BACKGROUND MATERIALS FOR CIRCULAR ECONOMY SECTORAL ROADMAPS

MINERALS AND METALS

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Smart Prosperity Institute

About Smart Prosperity Institute

Smart Prosperity Institute is a national research network and policy think tank based at the University of Ottawa. We deliver world-class research and work with public and private partners – all to advance practical policies and market solutions for a stronger, cleaner economy.
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ABOUT THE CIRCULAR ECONOMY GLOBAL SECTOR BEST PRACTICES

This publication series aims to provide a starting point in the journey towards a circular economy. These materials are intended to be used as a background resource and rich reference source for future efforts to engage Canadian firms and innovators in this transition, and to build sector-based roadmaps to a circular economy in Canada.

Twelve core strategies for *rethinking* resource consumption and *optimizing* the use of resources to transition to a circular economy are detailed in the Introduction to the series. Real-world practices supporting these strategies are being catalogued for seven sectors, each profiled in its own document:

1. Minerals and Metals
2. Electronics
3. Agri-food
4. Construction
5. Plastics
6. Bio-economy
7. Automotive

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MINERALS AND METALS

1.1. Introduction to Minerals and Metals

The Circular Economy Global Sector Best Practices series aims to provide a starting point, background resource, and rich reference source for future efforts to engage Canadian firms and innovators in the journey towards a circular economy, and to build sector-based roadmaps to a circular economy in Canada.

This report profiles the minerals and mining sector. It begins with an outline of the economic and environmental importance of the sector, including data on economic potential of waste resources where available. It then profiles the existing circular practices that were identified in the sector, organized according to a common framework for circular economy approaches and strategies developed in 2018 by L'Institut EDDEC in collaboration with RECYC-QUÉBEC, and described in the Introduction to the series. The profile begins with a high-level summary of the circular practices found in each sector, and snapshots of these practices in application, and then moves on to list applied, real world examples for each of these strategies and practices. Finally, it provides a list of additional resources for researchers, practitioners, and policy-makers: selected global public policies, and an annotated bibliography of key reports specific to circularity for the minerals and mining.

1.2. Background

The minerals and metals industries make a significant contribution to local and global economies and produce materials critical for clean technology. As the world's economy increases its reliance on clean technologies, there is a growing demand for the minerals and rare earth elements such as electric vehicle batteries, wind turbines, and nuclear reactors.[1] Canada is well-positioned to meet this growing demand, ranking third in the global production of aluminum, fourth in cobalt, fifth in nickel, and twelfth in copper.[2] Copper, in particular, is an important resource for many clean technology and energy components.[3] Canada is also a leading global producer of other minerals, including graphite, potash, diamonds, and uranium.[4] Mineral and metal products account for 19% of Canada's total domestic exports, worth C$105 billion in 2018, and 5% of nominal Gross Domestic Product.[5] The mineral sector as a whole, which includes mining, primary processing, and metal product manufacturing, directly employed 409,000 individuals in 2018,[6] and had Canada's second-highest indigenous representation, at 12% of the labor force.[7]

There is growing recognition that mining activities have the potential to significantly impact the environment. The primary production of mineral and metal commodities worldwide

generates over 100 billion tonnes of solid waste per year,[8] and there are approximately 3500 active mining waste facilities worldwide, consisting of waste rock dumps and tailing dams.[9] The liability for managing mine wastes in Canada and the United States exceeds C$50 billion.[10] The minerals and metals industry also consumes significant amounts of resources. For example, the process of comminution, which involves the crushing and grinding of solid materials, is one of the largest consumers of electricity, consuming 3% of all electric power generated in the world.[11] Energy intensity has improved over time. For example, the steel industry has reduced its energy intensity by 61% over the last 50 years, and a recent World Steel Association study shows potential for a further 15-20% reduction.[12]

To better position itself in a low-carbon, low-waste future, Canada has recently launched two initiatives.

