

TOWARDS A CIRCULAR ECONOMY APPROACH TO MINING OPERATIONS

Key Concepts, Drivers and Opportunities

Alan Young & Maria Laura Barreto | Materials Efficiency Research Group
Karen Chovan | Enviro Integration Strategies Inc.

December, 2021

Prepared for
Natural Resources Canada and



THE CANADIAN
MINERALS AND
METALS PLAN

LE PLAN CANADIEN
POUR LES MINÉRAUX
ET LES MÉTAUX



© Enviro Integration Strategies Inc., MERG 2021
www.merg.ca | www.envirointegration.com

Executive Summary

The minerals sector is receiving increasing international attention for the role it plays as a supplier of materials necessary to build the infrastructure for a low carbon energy future. While contributing to climate change solutions, it must also address mounting pressures from stakeholders and supply networks to tackle serious environmental and social impacts. Combined, these trends present a moment of opportunity and challenge for the mining industry.

There is a growing interest globally in the benefits associated with the integrated, zero waste/low carbon Circular Economy (CE). CE concepts and strategies focus on transformative approaches that design waste and pollution out of products and services, while capturing greater economic value throughout supply networks, by rethinking conventional “take-make-waste” linear business models.

Relatively little has been discussed about the implications of CE transition strategies for mining operations. Aside from their irreplaceable role in renewable energy infrastructure, minerals have unique properties of durability, recyclability and adaptability, making them ideal materials for the closed loops of production associated with CE systems.

Canada’s established history of mining innovation positions it well to address and benefit from these challenges. With the Canadian Minerals and Metals Plan (CMMP) identifying CE strategies as a way to advance a sustainable future for the industry, there is an opportunity to demonstrate leadership that builds on domestic strengths and larger global trends, both of which seek to capture greater value while reducing negative impacts.

Core CE Objectives and Principles

Regardless of sector, CE is guided by three core objectives:

- Design waste and pollution out of the economic system, by fully costing impacts and identifying potential for value in materials recycling, reuse and repurposing.
- Keep products and materials in the system and at their highest utility for as long as possible to optimize value.
- Regenerate natural systems to protect essential ecosystem services such as clean water, clean air, healthy soils, carbon storage, and flood protection.

Several principles inform CE solutions and define an approach to problem-solving using integrated and systemic strategies to address root causes of ongoing negative environmental and social impacts. The CE approach seeks to overcome siloed harm reduction tactics when dealing with environmental, social and governance (ESG) problems that address symptoms but not the underlying conditions or activities that lead to those problems.

Key CE principles relevant to the mining industry explored in the report include:

- Stock optimization – extending the value of materials;
- Eco-effectiveness – going beyond eco-efficiency;
- Eliminating the concept of waste by extending resource value;
- Extended Producer Responsibility (EPR);
- Circular product and process design; and,

- Creation of social value for everyone.

This report demonstrates these principles applied to mining operations throughout the mine life cycle.

CE Applications at the Mine Site

For mine operators, CE involves the minimization of waste generation, through all stages of extraction and processing, and the focused preservation of natural resources and their value by extending the life of extracted minerals. The emphasis is on maximizing value wherever possible but is not exclusively reliant on producers to bear this responsibility. Under CE scenarios, other market players may be drawn in to capture and share value (see Figure below, *Process and Product Stewardship in Minerals Value Chain*).

