SciEng Pages

Canada's role in the responsible supply of technology metals

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The demand for "technology metals", such as nickel, cobalt, and lithium, is increasing because of growth in advanced technologies, which have the potential to help Canada transition to a low-carbon economy by contributing to renewable energy production. However, while the application of these metals has shown great benefits, their production has been associated with several challenges related to securing supply and impacts on the environment and society. This document provides an overview of the opportunities and challenges of mining in Canada, and highlights the need for integrated collaboration between government, industry, and communities as a way forward to increase Canadian leadership in responsible mining of technology metals globally.

METALS AND MINING IN CANADA

The mining and metals sector has been important in the development of Canada, and contributes significantly to the Canadian economy, providing extensive employment throughout the country.[1] The sector continues to change and improve thanks to innovation and partnerships with other sectors, governments, and universities.

Mining has also created environmental, economic, and social impacts associated with the release of contaminants[2] and competing claims for the land. In Canada, Indigenous communities have often been first exposed to mining development; these impacts have been well documented, in particular for long-term exposure to legacy contamination.[3, 4] While mineral exploration and mining companies actively seek agreements and participation with Indigenous Peoples, and the approval of a broad range of stakeholders, improvement in these areas is a prerequisite for the success of the sector.

Despite these challenges, metals produced by mines are a necessary ingredient for new technologies, such as those that will help us deal with climate change and other realities. There is an opportunity to develop Canadian mining to meet new societal needs while ensuring that its impacts do not leave a legacy of problems for future generations. Taking advantage of the opportunities will require collective action by governments and industry that focuses on enhancing Canadian leadership in responsible mining.

Canadian mining industry overview[25, 26]

CANADIAN MINING INDUSTRY 2019 STATISTICS

TOP 5 Global producer of 17 minerals and metals

CONTRIBUTION TO GDP
$109B

JOBS

Direct and indirect employment
719,000

Indigenous participation
16,500

60 minerals & metals produced from

200 mines and

6,500 sand, gravel, stone pits and quarries

VALUE OF MINERAL PRODUCTION

TOTAL
$ 48B

METALS
$ 27B

VALUE OF EXPORTS
$ 106B

METALS AND SOCIETY – DEMAND AND RESPONSIBLE SUPPLY

In the last 50 years, increasing demand has resulted in exponential growth in metal markets. Recent additional demand has been driven by the need for technology metals, and demand will continue to increase for at least the next 30 years.[5, 6]

The energy transition and our connected technological world is clearly linked to metal demand. Power generation involving wind turbines and solar panels requires abundant copper and iron, as well as common elements like aluminum, zinc, silicon, and molybdenum. These technologies also use less readily available elements such as lithium, cobalt, rare earth elements, cadmium, phosphorous, tellurium, beryllium, germanium, indium, gallium, selenium, and silver. Electric vehicles need three to four times as much copper as conventional cars, and their batteries require significant amounts of lithium, nickel, cobalt, graphite, and rare earth elements, most of which are considered critical (see below).[7, 8] Battery storage is also necessary to stabilize intermittent renewable energy, optimize “smart grids,” and support data storage for the internet.

Some of the most important technology metals and minerals such as graphite (referred to as “critical metals or minerals”) are globally scarce and supplied by a limited number of producers. This could cause reliability and supply chain issues. Consistent supply of technology and critical metals and minerals was the basis for the Canada-US Joint Action Plan for Critical Minerals Collaboration finalized in January 2020[9] and recently Canada has released its own list of critical minerals.[8] Much of the concern is related to current limitations on source and supply. Many of these metals and minerals are not geologically scarce[10,11], but complex supply chains, sociopolitical issues in the jurisdictions that are major suppliers, and Environmental, Social, and Governance (ESG) issues represent major challenges.[12] For example, about 68 per cent of the cobalt vital to battery technologies is mined predominantly in the Democratic Republic of Congo[13], and China produces 85 percent of final products made using rare earth elements and used in batteries, wind turbines, and solar panels.[14] Diversifying supply chains is

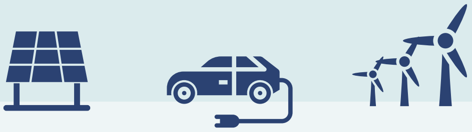
4x

Electric vehicles need three to four times as much copper as conventional cars, and their batteries require significant amounts of lithium, nickel, cobalt, graphite, and rare earth elements, most of which are considered critical (see below).[7, 8]

Critical metals and minerals – implications of climate change mitigation[5, 6]

TECHNOLOGY AND CRITICAL METALS AND MINERALS

Metals are a major ingredient in infrastructure (e.g., buildings, roads, rail, planes and cars) and technologies (e.g., defense, space, engines, batteries, IT and communication). The latter technology metals are also needed for the energy transition and green economy. A subset of the technology metals, and in some cases minerals (e.g., graphite), are termed critical due to limited supply chains linked to jurisdictions that may be vulnerable to disruption, and their essential roles in the manufacture of products of strategic importance. The list of critical metals and minerals varies by country[7, 8] and is dynamic – pending changes in supply and economic conditions.