The Canadian Minerals and Metals Plan, released in March 2019, identifies three primary goals for the mining sector:[13]

- firstly, the continual reduction of the mining sector's environmental footprint;
- secondly, a circular economy where mine waste is transformed into useful products, with enhanced mine closure planning and environmentally-reclaimed mine sites; and
- thirdly, systemic climate change adaptation planning.

Canada also has a **Green Mining Initiative**, with two overarching objectives:

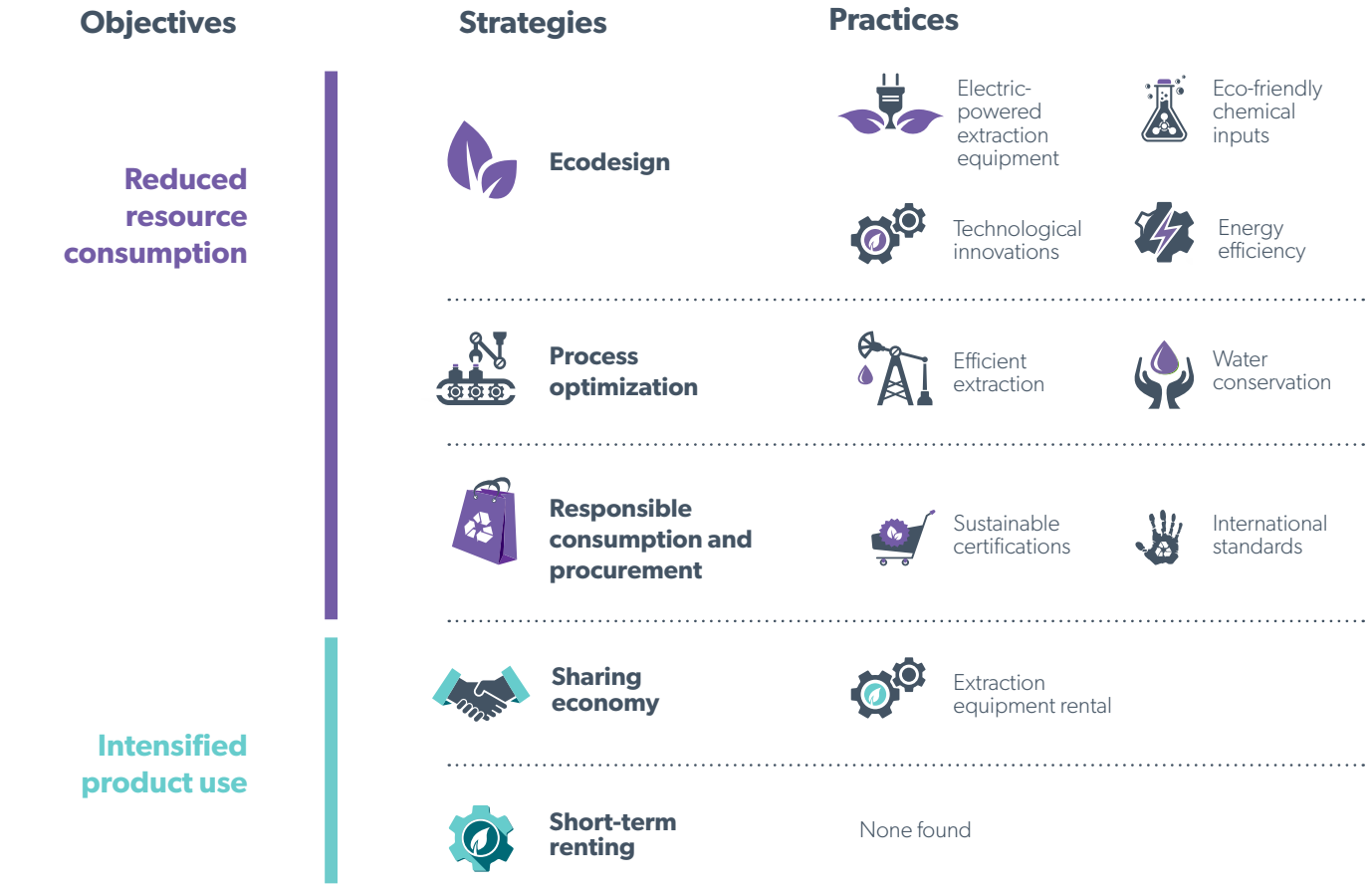
- reducing the environmental impacts of mining; and
- improving Canada's competitiveness.[14]