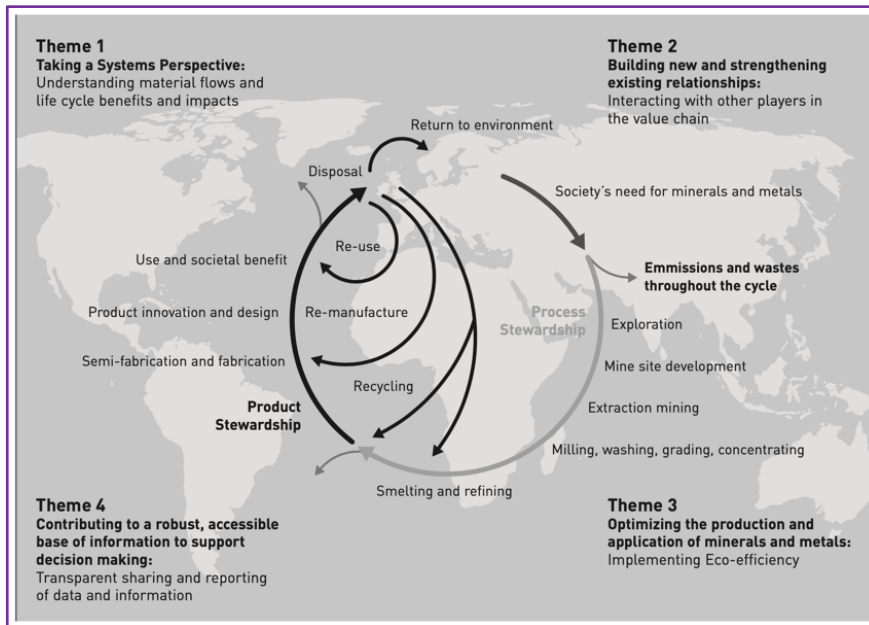
Mines are understood not only as suppliers of materials but also as major purchasers and users of products and services, themselves subject to principles of optimal use. Thus, mining companies engage with “closed loop” systems that contribute to a CE of minerals-related products, and feed new materials into those systems as needed to meet growing demand.

Opportunities also occur when the mine operator partners with others not involved in the operations. This can include co-development of regional infrastructure, processing or utilizing others’ process residuals to the benefit of each party and regenerating lands and transitioning ownership of assets for post-mining uses.

Mine operators can engage various strategies in the practice of CE smart mining. Mine development viewed from a “cradle-to-cradle” perspective re-imagines such possibilities for all the materials extracted, the assets and infrastructure constructed, and the land reformed and supports responsible design and decision-making.

This report describes a hierarchy of categories of circular practice that an operating site or mining organization can consider. These practices fall into two areas of influence and activity:

1. The technical operating system of infrastructure, equipment and assets created or utilized at a mine site; and
2. The natural resources that mining operations disturb, extract, consume, use and/or otherwise manage.



Process and product stewardship in minerals value chain ¹

¹ ICMM. (2006). [Maximizing Value, Guidance on implementing materials stewardship in the minerals and metals value chain](#). The graphic was adapted by ICMM, from NRCAN. (1995). *Sustainable Development and Minerals and Metals: An Issues Paper*

Adapting Technical Systems to Maximize Value Creation at the Mine Site

The technical system considers the physical infrastructure, equipment, and assets that a mining company purchases, establishes, or utilizes to operate the mine. These systems are present from development and excavation of the deposit, through comminution, extraction, and tailings production, and through packaging and transport to the customer (whether they be refiners, smelters, semi-fabricators, fabricators and/or manufacturers). Key CE principles in this area include:

- *Whole systems design for inter-related CE strategies:* start with a system wide review of how different elements of the mine cycle can be designed to advance zero waste, low carbon, and social objectives.
- *Safely dispose:* re-think “end of life/waste” definitions and practices to explore new value capture opportunities.
- *Recycle, upcycle, reuse, redeploy:* get the maximum value possible from products already on site.
- *Refurbish, remanufacture:* reimagine/recreate on-site products to extend value.
- *Share, rent, prolong, maintain:* re-think supply and ownership to optimize use and value.

This report contrasts the use of incremental adjustments to linear processes with the implementation of a combination of inter-related changes from the outset to achieve system-wide targets in the pursuit of efficiency and economic gain.

Reducing Impacts, Maximizing Value of Natural Resources and Disturbed Lands

Several CE strategies focus on optimizing natural resource management and deriving the greatest value from the resources that are disturbed, extracted, used and/or otherwise managed. Key activities in the mining sector would be to:

- *Consider lower impact options:* use mine-impacted waters from the site instead of fresh water; capture and use waste energy or geothermal energy via heat transfer or converted power from exhausts, circulating fluids (processing or water); replace fossil fuel-based power systems with renewable energy and hybrid electric options; exchange toxic consumables with safer options; and purchase refurbished, used or consumables bearing recycled content.
- *Extract embedded value from mining wastes making the most out of stored geological resources:* repurpose, redirect, reprocess on-site and local off-site resources; develop re-valuations for new markets or buyers; discover new value-add uses.
- *Extend materials life and industrial symbiosis: creating value through waste exchanges with others:* engage separate industries in a collective approach to competitive advantage – industrial symbiosis – involving physical exchange of materials, energy, water, and/or by-products.
- *Re-think mine reclamation from harm reduction to value generation:* reclaim and regenerate land for recreational, commercial, agricultural purposes and to natural ecological systems as appropriate.