Technology metals are also needed for the energy transition and green economy

WORLD BANK – METALS AND THE ENERGY TRANSITION

The World Bank has completed two studies in 2017 and 2020 to evaluate the increase in metal demand that will be required to mitigate climate change under different warming scenarios. Results from the 2020 report[6] are summarized below for some technology and critical metals:

METAL demand to 2050	LITHIUM	COBALT	INDIUM	NICKEL	ALUMINUM	COPPER
% annual increase in demand from energy technologies	>450	>450	>200	~100	~10	~10

one way of helping Canada and international partners ensure access to resources that meet their clean energy needs.

Recycling can play a role in meeting demand, but it comes with many limitations. Although some metals, such as aluminum, lead, copper, and iron are easily recycled, other metals face significant impediments. For example, zinc used in galvanized steel and paint products is very difficult to recycle. Efforts to recycle critical metals are hindered by complex designs and precise multi-element alloys required for materials in many advanced technologies. The lack of Canadian processing facilities and complete supply chains for critical metals further limits recycling efforts. Ideally, metals from mines should stay in use through multiple cycles, but this will require changes in the attitudes of both consumers and technology providers. Some of the ways to achieve these societal changes can be found as part of the circular economy concept.

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Consumers in Canada and elsewhere are becoming more aware of the questionable sources for some metals that are important for the energy transition and consumer products such as smartphones and computers. In some cases, this may translate into increasing support for diversified supply chains and increased mining in resource-rich countries such as Canada.[15]

RESOURCE DISCOVERY - CAN WE FIND MORE IN CANADA?

If Canada is to become a key supplier of metals for the energy transition, new resources will have to be discovered, evaluated and brought to production. But exploration is a difficult, high-risk enterprise with no guarantee of success. Past successes have come from integrated efforts among industry, universities, and governments (including First Nations and Inuit governments) that have created new knowledge and methodologies that help to focus exploration efforts for metals.

The goal of exploration is to discover high value deposits, which are determined by the amount of metal in the rocks, the size of the deposit, and economics that generate sufficient long-term benefits for companies, shareholders and communities. Greenfield, or new, exploration needs to focus in areas that are suitable for production with minimum impacts and maximum socio-economic benefits, even in cases where new infrastructure will be required. It is increasingly likely that these discoveries will be in remote locales, such as northern Canada, or will be found deep below ground, where historical prospecting and exploration were limited. In remote areas, exploration is often associated with risks due to high cost and low probability of success. New geoscientific surveys and the resulting data provided by governments, combined with innovative approaches and technologies, mitigate some of the risks for both companies and investors.