This initiative guides research and development in the mining sector from 2016-2021 and has four main priority areas: energy efficiency, enhanced productivity, waste management, and water management.[15]

1.3. Overview of Circular Economy Practices in the Minerals and Metals Sector

Minerals and metals companies have begun to invest in researching and implementing circular solutions. These investments are being made to help address the sector's greatest challenges, such as increasing efficiency, providing cleaner inputs, reducing mining waste, and reclaiming and recycling post-consumer minerals and metals. Figure 1-1 summarizes the specific practices employed in the minerals and metals sector, organized according to the four objectives for a circular economy and twelve core supporting strategies described in the Introduction to this publication series. Some of these are highlighted below. This is followed by a listing of applied examples of these strategies and practices, with hyperlinks to additional information. Canadian examples are denoted by a red superscript ([CDN]).

Figure 1-1. Circular economy objectives, strategies and practices found in the minerals and metals sector



Objectives, Strategies and Practices

REDUCED resource consumption is one of the most commonly used circular economy approaches in the mining industry. To achieve this goal, companies employ **eco-design** strategies, such as the development of electric extraction equipment, eco-friendly chemical inputs, and other technological innovations.

Another strategy used to reduce resource consumption is **process optimization** throughout the production process. For example, the use of freshwater by mine sites is of particular concern, both environmentally and socially. To address this issue, Newmont Goldcorp[16] has implemented a ten-year H2Zero vision, aimed at significant water conservation measures of freshwater and net-zero new freshwater input into their operations. In 2018, the company achieved an average reuse and recycle rate of 65%. Innovative technologies are also improving the efficiency of mining extraction. Tomra Systems[17] uses a sensor-based ore sorting system for dry materials separation of various ores and minerals for more efficient extraction. These systems contribute to increased efficiency by extending the lifetime of mining operations, increasing the value derived from deposits, and reducing the number of inputs, such as water, energy, and process reagents per ton of product. **Responsible consumption and procurement** can be applied in a number of ways, such as through the use of sustainable certification that gives purchasers confidence to choose sustainably sourced materials, as being offered through ArcelorMittal.[18]

Extending the life of products and components is another strategy that can optimize resource use in the mining sector. Although this objective remains under-developed in this sector, Toromont Industries is a Canadian machine dealer that offers customers rental deals on an as-needed timeline.[19]

Tormont Industries also facilitates maintenance and repair on their equipment by offering ongoing service assistance.

Other practices in this sector look to **OPTIMIZE** resource use through strategies to **give resources a new life.** The practice of **industrial ecology** prevents and reduces waste in industries, by turning waste into a resource. For example, AngloAmerican[20] has committed to a zero-waste-to-landfill strategy in South Africa through the reuse or recycling of mining waste. This goal was primarily driven by a shortage of suitable landfill sites in the country which drives up the cost of waste disposal. Amongst other waste reduction practices, they are using a bioremediation plant to rehabilitate soil affected by hydrocarbon spills, reducing hazardous waste sent to landfill. Additionally, at AngloAmerican's Rustenburg Base Metal Refineries, an offtake of sodium sulphate produced as a by-product is now sold into the market.