CE Business Models and Business Case Considerations

Most CE mining approaches have the potential to be deployed, in some capacity, in all mines, for all commodities, for any scale of mine, and at any life cycle stage of a mine. However, the greatest benefits

derive when all CE strategies are considered, and circularity is “designed and built in” to new developments and implemented at the earliest phase of the mine’s life cycle.

Responsible mining standards address questions of carbon, waste reduction and/or social development (e.g., *Climate Smart Mining*, World Bank, *Towards Sustainable Mining*, Mining Association of Canada (MAC), *Initiative for Responsible Mining Assurance*, IRMA, and *Green Mining Innovation*, CanmetMINING, Natural Resources Canada [NRCan]). Because these initiatives relate to issues under the umbrella of CE in mining, operators in the mining space already may be at various points within this spectrum and, without knowing it, on the circular agenda. For example, many companies long ago began improvements in social and environmental performance beyond specific regulatory requirements, and many of these goals align with CE objectives. Energy efficiency and process optimization efforts aimed at cutting operational costs, and climate-smart mining, have led the sector along the path of low carbon developments. As a result, aspects of circularity may now fall within core business practices.

This report proposes that opportunities for savings, for systems value generation, and for creating benefits beyond the mine border exist in transformational innovation. Benefits of a move towards CE are reflected at the mine site and beyond and are realized through increased partnership and collaboration, as summarized in this and the next three sub-sections.

Benefits for the Mine Site and Beyond

Circular practices introduce mechanisms to reduce water and energy consumption and CO₂ emissions, and to eliminate the generation of waste. These lead to reductions in costs related to operational risk management and consumption in general. Stored waste materials exposed to climatic conditions may cause environmental problems over time, often well after operations have ceased. The costs of rehabilitation of impacted lands and water can be substantial. Circular practices lessen the risk of potential environmental impacts because fewer waste materials accumulate on the site during operations and over the longer term. Therefore, potential liability and associated closure and financial assurance costs are reduced.

The introduction of circular actions demonstrates an operator’s commitment to sustainable and responsible production. It improves the organization’s reputation, upholding its social license to operate and inviting preferential market access, responsible investment interest and improved ability to attract and retain personnel aligned with these corporate and professional values.

Building on the foundation of responsible mine strategies, the implementation of CE practices in the mining sector would reduce greenhouse gas (GHG) emissions and environmental impacts over the longer term. CE seeks to maximize value from resources, increase resource security, and restore or regenerate natural capital and ecosystems. Because some CE strategies will require innovation, new technology and exchange capabilities, CE will lead to jobs in diversified value chains (e.g., specialized processors, systems designers, land and infrastructure repurposing planners and specialists, technology and digital developers, technical operators, and more). CE activities will also attract investment, relieve pressure on municipal budgets, and demonstrate technological leadership.²

Local Partnership Models

Mines can partner to facilitate circular benefits beyond the mine by utilizing excess materials and planning for mine closure. The first opportunity comes when there are excess materials or resources generated by the mine (deemed uneconomic under conventional accounting methods) that could be

² Responsible Mining Foundation. (2020). [Mining and the SDGs: a 2020 status update](#).

utilized by others within the region - during operations or after the mine has closed. The second opportunity involves transition planning in preparation for mine closure. When a mine is a primary contributor to the local economy, it can be difficult for local communities to sustain economic health or growth beyond the mine. This report defines this transition with a CE lens. For example, infrastructure assets developed to support the mine can be designed with consideration of the longer-term needs of the community.

Engagement, Collaboration and Partnership Considerations

CE business benefits for the mining sector include increased supply chain security; additional value from products and materials; and mitigation of risk from volatile commodity prices.