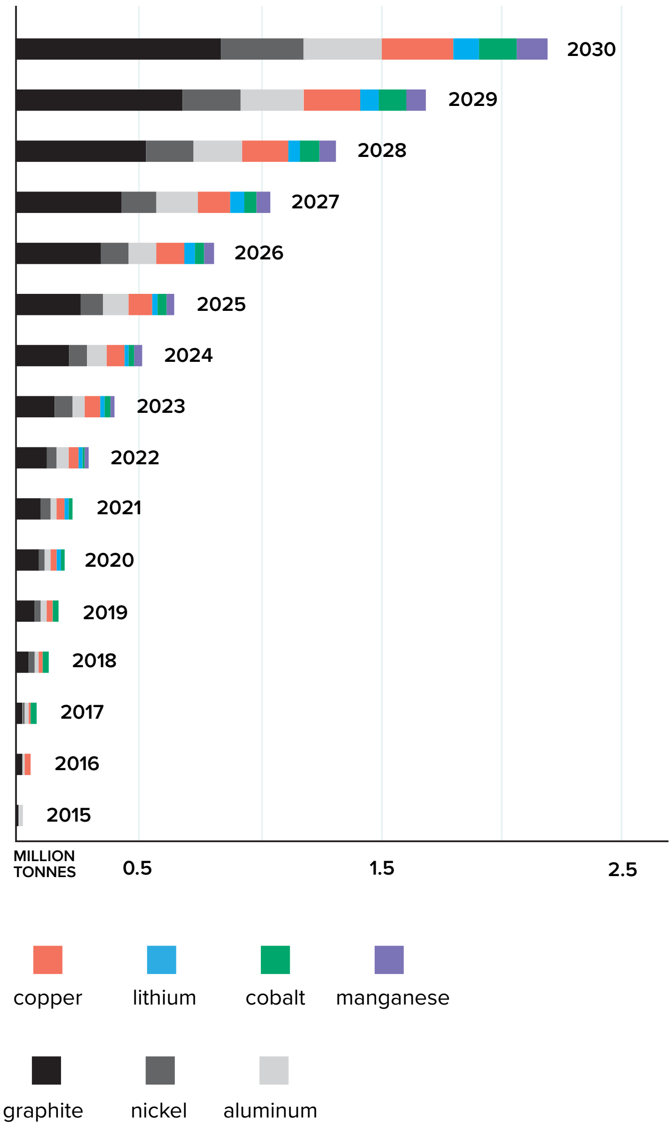
HIGHLAND VALLEY COPPER MINE

JENNIFER STAHN/INFONEWS.CA 2016

Understanding of the earth and the processes that concentrate metals to economic levels is fundamental for successful mineral exploration. This involves the collection of data at all scales – continental to microscopic. Many disciplines contribute to breakthrough concepts. For example, microbial studies may indicate concealed deposits[16], and geophysical methods developed for oil and gas exploration, such as seismic surveys, are being

METAL DEMAND FORECAST FOR ELEMENTS REQUIRED FOR ELECTRIC VEHICLES

SOURCE: BLOOMBERG NEW ENERGY FINANCE



adapted and combined with other methods to image mineral targets at depths up to one kilometre. Increasingly sophisticated data analytics, including artificial intelligence and machine learning, are being applied to vast geological, geophysical, remote sensing and geochemical databases at regional and project-scales to identify exploration targets and better discriminate true from false positives or negatives.[17]

THE CHALLENGES OF METAL MINING AND EXTRACTION

Once a mineral deposit is discovered, metals have to be separated from the surrounding rocks and minerals. The process is expensive and energy-intensive, and often creates waste that has negative environmental effects. The increasing demand for technology metals has focused attention on improving these extraction processes.

Metals usually occur in minerals (gold is a major exception); extraction of metals involves separating the host mineral from the rock, and then processing that mineral to recover the metal. The economic metal content can be more than 65 per cent for iron, around 1 per cent for copper, less than one part per million for gold, and even less for some of the critical metals that are important for the energy transition. When the concentration of metals is low, extraction requires mining and processing significant amounts of rock, as much as 100,000 tonnes per day, most of which becomes waste. Liberating the metal-containing minerals uses vast amounts of energy to break, crush and grind rocks to a fine powder. Increased global demand for many metals has driven the industry toward large "open pit" operations with lower and lower concentrations of metals[18], although Canada is fortunate to have a significant number of mines with high concentrations of metal that have not followed the global trend to date. As a result, for most of the last century, mines have increasingly extracted less metal from more rock, requiring more energy and

EXAMPLES OF CANADIAN GEOSCIENCE RESEARCH RELATED TO MINERAL RESOURCES

LITHOPROBE (1984-2004)[27]

NSERC-Canadian Mining Innovation Council (CMIC) **Footprints** (2010-2020)[28]

Canada First Excellence Research Fund (CFERF) **Metal Earth** (2017-present)[29]

NRCan's **Geo-mapping for Energy and Minerals (GEM)**[30] and the **Targeted Geoscience Initiative (TGI)**[31] water use per unit of metal produced. Developing new technologies that improve extraction efficiency is the focus of research and innovation in Canada and elsewhere.

The increasing scale of mining has also resulted in more waste being generated. This includes both rock that is removed to get to the economic material and the finely ground rock called "tailings" that is left over after extracting the valuable minerals. Typically, tailings are deposited with water behind dams in valleys. Unfortunately, some dams have failed with tragic consequences and, in some cases, significant loss of life (e.g., Brumandinho in Brazil, 2018).[19]

Most mines for major metals, such as iron, require massive material moving operations. Critical metal mining is more diverse. When the metals are present at high concentrations, extraction can focus on a single metal, such as nickel. When concentrations are low, the metal is usually recovered as a by-product of extraction of other metals, such as when cobalt is produced from nickel or copper mines. When metals are present in only trace amounts, they are only recovered during the smelting and refining of other metals, as is the case with gallium from aluminum, indium and germanium from zinc, and tellurium and selenium from copper. This creates complexity in the markets and supply chains that hinders efforts to ensure these metals are derived from acceptable sources.

Increasing our understanding of the distribution of metals in rocks and minerals at various scales using new technologies and data analytics may result in more efficient and environmentally sensitive processing and extraction.