Another practice used to give resources a new life is the strategy of **recycling** post-consumer minerals and metals at their end-of-life stage through mineral recovery. For example, Mitsubishi Materials[21] based in Japan has adopted a group-wide recycling-oriented business model. In this model, the company recycles materials and resources across a wide range of fields and throughout its activities, including home appliances, aluminum beverage cans, tungsten and palladium. Similarly, Sumitomo Metal Mining[22] has almost doubled its recovery rates of copper scrap in the 2010-2015 period. High-purity copper scraps are processed directly in its Tokyo smelter and refinery. Finally, **energy recovery** practices can be used to recover the heat generated from mining processes and turn it into usable energy by increasing comminution efficiency.[23]

Elysis: Improving the aluminum smelting process

Rio Tinto and Alcoa, two large international companies, have joined together to form Elysis™, a new technology to improve the aluminum smelting process,[24] one of the most important innovations in the aluminium industry in more than a century. If the ELYSIS™ technology for carbon-free smelting is adopted in Canada, it has the potential to reduce the annual GHG emissions by approximately 7 million metric tons, which is an equivalent of removing 1.8 million cars from the road.[25]

Mineworx Technologies Ltd: Tapping smaller, high-grade deposits

Mineworx Technologies Ltd. is a solutions provider for environmentally-friendly extraction of precious metals by tapping smaller, high-grade deposits previously dismissed by the mining industry. These smaller deposits have previously not justified the high capital costs of conventional mining. Mineworx has developed the following three technologies to reach this underexploited segment of the mining industry:

- HM X-leach is a cost-effective and eco-friendly alternative to the hydrometallurgical extraction of precious metals in the mining. Unlike cyanide or acid methods of extraction, HM X-leach does not generate poisonous off-gasses. This cyanide-free reagent mixes non-toxic dry ingredients with water. It allows Mineworx to reach smaller, high-grade gold deposits, on properties experiencing permitting issues with respect to toxic cyanide leaching or where owners are seeking an environmentally-friendly alternative to cyanide.[26]

- HM X-mill is a new form of mineral grinding technology which significantly reduces the operational footprint, energy consumption, operational costs and capital costs of fine grinding. It is designed to be energy efficient and portable, allowing for low-cost operation in remote installations with minimal infrastructure required. It can be used as a stand-alone application, or as an additional component for the HM X-tract.[27]

- HM X-tract is a complete modular, turn-key portable processing unit, which includes crushing, grinding, gravity separation, floatation, concentration, clarification, water recycling, power generation and operational service and support modules. The combined water clarification and filtration technologies allow operators to recycle most of the process water used at a typical mine site and reducing the necessity for tailing ponds. Using this portable processing technology Mineworx partners with existing owners and operators of advanced stage mines to reach smaller, high-grade deposits, which were previously unexploited.[28]

Caterpillar Inc: Applying a lifecycle lens to mining machinery

Caterpillar Inc. designs, develops, engineers, manufactures, markets, and sells, amongst other things, mining machinery. Caterpillar views its products through a lifecycle lens and wherever possible, keeps resources in the value chain through a circular flow of materials, energy, and water.[29] The company offers a number of products and services which contribute to a circular economy.

- Rentals: The Cat Rental Store has the largest equipment rental fleet in the world and offers flexible options for renting equipment for short- or long-term needs. The Cat Rental store has a wide range of machines and over 1,300 locations.[30]
- Rebuilding: A completed rebuild through the Cat® Certified Rebuilds program includes more than 350 tests and inspections, automatic replacement of approximately 7,000 parts and a like-new machine warranty. Caterpillar provides information, data, training and service tools to help dealers make the most appropriate decisions on which parts to reuse in order to achieve expected longevity of rebuilt components.[31]
- Remanufacturing: Since 1974 Cat Reman has offered customers high quality, low cost replacement parts remanufactured from genuine Cat components. Replacement parts under Cat Reman are covered under the same warranty as new Cat parts. Cat Reman's mandate is to reduce waste, lower the cost of ownership, and extend the value of the customer's investment in the product.[32]

Specific Examples: Objective 1, Reduced Resource Consumption

Ecodesign

Electric extraction equipment

- GHH Fahrzeuge[33] is offering electric Load, Haul and Dump (LHD) machines with capacities ranging from 10 to 21 tons. In connection with an intelligent monitoring system, efficiencies are increased, and power consumption is reduced significantly.
- ETF Equipment[34] has designed a Battery-Operated Modular Mining Equipment which is fully powered by a heavy-duty rechargeable lithium-Ion D5 battery arrangement. The D5 battery system creates no emissions, lower noise levels, and requires less maintenance than a conventional diesel-powered vehicle.