With respect to the supply network and markets, CE activities could be furthered by:

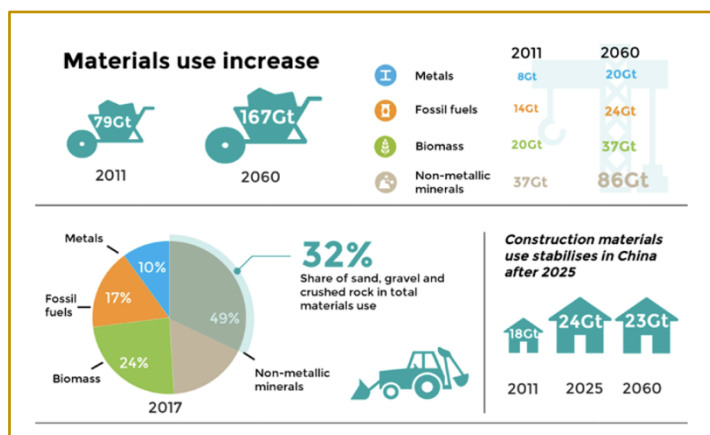
- Engaging the supply network with an emphasis on greater transparency and flexibility;
- Engaging with local communities, Indigenous rights holders, regional planners and government to optimize value creation and local economic benefits; and,
- Applying systems-based, life cycle assessments to enable better understanding of value network potentials for all aspects of mining operations upstream, downstream and adjacent.

An investigation of CE opportunities should start with regionally located mining operators, upstream supply vendors, local stakeholders, and then with players in the downstream value network. Most

companies are already focused on operational efficiencies, and sourcing equipment and new technologies which may require engaging the supply network or finding new vendors who can meet new requirements. Some of the biggest potential gains, however, exist in local partnerships and on the downstream side of the value chain – in the segregation and development of secondary or tertiary products, or continued use of assets over the long term.

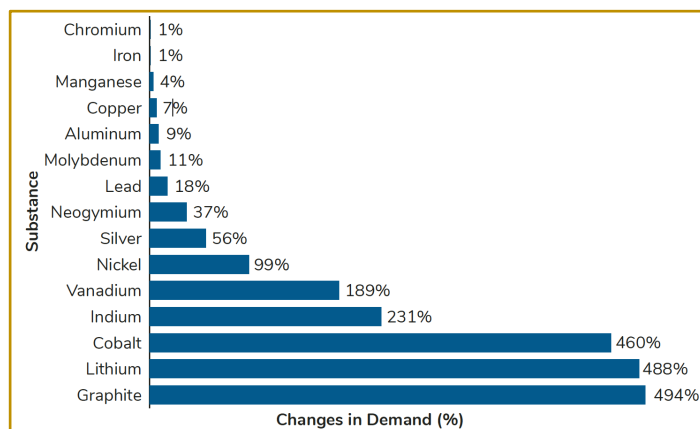
CE and Minerals: Drivers, Demands and Market Opportunities for Mining Companies

The current trajectory of population and economic growth, with its associated materials consumption, is sobering in terms of potential environmental and social impacts. In an already stressed human and environmental context, global materials use is projected to more than double from 79 Giga tonnes (Gt) in 2011 to 167 Gt in 2060. Growth in demand for motor vehicles and electronics in turn is driving increased demand for a range of minerals.



Materials use increase 2011 to 2060.³

³ OECD. (2019). [Global Material Resources Outlook to 2060: Economic drivers and environmental consequences](#).



Changes in demand for green energy transitions 2018-2050 ⁴

In addition to these consumer market trends, the minerals required for the expansion of renewable energy generation, transmission and storage will result in unprecedented increases in demand for minerals. At the same time, addressing carbon emissions associated with meeting these needs is imperative but is a substantial challenge.

CE Approaches Reduce Carbon and Address Responsible Mineral Demands

Addressing climate risks is an ever-increasing priority for the mining industry, under pressure from governments, investors and consumers to develop strategies for carbon emissions reduction. Many companies have begun to set ambitious emission-reduction goals ranging from zero to 30 percent by 2030, though below the broadly defined national objectives associated with the Paris Agreement goals. In theory, mines *can* fully decarbonize (excluding fugitive methane) through operational efficiency, electrification, and renewable energy use.⁵ They can do so even in the context of increasing market demand for mineral commodities.

To highlight the importance of ambitious strategies around climate solutions in addressing mineral development challenges, the World Bank, among others, has proposed an integrated CE approach to address waste reduction, carbon emissions and socio-economic value generation.

