120	20,494
Niobium	-	61,793	10,618	3,012
Lithium	-	7,430	5,433	61,317
Molybdenum	-	-	67,580	5,692
Vanadium	-	-	-	39,568
Titanium	-	-	5,195	46,500
Tungsten	-	-	0	8,363
Antimony	-	-	495	137
REE	-	-	9,309	45,539
Tin	-	-	-	3,545
Manganese	-	-	-	640
Tantalum	-	577	-	14,183
Indium	-	-	-	20

Source: S&P Market Intelligence. Note: *critical minerals are defined by the Ontario preliminary critical mineral list

C.2 Summary of Financial Incentives in the Mining Sector

Country	Federal/Province	Incentive Name	Description
Canada	Federal	Canadian Exploration Expenses (CEE)	This provision of the federal Income Tax Act provides a deduction of 100% of eligible exploration expenses against taxable income. Eligible CEEs include grassroots exploration expenses, as defined in subsection 66.1(6)(f) of the Income Tax Act.
		Flow-Through Shares (FTS)	The FTS provision, is outlined in sub-section 66(15) of the Income Tax Act and allows an investor to claim a CEE or Canadian Development expense (CDE) or a Canadian Renewable Energy and Conservation expense deduction (CRCE) earned by a publicly listed company against their taxable income.
		The Mineral Exploration Tax Credit (METC)	METC is a temporary 15% tax credit, linked to flow-through shares, that can be claimed on a more limited part of grassroots expenses, for exploration conducted "from or above the surface of the earth" as defined in sub-section 127(9) of the Income Tax Act as "flow-through mining expenditures".
		Prospector's and Grubstaker's Shares Deduction	This provision, as defined in sub-section 110(1) (d.2) of the Income Tax Act, allows a deduction from income of 50% of the value of shares, received and included as income, for that year.
	Ontario	Flow-Through Share Tax Credits	The Ontario Focused Flow-Through Share Tax Credit is a refundable tax credit of 5% of eligible Ontario exploration expenses. It is payable to individual investors in flow-through shares, who pay Ontario income tax.
		Prospector Grants	The Ontario Exploration Corporation (OEC) offers grants of up to $85,000 to qualified prospectors with properties with high economic potential. The OEC completes a purchase agreement with the prospector for a 0.50% Net Smelter Royalty (NSR) for $10,000 in the first phase.
		Ontario Junior Exploration Program (OJEP)	OJEP helps junior mining companies finance early exploration projects. These projects help boost mineral exploration, growth and job creation in the province, particularly in northern and Indigenous communities.
	Quebec	Flow-Through Share Tax Deductions	Quebec's Taxation Act provides a basic deduction of 100% of the cost of flow-through shares. From June 4, 2014 and for shares acquired after March 30, 2004, an extra 10% deduction is granted if the expenses are incurred in Quebec by a non-operating company. An additional 10% deduction is allocated if the exploration is conducted from the surface, which gives a total possible deduction of 120% of the amount invested.
		Tax credit relating to resources	Eligible exploration expenses incurred may qualify for a refundable tax credit.
		Mining tax regime exploration provisions	Provisions include the total of: (1) ⊠ the operator's exploration expenses incurred after March 30, 2010, and (2) 25% of the above exploration expenses that were incurred in Northern Quebec by the operator, and for which the refundable tax credit relating to resources could not be claimed.
		Venture capital for mineral exploration and development	Venture capital is available from several Quebec government organizations: Diversification of Exploration Investment Partnership established by the Government of Quebec (SIDEX), the Caisse de depot et placement du Quebec, Ressources Quebec, Aboriginal Exploration Boards and Funds.

Source: PDAC, MNDNRF

C.2 Summary of Financial Incentives in the Mining Sector

Country	Federal/State	Incentive Name	Description
Australia	Federal	Junior Minerals Exploration Incentive	The incentive was created to encourage investment in small mineral exploration companies, and allows eligible companies to generate tax credits by giving up a portion of their losses from greenfields mineral exploration expenditure. Following that, the tax credits can be distributed to investors who buy newly issued shares during a certain period.
		Industry Growth Centres Initiatives	The initiative includes six areas: advanced manufacturing, cybersecurity, food and agribusiness, medical technologies and pharmaceuticals, mining equipment, technology and services and oil and gas and energy resources. Each industry centre has a 10 year strategy for the sector, identified regulatory reform opportunities and industry knowledge priorities.
	New South Wales	New Frontiers Exploration Initiative (NFEI)	The program is designed to provide significant funding to future exploration for mineral and petroleum resources.
	Queensland	Strategic Resources Exploration Program (SREP)	Through this program, the Australian government is set to invest AU$ 27.125 million over four years to boost exploration and support for resource development projects.
		Collaborative Exploration Initiative	The program provides industry grants to help encourage investment in underexplored areas and support innovative exploration techniques.
	Western Australia	Exploration Incentive Scheme (EIS)	EIS is a State Government initiative that aims to encourage exploration in Western Australia for the long-term sustainability of the State's resources sector.
	Victoria	TARGET Minerals Exploration Initiative	The TARGET Minerals Exploration Initiative is a Victorian Government grants program to encourage investment in exploration for copper, other base metals and gold in Victoria. TARGET grants cover up to half the cost of eligible exploration activities, which include geophysical surveys, drilling and sampling analysis.

Sources: Australian Taxation Office, NSW Government, Queensland Government, Government of Western Australia, Victoria State Government

C.3 Trade Balances, 2019

Legend

Net import

Mineral	EU+UK	China	Japan	USA
Negative values indicate net export	USD$, million			
Antimony	-132.9	-263.5	0.2	-14.7
Barium	297.6	-126.9	45.6	2,346.2
Beryllium	-5.3	-0.1	-0.8	-27.3
Bismuth	-16.3	-42.6	-3.8	-5.6
Chromite	177.7	15,533.1	60.3	189.6
Cobalt	-742.2	73.9	-100.6	-291.0
Copper	-32,595.0	21,246.5	-2,339.8	-9,124.1
Fluorspar	545.7	449.1	117.4	421.2
Graphite	-3,403.2	-956.8	-946.0	-1,527.8
Lithium	-235.8	-753.0	59.6	-118.2
Magnesium	1,625.8	-1,995.4	686.7	521.2
Manganese	1,738.7	-1,021.7	1,367.6	1,125.9
Molybdenum	-1,436.6	-393.5	-5.5	-1,139.3
Nickel	-7,207.4	57,494.9	2,887.7	-3,604.6
Niobium	-70.9	44.4	7.6	-0.5
Phosphate	3,038.8	-677.8	191.5	1,913.9
Platinum	-6,477.2	-939.0	-900.6	-1,411.5
Rare-earth	-79.8	-388.2	-123.4	-64.9
Selenium	-20.3	-32.6	-13.7	-6.8
Tantalum	-78.9	-186.5	-72.2	-210.5
Tellurium	-13.0	-170.4	-6.6	-5.6
Tin	-777.2	-116.5	-56.5	-96.0
Titanium	-1,425.1	1,904.5	-312.5	-970.8
Tungsten	-340.5	-292.5	-69.6	-121.3
Uranium	-2,433.1	-101.4	-0.0	-192.9
Vanadium	-539.9	-495.7	-35.7	-161.9
Zinc	-4,281.8	122.9	499.9	-1,331.1
Zirconium	-141.2	1,017.5	-59.7	-178.3

Source: UN Comtrade. Note: Trade statistics include stage one and two minerals (i.e., mined, smelted and/or refined materials)