Eco-friendly chemical inputs

- Mineworx Technologies Ltd[35] CDN (in joint partnership with EnviroLeach[36]) is reducing its operational footprint and energy consumption through the use of the HM X-leach, an innovative new eco-friendly technology which offer cyanide-free precious metals extraction.

Technological innovation

- Rio Tinto[37] has achieved gains in mining automation through the Mine of the Future program. The program was founded to help the company find innovative ways of extracting minerals while reducing environmental impacts and improving worker safety.
- Rio Tinto[38] has modernized it's 60-year-old Kitimat aluminum smelter in British Columbia using the latest evolution of their APTM technology. The result was an environmentally superior, safer, and more productive facility. The project also reduced the smelter's overall emissions by nearly 50 percent.
- Elysis[39] CDN is delivering a new technology which eliminates all greenhouse gas (GHG) emissions from the aluminum smelting process and is the first technology ever that emits pure oxygen as a by-product.

Energy efficiency

- ArcelorMittal[40] has designed industrial gas-injection technology. This technology is increasingly used to replace metallurgical coke with alternative sources of carbon such as pulverised coal or natural gas. Some of their most advanced blast furnaces are now injecting 50% of the total carbon required for the process using this technology – with the effect of reducing the total amount of fossil fuels required.

- ZeroBrine[41] is piloting a project in Poland which aims to decrease the energy consumption by 50% compared to the energy consumption of a reverse osmosis-vapour compression system which represents current best practice.

- B2Gold Corp.[42] CDN is reducing its reliance on fossil fuels by adding a 7MW solar-panel plant to its mine in Namibia and is planning to expand to its other mining operations.

The Ideal

- Extraction is designed with a holistic approach, considering the environmental impacts of the mine site at every stage of the process, from the planning phase to the remediation phase.

- Extraction is designed to have a minimal impact on the surrounding environment through low-carbon considerations, fewer harmful chemical inputs, minimizing waste and providing environmental offsets to reduce the impact of mining on local biodiversity.

Process optimization

Efficient extraction

- Tomra Systems[43] is delivering a sensor-based ore sorting system for dry material separation of various ores and minerals, in addition to enabling metal recovery from slag. Numerous TOMRA Sorting Mining systems have been installed worldwide, each contributing to extending the lifetime of mining operations, and increasing the value derived from deposits and increasing production efficiency.

- Mineworx Technologies Ltd[44] CDN is combining its X-Tract mobile mining/extraction process with a new business model to offer the service of mining smaller, high-grade deposits on existing mine sites and tailing ponds, deposits which are often overlooked by large mine owners and operators.

Water conservation

- Mineworx Technologies Ltd[45] CDN has developed a process which combines water clarification and filtration technologies to allow operators to recycle most of the process water used at a typical mine site. This conserves water, minimizes environmental discharge and significantly reduces or eliminates the necessity for tailings ponds.

- Newmont Goldcorp[46] CDN has implemented a ten-year H_2Zero vision, starting in 2017. This vision aims at making significant reductions in the company's consumption of fresh water and maintaining the goal towards net zero new freshwater input into their operations. In 2018, the company achieved an average reuse and recycle rate of 65%.

- ZeroBrine[47] is piloting a project in Poland which treats coal mine water. The goal is to recuperate valuable raw materials, such as concentrated brine, magnesium hydroxide, and high-quality RO permeate.

The Ideal

- Mining operations extract as close to 100% of the mineral as possible.
- Little to no waste is produced by the manufacturing process.
- Water used in mining processes is recycled in a closed-loop process.
- Minimizing waste generation such as tailings, gas emissions, and waste water

Responsible consumption and procurement

Sustainable certifications

- ArcelorMittal[48] has taken a leading role in forming "Responsible Steel", the steel industry's first multi-stakeholder global certification initiative. "Responsible Steel" aims to give businesses and consumers confidence that steel certified under this standard has been sourced and produced responsibly at all levels of the supply chain.