In parallel to the focus on carbon emissions reduction, consumer and investor attention to negative impacts from mining is growing, with companies concerned about stigmatizing certain products (e.g., automobiles, electronics, and jewelry) and increasing interest in the idea of responsible sourcing of mineral products. These sourcing concerns are expressed through procurement policies that provide criteria and standards for suppliers to insure against specified impacts.⁶ Responsible/ethical procurement strategies have been adopted by both public and private sector organizations and present opportunities for market differentiation for low impact operations.⁷

CE strategies show the potential for a coherent and comprehensive approach to dealing with these challenges and supply chain opportunities. By applying CE systematically, early adopters benefit from preferential access to responsible sourcing markets and investors. Related criteria focus on carbon and waste reduction that can help shape the nature of the dialogue on how a CE for minerals can be defined and realized.

⁴ World Bank. (2020). [Minerals for Climate Action: The Minerals Intensity of the Clean Energy Transition](#).

⁵ Delevingne, L., Glazener, W., Grégoir, L., & Henderson, K. (2020, January 28). [Climate risk and decarbonization: What every mining CEO needs to know](#).

⁶ van den Brink, S., Kleijn, R., Tukker, A., & Huisman, J. (2019). [Approaches to responsible sourcing in mineral supply chains](#). Resources, Conservation and Recycling, 145, 389-398.; [Responsible Minerals Initiative](#).

⁷ European Commission. (2017). [Public Procurement for a Circular Economy](#).

As we move towards a future powered by “green metals”, circular closed loop industrial models will become the norm. This shift invites a reimagining of the linear mineral extraction business. While raw extraction isn’t going away any time soon, opportunities for new business models, including integrated materials companies, mineral solutions providers, and closed-loop metal-as-a-service offerings, will emerge. These are opportunities that mining companies are well-positioned to seize. Lose or acquire market share, disrupt ourselves, or be disrupted. The choice is ours.⁸

Government Policy Support for CE in the Mining Sector

Market and civil society forces are aligning around CE strategies, such as integrated carbon and waste reduction. Governments are articulating policies to frame and support CE strategies for mining companies.

Canada is in the early stages of exploring applications of CE strategies in various sectors of the economy. Aside from its commitment to host the World Circular Economy Forum in 2021,⁹ there has been an initial emphasis on deploying CE strategies to engage public, private and civil society institutions in addressing the issues associated with plastic waste.¹⁰ Other areas of CE strategy interest across Canada include urban design, agriculture and food, and energy transitions.

In the mining and minerals sector, there are emerging opportunities associated with the green energy revolution that can capitalize on Canada’s unique geological resources, mining capacity and regional economies. For example, the CMMP identifies extracting valuable residual minerals from existing mine waste as an area of focus.

Another track having significant potential synergies with a CE mining strategy is the increasing focus on the supply chains for Critical and Strategic Minerals (CSM). Canada has established policy and trade-related programs with the EU, USA, Japan and Australia, to promote innovation in extraction, recovery, processing, and manufacturing related to minerals essential for green energy transition infrastructure.

At the provincial level, the Quebec government has taken an aggressive approach to advancing a circular CSM development strategy.¹¹ To stimulate responsible sourcing of minerals, the province made an initial investment of \$68M to build a regionally coordinated business innovation hub for the rapidly expanding large-scale and electric vehicle (EV) battery market, as well as telecommunications, aerospace, renewable energy production, the medical sector and transportation electrification. These are high-growth sectors in which the CSM supply is vital and to which CE supply networks could add substantial economic and environmental benefit.

Linking the interest in CSM with CE systems supports value-creation and supply chain efficiencies, which are integral to the commitment to environmentally and socially responsible mining. Establishing well-defined and resourced CSM strategies, federally and provincially, in partnership with the private sector, invites strategic investments to exploration programs, research and development. This advances the “circular use of critical minerals” (including increased blending of both primary and recycled sourcing) and

⁸ Cheadle, A, & Freele, E. (2020, December 4). [Quo Vadis? Mining, metals and minerals in a circular economy](#). The Northern Miner, 106(26).