One difficulty of mining is the variable nature of the raw materials at the front end of the process; these rocks contain the minerals that host metals. Increasing our understanding of the distribution of metals in rocks and minerals at various scales using new technologies and data analytics may result in more efficient and environmentally sensitive processing and extraction. Sensors allow selection of metal-rich material for processing, reducing energy consumption and tailings by avoiding the processing of rocks with low metal contents.[20] In some deposits, rocks can be chemically leached in piles or tanks to extract metals, or reagents can be injected into the ground to recover metals. Leaching processes may reduce the mining footprint and waste, but challenges include potential contamination of surface and subsurface water. Metals such as lithium are also recovered by large-scale evaporation of natural ground waters (e.g., from salt lakes in Chile and Argentina), but even this ostensibly benign approach involves significant water consumption in a region of the world with limited water.[21]

In existing mines, the focus is on optimizing processes and decreasing energy and water consumption. Automation and digital control improve performance and safety. Reducing and managing waste, especially tailings, from large mines is vital[17] and requires new ways to store tailings, better monitoring and risk assessment, and use of integrated systems to redesign mines with less waste. Opportunities to extract critical metals, and ways to use tailings for materials and other purposes, may create value and reduce environmental legacies. Similarly, some tailings may be useful for sequestering CO_2, thereby offsetting greenhouse gas emissions and effectively stabilizing the tailings.[22]

MEETING METAL DEMAND RESPONSIBLY

The increasing need for technology and critical metals is matched by a growing desire to see these metals produced responsibly without adding to the problems that we hope to mitigate.

Major Canadian and global mining companies have endorsed the UN Sustainable Development Goals, with targets set for 2030. Meeting these goals will require significant investments and innovative solutions. Measuring and communicating progress to these goals is necessary but remains lacking for some companies and communities. Increased data transparency, with the inclusion of real-time data where possible, is vital to increase trust and shared participation.

In terms of the environment, there is potential for more extensive environmental studies for proposed new mine sites and related infrastructure corridors. Taking an integrated approach to land use management has been proposed as a way to better assess the state of the land and its current use by involving all stakeholders and affected parties in decision making.[23] Such integration is now part of recent regulations (i.e., Impact Assessment Act) which require a broader range of factors to be assessed at the proposed site, including data on geology, climate, soil, water, biodiversity, heritage, communities, and human activities. With high quality data and spatial analysis, transparent decisions can be made to minimize impact, preserve vital areas, seek mutual benefits, and avoid conflicts.[24] These expanded studies are particularly important in areas where multiple mining operations and overlapping land use is likely, and where future cumulative impacts may have unintended consequences.

It is increasingly recognized that Indigenous Peoples, neighbouring communities, and the broader general public expect a minimum level of social performance for a potential mine to be accepted. Many changes are being made to the way in which companies engage with Indigenous and non-Indigenous communities, and these have resulted in agreements that deliver guaranteed benefits, employment, and environmental protection. These changing ways of engaging will continue to evolve towards more collaborative arrangements, partnerships, and other novel business agreements. The development of sustainable economic activity that lasts beyond the life of the mine will require focused efforts on capacity-building, new business opportunities and independent entrepreneurship. Expanding this approach to regions – the landscape-scale – will require broad collaboration among communities, companies, and governments.

Consumers seek assurance that the metals in their products are sourced responsibly, particularly when the technology is proclaimed as green and clean. Hence, consumer-facing technology companies may become involved directly or indirectly with resource extraction. Validating the source of metals through the supply chain will open up new technological and business models and increased opportunities for recycling and reprocessing. Ultimately, these will be the building blocks of the circular economy where the mining industry both provides metals responsibly and also plays a role in keeping these metals in use for as long as possible.

To be successful, the sector will require multi-disciplinary efforts involving the high tech, biotech, data science, and social science sectors as well as earth science, engineering and environmental science.

POSITIONING CANADA'S MINING SECTOR AS A LEADER IN TECHNOLOGY METALS

The prospect of Canada becoming a key producer of technology metals is gaining attention, as these materials will contribute to the global transition to a low-carbon economy. The ability of Canada to lead this transition is made possible by the broad network of thought leaders, innovators, researchers, and educators who are working to create the next phase of the Canadian mining industry. To be successful, the sector will require multi-disciplinary efforts involving the high tech, biotech, data science, and social science sectors as well as earth science, engineering and environmental science. Collective expertise across Canada, with meaningful involvement of Indigenous Peoples at all levels, can deliver the technology and critical metals that we need to mitigate climate change and achieve other societal goals.

ABOUT
SciEng Pages

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Le Partenariat en faveur des sciences et de la technologie

SciEng Pages is an initiative of the **Partnership Group for Science and Engineering**. SciEng Pages aims to increase discussion on topical issues that have science and engineering at their core, by summarizing the current state of knowledge and policy landscape. Each issue is prepared and reviewed by a multi-disciplinary team of volunteers, and published free of charge.

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