- Rio Tinto[49] is the first company to be certified under the Aluminum Stewardship Initiative (ASI), the highest internationally recognised standard for robust environmental, social and governance practices across the lifecycle of aluminium production, use and recycling.

International standards

- IRMA[50] is an international body that provides global standards for mining procurement practices. Committed to transparency and continuous improvement, IRMA offers greater options for purchasers who want to make sure the mining corporations they do business with are dedicated to environmental and social betterment.

The Ideal

- Extraction equipment is being shared by mine sites in a similar geographic vicinity.
- Extraction equipment is available to any mine operator for rental with options for short- and long-term solutions

Specific Examples: Objective 2, Intensified Product Use

Sharing economy

Extraction equipment rental

- Toromont Industries[51] CDN is supplying and servicing new and used equipment, as well as daily, weekly and monthly equipment rental.

The Ideal

- Extraction equipment is being shared by mine sites in a similar geographic vicinity.
- Extraction equipment is available to any mine operator for rental with options for short- and long-term solutions.

Short-term renting is not significantly addressed by the sector.

Specific Examples: Objective 3, Extending Life of Products and Components

Maintenance and repair

Extraction equipment designed for reuse and repair

- ETF Equipment[52] is redesigning extraction equipment to facilitate reuse and repair. The modular designed vehicles feature components that can be removed from the vehicle for maintenance and repairs without bringing the entire truck to the shop.

The Ideal

- Continued growth in this practice.

Donating and reselling is not significantly addressed by the sector.

Refurbishing

Extraction equipment refurbishment

- Caterpillar[53] is offering a repackaging service through its Cat Reman brand, which refurbishes products at their end-of-life. Through this service, products are completely dismantled, cleaned, inspected and restored to give them a second life.

Repurposing the mine site

- Teck Resources Limited[54] CDN has fully reclaimed its former Sullivan mine and transitioned the site into the SunMine solar plant.

The Ideal

- All mining equipment can be refurbished with relative ease, whilst the use of refurbished components is maximized.
- A greater ease of disassembly and more durable product components to lower costs of 'production' for refurbished goods.
- Mine sites are fully reclaimed after operations have been completed.

Performance economy: is not significantly addressed by the sector.

Specific Examples: Objective 4, Giving Resources New Life

Industrial ecology

Tailings as a product

- Weir Minerals[55] is helping its clients find more sustainable solutions for mine tailings using the Weir Technical Centre (WTC). At WTC technicians have the ability to simulate what exists onsite and, from there, investigate new methods for tailings handling, reuse and disposal.

Carbon capture

- ArcelorMittal[56] is partnering with LanzaTech to build a plant in Europe that uses waste gases from steelmaking to produce ethanol on a commercial basis.

Reuse or recycling of mining waste

- Rio Tinto[57] has found off-site opportunities for reuse or recycling of 353,877 tonnes of their non-mineral waste and 740,249 tonnes of mineral waste in 2018.
- AngloAmerican[58] is using a bioremediation plant to rehabilitate soil affected by hydrocarbon spills, reducing hazardous waste sent to landfill. Additionally, an offtake of sodium sulphate produced as a by-product is now sold into the market from its Rustenburg Base Metal Refineries.

Solar panels on site

- Chevron Technology Ventures[59] is using mine tailings and other mine waste sites to produce renewable energy. The solar farm in New Mexico follows the sun, concentrates its light, and converts it into electrical energy. It generates enough power for 150 homes.

Planting bio-crops on site

- Harmony[60] is rehabilitating mine sites for the cultivation of bio-crops to generate renewable bioenergy to be used as a substitute for polyfuel.

The Ideal

- Proper storage of mine tailings for subsequent extraction based on technological development and value.
- Recycling of mine tailings and residues.
- All mine sites which are no longer in use have been rehabilitated for productive use.