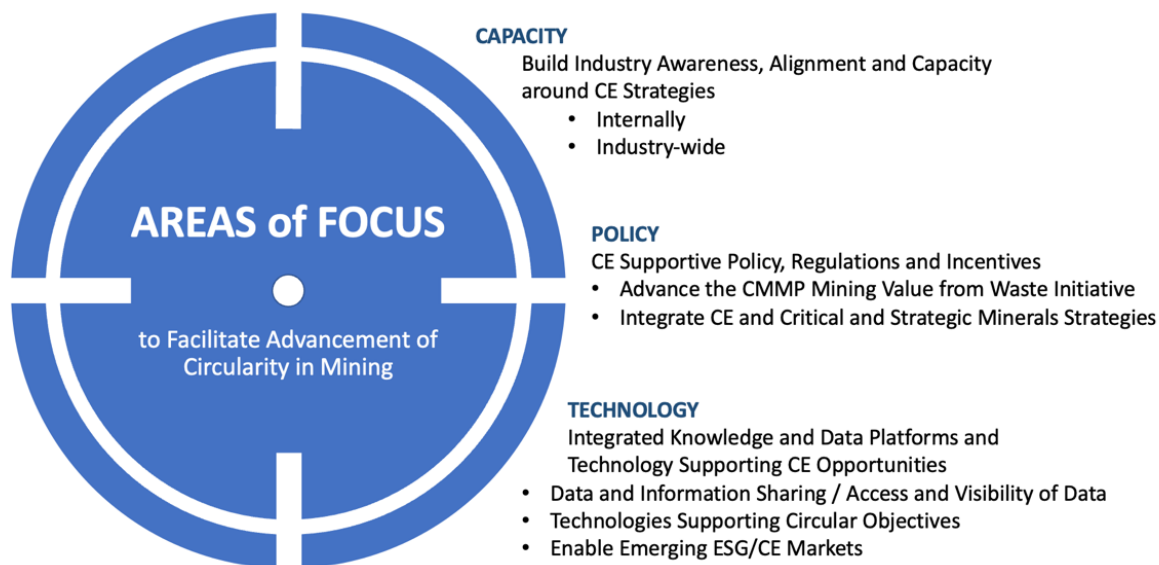
⁹ Government of Canada. (2021). [World Circular Economy Forum 2021](#).

¹⁰ Environment and Climate Change Canada. (2021). [Government of Canada invests in reducing plastic waste and supporting the transition of a circular economy for plastics](#).

¹¹ Mining [Dot] Com. (2020, November 3). [Québec unveils \\$68m plan to promote critical and strategic minerals sector growth](#).

boosts domestic refining and manufacturing capacities capable of drawing on domestic mineral supplies and feeding international market demands.

Building CE Capacity – Gaps and Recommended Next Steps



Advancing Industry Awareness, Alignment and Capacity

Challenges to advancing the CE agenda within the mining sector are awareness and understanding of what it is, how it applies, and the key benefits of doing so. Another challenge comes with mindset and culture, and the behavioural shifts required to meet new expectations for performance, or to perform business under new operating models.

Changing the culture may prove to be a greater challenge than implementing new and effective operational performance technologies.

The report focuses on the meaning of CE for mining, and how the sector can participate in the CE, and/or practice it internally. The information can be utilized to educate and engage industry and its workforce to identify and prioritize opportunities that each site could advance. However, for an organization to be successful, it is not enough to raise awareness levels – internal company change and industry-wide change need to be supported.

Internal Change

Keys to advancing CE strategies and tools include:

- Establishing CE goals, metrics and incentives;

- Building internal awareness and engagement of CE innovation potential;
- Mainstreaming CE resourcing and evaluation strategies; and,
- CE progress tracking and communications.

Industry-wide Change

A pre-competitive approach to enabling and accelerating greater CE benefits for mining includes:

- Evaluating geological resources beyond primary/conventional target commodities focus;
- Conducting comprehensive waste materials and assets classification throughout the mine cycle;
- Revising closure objectives guidance to enable future CE strategies; and,
- Providing active support for CE information sharing and innovation collaboration (within the mining sector and with other extractive sectors).

Recognition by industry of the potential value of CE strategies to achieve economic, social and environmental objectives is needed. If agreement can be established then information sharing, identification of opportunities, experimenting, technology development, co-development of synergistic plans, and execution should follow.

Towards CE Supportive Policy, Regulations and Incentives

Governments can accelerate the adoption of CE strategies and systems for mining operations. Public policy and regulations play a role in enabling value creation and liability reduction associated with applied CE practices. Government can help reduce obstacles to innovation in mineral extraction processing by incentivizing investments in new technologies and practices, and by encouraging CE through infrastructure support, network development, and procurement policies.

Including CE as an element of the CMMP represents an important opening that could be expanded beyond the current focus on tailings waste recovery and liability reduction. By employing an integrated CE framework, governments can leverage trends such as the growing concerns around CSM and the increasing market interest in climate, environment and social performance measures.