Recycling and composting

Minerals recovery

- Sumitomo Metal Mining[61] has doubled its recovery rates of copper scrap from 2010 to 2015. High-purity copper scraps are processed directly in its Toyo smelter and refinery.
- Mitsubishi Materials[62] has adopted a group-wide recycling-oriented business model, recycling materials and resources across a wide range of fields and throughout its activities, including home appliances, aluminium beverage cans, tungsten and palladium. Smelting technology is used for the purpose of recycling metals at Mitsubishi's smelters and refineries, alongside the recycling of scrap for raw materials, thermal energy or recovery of valuable metals.
- Horne Smelter[63] operated by Glenco Recycling in Rouyn-Noranda Québec is the world's largest processor of electronic waste containing copper and precious metals. It has the ability to process 840,000 tonnes of copper and precious metals per year and has the distinction of being able to process a wide variety of inputs.

The Ideal

- Landfill mining to extract metals from consumer waste.
- There is adequate infrastructure in place so that metals and minerals can be easily recycled and used in new products.

Energy recovery

Increasing comminution efficiency

- Raglan Mine[64], which is operated by Glencore, has reduced the 99% inefficient rate that has been cited in comminution practices. Operating at a 34.6% inefficiency rate, the Raglan mine is able to increase efficiency through a variety of energy recovery methods, including the capturing of heat loss.

The Ideal

- Mines operate at maximum energy efficiency levels and mainstream energy recovery practices

1.4 Additional Resources

The following are additional resources that researchers, practitioners, and policy-makers can draw on to further advance awareness and understanding of opportunities for circularity for Canada's minerals and metals sector.

Selected Global Public Policies Supporting Minerals and Metals Circularity

- *Circular Economy Promotion Law (China):* The Law is formulated for the purpose of facilitating circular economy, raising resources utilization rate, protecting and improving environment, and realizing sustained development. Article 22 and Article 53 specifically outline the requirements for the mining sector, as well as the fines associated with non-compliance.[65]
- *Circular Economy Action Plan (EU): This* guiding document for the EU-wide Circular Economy Package pertains to the guidance and promotion of best practices in the mining waste management plans.[66]
- *The Canadian Minerals and Metals Plan (NRCAN – Canada):* The plan envisions (1) the continual reduction of mining's environmental footprint, (2) a circular economy where mine waste is transformed into useful products and environmental liability is reduced, (3) enhanced mine closure planning and environmentally-reclaimed mine sites, and (4) systemic climate change adaptation planning.[67]
- *Green Mining Initiative (NRCAN – Canada):* This research plan is intended to guide research and development for five years (2016-2021) and has four main priorities: energy efficiency, enhanced productivity, waste management, and water management. The two overarching objectives of this research are to reduce the environmental impacts of mining and improve Canada's competitiveness.[68]

Selected Documents on Circular Economy and the Minerals and Metals Sector

Mining in a Sustainable Future

World Economic Report. (2013). *The Role of Mining in a Sustainable Future*. Retrieved from http://reports.weforum.org/mining-and-metals-in-a-sustainable-world/executive-summary/?doing_wp_cron=1576968459.5270800590515136718750

At the World Economic Forum's Annual Meeting 2013, the Governors for the Mining & Metals Industry asked the Forum to prepare a scoping paper on the role and contribution of mining and metals companies in a sustainable world. This paper seeks to set the strategic vision for mining and metals companies in a sustainable world and to outline their immediate priorities.

The World Bank. (2020). *Minerals for Climate Action*. Retrieved from https://web.archive.org/web/20200619202345/http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

Produced by the Climate Smart Mining-Initiative, a program developed by the World Bank, this report highlights the important role the mining sector will play in the clean energy transition. It highlights predicted upcoming changes in demands upon the mining sector for resources necessary to shift towards sustainable energy systems as well as examines the mineral resource intensity of various renewable energy sources.

Mining and the Circular Economy—international resources

ArcelorMittal. (2019). *Climate Action Report*. Retrieved from https://web.archive.org/web/20191127230825/https://corporate.arcelormittal.com/~/media/Files/A/ArcelorMittal/investors/corporate/AM_ClimateActionReport_1.pdf

This report outlines the environmental achievements, plans, and policies from the steel company ArcelorMittal. Although many of the examples are specific to the company itself, the report references the circular economy and the transition to the circular economy, while also suggesting interesting strategies and policy opportunities throughout. Worth reading for a better understanding of central themes such as circular carbon, circular materials, and global policy requirements moving forward.

Golev, A., Lebre, E., & Corder, G. (2018, August 16). *Contribution of mining to the emerging circular economy.* Retrieved from https://www.ausimmbulletin.com/feature/the-contribution-of-mining-to-the-emerging-circular-economy/

This article outlines various circular business models which could be used to address waste in the mining sector.

International Council on Mining and Metals. (2016). *Mining and Metals in and the circular economy*. Retrieved from https://www.icmm.com/website/publications/pdfs/responsible-sourcing/icmm-circular-economy-1-.pdf

This document provides a basic overview the role of mining and metals in the circular economy and touches on what more can be done to facilitate the circular economy in mining.

Tayebi-Khorami, M., Edraki, M., Corder, G., & Golev, A. (2019). *Re-Thinking Mining Waste through an Integrative Approach Led by Circular Economy Aspirations.* Minerals, 9(5), Minerals, May 2019, Vol.9(5). Retrieved from https://www.mdpi.com/2075-163X/9/5/286

The estimated worldwide generation of solid wastes from the primary production of mineral and metal commodities is over 100 billion tonnes per year. In this paper, the authors identify and review current knowledge across five key domains, which can form an integrative, cross-disciplinary approach for "re-thinking" mining wastes, framed around the circular economy.

Mining and the Circular Economy—Canadian resources

Institut EDDEC. (2017, May 31). *Métaux et Économie Circulaire au Québec*. Retrieved from https://web.archive.org/web/20200129004248/https://mern.gouv.qc.ca/publications/mines/freins-leviers-eddc.pdf

The document assesses the circularity potential of three strategically important metals for Québec: copper, iron, and lithium, as well as documenting the impacts of the Québec mining industry on the environment. The objective of the summary is to identify mining industry trends in Québec, identify the indicators, and finally, provide an overview of potential policy options for improving circularity in the mining industry.

Natural Resources Canada. (2016). *Green Mining Initiative*. Retrieved from https://web.archive.org/web/20191228155850/https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/mining-materials/PDF/CanmetMINING_research_plan_document_access_e.pdf

This research plan is intended to guide research and development for five years (2016-2021) around four priority issues: (1) energy efficiency, (2) enhanced productivity, (3) waste management, and (4) water management. The two intertwined objectives of this research are to reduce the environmental impacts of mining and improve Canada's competitiveness.

Natural Resources Canada. (2019). *The Canadian Minerals and Metals Plan*. Retrieved from https://web.archive.org/web/20191128011416/https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/CMMP/CMMP_The_Plan-EN.pdf

The plan envisions (1) the continual reduction of mining's environmental footprint, (2) a circular economy where mine waste is transformed into useful products and environmental liability is reduced, (3) enhanced mine closure planning and environmentally- reclaimed mine sites, and (4) systemic climate change adaptation planning. From this vision, the plan outlines the approach to achieve this vision, putting the plan into action and the strategic directions.

1.5 Conclusion to Minerals and Metals

This global scan of best circular economy practices in the minerals and mining sector reveals that selected firms and operations are already implementing a wide range of practices that support circular economy objectives and strategies, whether or not these practices are explicitly identified as circular.

In cataloguing these examples, our intent is to demonstrate real-world strategies and practices that offer a starting point in the journey towards a circular economy. This information is offered as a background resource and reference source for future efforts to engage Canadian firms and innovators in the journey towards a circular economy, and –ideally--to begin building a Canadian minerals and metals sector roadmap to a circular economy.

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