Governments can take steps along the road to CE for the mining sector, engaging with other actors as appropriate to:

- Establish a dedicated Secretariat and a multi-stakeholder technical committee to advance the Mining Value from Waste (MVFW) initiative¹² to address identified institutional and knowledge gaps, regulatory and financial barriers and areas for investment.
- Capitalize on synergies between CE and CSM strategies by actively integrating the policies to:
 - a. Support technological innovations and associated CE value network partnerships needed to extract and refine CSM;
 - b. De-risk investments in new projects to attract a broader array of financiers to non-conventional mineral projects;

¹² Siwik Consulting. (2020). *Implementation Strategy for Mining Value from Waste Initiative*. Prepared for CMMP, NRCan (not publicly released).

- c. Review, identify and reform mining regulations to address barriers to operationalizing non-conventional primary and waste extraction projects (where they exist); and,
- d. Examine strategies to support integration and economic feasibility of primary and secondary source processing capacity and infrastructure to optimize potential for producing blended CSM products for market.

Enabling Emerging ESG/CE Markets

To support industry's transition to a CE model, governments could:¹³

- Provide incentives to level the playing field for CE practices by accounting for environmental externalities and supporting the creation of new value chains.
- Promote private and public sector partnerships that promote knowledge sharing, experimentation, and skills-building to create effective CE policies.
- Align and integrate CE policies with mainstream policies to promote mutual learning and complementary objectives and goals.
- Work with industry to set traceable actions and targets to guide and generate tangible results and hold stakeholders accountable for their progress.

Integrated Knowledge and Data Platforms, and Technology Supporting CE Opportunities

The mining sector is shifting towards digitization for improved data analysis and decision-making. Operational sites are optimizing information collection efficiencies and performance, spanning the “pit to product” value chain. Organizations are investigating the use of digital twins¹⁴ to assess and optimize design of future processing systems. These advances can help identify opportunities for reducing inefficiencies, optimizing re-circulation of resources, and for decreasing waste generation overall.

Other useful information worth tracking and reporting on include the types of technologies available (commercialized and proven at pilot scale) to support CE processes, their capabilities and relevant applications, supporting research and technology development in progress, and any organizations interested and/or participating in CE strategies. Mapping the ecosystem of stakeholders in CE, with an ability to sort by region, commodity, and by service offering, would help support companies willing to explore CE to find solutions to meet their needs, and identify gaps in the ecosystem.

Embracing a Pragmatic, Collaborative, Systems Approach

Finally, while the report covers a wide range of concepts and issues that outline what CE can mean for mining operations, the path to CE can be launched with a few core principles and goals in mind.

- Break out of silo thinking on problem solving to explore and embrace a full systems approach to challenges (regarding carbon/water/tailings/wastes/social license). This is key to unlocking new value generation.
- Catalyze new forms of collaboration among interested parties in the mineral supply ecosystem. These new relationships apply to both the industrial use of products and services for extraction,

¹³ World Business Council for Sustainable Development (WBCSD). (2019). [Policy enablers to accelerate the circular economy](#).

¹⁴ Digital twins are virtualized representations of physical things, which are used to simulate and experiment with conditions and behaviours to enable design and process innovation in everything from machinery design to building and industrial systems.

and the opportunity to feed new responsibly sourced materials into systems that are managing growth in demand.

- Create new value networks in the mining and minerals sector by:
 - a. Finding new markets for waste products;
 - b. Identifying suppliers of products and services who can help monetize social and environmental objectives; or,
 - c. Seeking innovators who can re-design extraction and processing systems for critical minerals.
- Focus on using these tools and approaches to realize reductions in risks and impacts. A fulsome suite of public policies and incentives will take time to design and deploy, but in the meantime, companies can re-examine conventional practices that generate waste and miss potential value, both on the mine site and with their upstream and downstream stakeholders.

Key Messages

How is CE mining different from or related to green or climate smart mining (and related “responsible” or “sustainable” mining initiatives)?

CE complements and builds on “responsible mining” programs by bringing disparate initiatives under an integrated strategy. By solving for mine waste, water risks, energy use and carbon emissions, disturbed and impacted lands, and social impact concerns through a systems-based integrated strategy, CE contributes to responsible mining.

Further, it seeks to add value by (a) looking for synergies and efficiencies between different green mining reforms, and (b) focusing on capturing greater value in the marketplace, including for communities and ecosystems. The World Bank refers to this integrated approach as a “Climate Smart Mining” framework.

How can the adoption of CE strategies and practices affect cost-effectiveness and global competitiveness?

CE strategies aim to increase cost-effectiveness by revenue generation. They are rooted in the goal of maximizing economic returns by: reducing consumption, reducing waste, increasing efficiency, and expanding valuable relationships throughout all stages of the mineral life cycle. They also help to retain market share in areas where increased scrutiny of carbon footprints, waste reduction and ESG issues need to be managed in a more systematic and integrated way.

Additionally, sensitivity to supply chains of CSM currently rooted in China, for example, present an opportunity and imperative for other regions to use CE strategies to differentiate and consolidate market relationships.

CE adopts a systems approach to analyze where potential value is being lost, and where avoidable liabilities are accumulating. (e.g., consider the “un-extracted” value from mine waste, where extraction processes could be better designed, environmental risks avoided, and by-products or used assets be re-used by others.)

This report outlines the growing interest of investors and downstream mineral buyers in ensuring that mined materials do not contribute to environmental and social harm. The ability to access these markets will be predicated on a demonstrated ability to solve for a range of concerns, including carbon emissions, mine waste and human rights. A solid CE strategy provides a coherent means to plan for and execute these kinds of programs in a coordinated and efficient manner.

Is a CE mine possible in and of itself or does it require the establishment of extensive CE-oriented “support” systems throughout the Canadian and global economies?

CE strategies imply and encourage engagement with supply network partners upstream, downstream, and adjacent to the actual mine operations, to reduce waste and increase opportunities to generate greater value from materials and assets.

Application of CE strategies and practices can vary in scale and scope, depending on the technical characteristics and location of mining operations. Opportunities to engage with suppliers to the site and potential partners (e.g., for waste products) will differ significantly between remote operations and those in a region with multiple mines and associated infrastructure, industrial services, manufacturing and commercial centres, and potential community/municipal partners. Nevertheless, CE system design principles identified in this report can yield benefits in a variety of circumstances. In the absence of

supporting systems (market or regulatory), companies can still seek opportunities to apply CE strategies internally and within their own supply networks and build from there.

What role do markets play vis-à-vis the supply and demand for primary versus secondary materials?

Demand for minerals to meet renewable energy generation, transmission and storage needs will drive increases in primary and secondary minerals production over the next 2-3 decades at least. In addition, green energy-oriented demand for strategic materials and global mineral demands are being driven by population growth, urbanization and increased levels of consumption in expanding economies.

While there is a substantial opportunity and imperative to expand recycled minerals production from “urban mines” and responsible producer “take-back” programs, this increase in secondary minerals will not offset growth in demand for primary minerals. As has occurred in the forestry sector, blending primary and recycled materials increasingly will be expected. In fact, recycled and primary mineral resources are already blended in smelters and foundries in Canada and around the world. Recovered metals will be essential to EV battery production demands over the next decade.

Demand for commodities of any type is guided by material specifications. Historically, the use of secondary feedstock was constrained by industrial specifications that favoured primary or virgin inputs (e.g., in road construction). Progressive markets accept recycled materials with the understanding that: (a) it is good for the planet; and (b) product performance will not be undermined. In addition, the metallurgical expertise for removing impurities from all material inputs has greatly improved.

What are the impacts and risks of adopting (or not) CE practices in the Canadian mining sector?

With growing market and investment attention paid to how minerals are extracted and managed throughout their life cycles, companies who are engaged with zero waste, low carbon CE strategies will be well positioned to gain market share and maintain competitive positions. Whether associated with the supply of critical and strategic materials for the green energy transition, supplying materials to consumer-sensitive markets like electronics or automobiles, or creating new specialty materials to develop circular products, CE strategies are efficient and effective ways to manage complex customer demands.

Retaining conventional mining practices without innovating to keep pace with market demand and opportunities could result in Canada losing its competitive advantage in the mining industry. It is also about being prepared to participate in market disruptions that may influence future production and purchasing patterns. Canada has the potential to continue to lead in this rapidly evolving market environment if it embraces the application of CE principles across its industry. However, other nations, like Australia, Chile and even China, are already moving in this direction guaranteeing strong competition in this space over the coming decades.