Responsible Innovation in Green Mining

for a

Sustainable and Equitable Future

CIFAR IEP Memo

Background

The critical minerals and metals sector is essential to green energy transitions. Many green technologies, products and processes that are expected to replace carbon-intensive options rely on a mix of minerals and metals, with demand for certain resources expected to grow exponentially (IEA 2023). Yet the mining industry struggles to develop and diffuse the kinds of innovation, productivity improvements and practices necessary to achieve that growth in environmentally sustainable, socially responsible, and locally beneficial ways (Franks 2015; IEA 2021; OECD 2023a).

Natural resource industries, such as mining, are often perceived as dinosaurs that have had their day and are not part of future economies. In reality, many such industries are not in decline. In the case of mining, they will remain important to economic and social development, particularly in view of the green energy transition. They do, however, require long term planning, which has been both a desired objective of public policy and a major challenge.

Historically, the mining industry has lacked robust incentives, resources, and strategies for sustainable and responsible innovation. Among mining firms that have the potential to innovate, many face capital constraints (Beatty 2023; Dufour 2023), labor and skills shortages (Da-Ré 2023), technological challenges (Gosine & Warrian 2017) while also coping with exogenous shocks like the Covid-19 pandemic (Jowitt 2020). Furthermore, large multinational corporations with exclusive rights to operate in certain locales face limited competition, thus depriving the sector of a key spur to innovation (Expert Panel on Business Innovation 2009; OECD 2023b). Additionally, mining firms must navigate an increasingly complex array of regulatory processes and requirements that consume time and resources that could otherwise be allocated to innovation (Da-Ré 2023). Mining firms will also need to secure and maintain a social license to operate and innovation, particularly technological innovation, is sometimes seen as a threat to the types of benefits that have accrued to some mining communities and regions. Unless policies, practices and strategies are identified to help mining firms and other stakeholders overcome these barriers to innovation, the sector will be unable to generate the responsible growth needed to support green energy transitions.

At the same time, the sector has a less-than-ideal track record operating and pursuing innovation *responsibly* (Smith 2021). New and emerging technologies can improve the sector's environmental performance, but current practices are highly intrusive (LeCain 2009) and carbon-intensive (Anani et al, 2022; Dunbar 2016), while globally dispersed refining and processing supply chains only add to the industry's carbon footprint (Duzgun 2023). Similarly, meaningful consultation with local - and especially Indigenous - communities is necessary, yet many mining companies tend to avoid or are actively hostile to community concerns (Phadke 2018; Smith & Smith 2018; Dorobantu & Odziemkowska 2017).

Furthermore, while local communities have derived some benefits through taxation, royalties and licensing, robust and equitable benefits can be the exception rather than the rule. Communities near mining operations often experience stark income inequality; housing affordability challenges; limited job opportunities for local workers; negative health impacts through the deterioration of air, land and water quality, among other adverse effects (OECD 2023a). As the sector looks to accelerate growth to meet the needs of these low-carbon technologies, there is substantial risk that these and other negative effects will be exacerbated. It is important to consider the tradeoff between growth and equity in technology intensive sectors and how policy could be used to foster equitable growth.

Research Objective

The **objective for the research program** is to better understand the challenges of innovating in ways that increase equity, prosperity, and sustainability, and to identify policies, practices and strategies to achieve those goals. Specifically, the program will work to generate a ***framework for understanding the barriers to innovation and responsible innovation*** in established extractive industries generally – and the mining industry specifically. In addition, the program will develop an ***understanding of how the barriers can be addressed and will provide a framework with which to assess the impacts of innovation across a range of key stakeholders,*** to enable the industry to be a trusted, strong and responsible contributor to green transformation. In short, the research will investigate how to *spur innovation* and *steer responsible innovation* in the critical minerals and metals sector in ways that build the confidence and trust of the regions where companies operated.

Knowledge Gaps

The transition to low-carbon technologies will constitute a technological transformation, fundamentally changing the way energy is produced, transported and stored (Perez 2010). There is a substantial theoretical and empirical literature on the origins and trajectories of comparable technological revolutions (Kondratiev 1935; Schumpeter 1939; Perez 2010), as well as on the innovation-stimulating role of the state (Breznitz 2007, 2021; Block 2008; Mazzucato 2021), regional networks (Feldman et al. 2019; Saxenian 1996) and the imperatives of national security (Taylor 2016). Yet, little is known about how transformation emerges and evolves within *established* industries, such as the mining industry which faces weak competitive pressures, waning investor interest, ongoing deficits of labor and skills, and arguably a general disinterest and lack of capacity to change. The question of how to transform an *established* industry under multiple constraints adds complexity that current innovation theories are not presently able to answer.

Existing research and literature on the challenges and opportunities facing the mining industry in the age of the green energy transition are sparse. There are few answers to high-level questions such as:

- How can an established industry like mining overcome labor and skills shortages, capital constraints and investor apathy to achieve exponential growth in investment and production ?

- How can mechanisms and incentives for greater coordination between firms and relevant actors be generated to overcome widespread network failures and collective action problems ?

- How can technology development and diffusion to support innovation and growth be facilitated ?

- How can industry shift to practices that are both high-growth *and* responsible (e.g., environmental sustainability, social responsibility and local benefits) ?

- How can the costs and benefits of innovations across minerals projects be simulated in a manner that can be understood by a diverse range of stakeholders ?
- How can confidence and a strong sense of social licence for innovations related to mineral projects be secured ? and

- How can growth through "friend-shoring" be supported, thereby limiting the current reliance on mineral and metal imports from Russia and China (Condon 2022; Humphries 2019).

The impact of innovation, particularly technological innovation, on minerals projects raises important questions that need to be considered by the research team in collaboration with industry stakeholders, policymakers, community leaders and researchers. These more specific questions include:

Innovation and Research:

- What ongoing research and development efforts are being made to support technological innovation in the mining industry ?

- How can collaboration among industry, government, research institutions, communities and technology providers drive innovation ?

- How can collaborative approaches blend Indigenous knowledge with modern technology leading to more sustainable and culturally sensitive innovations in mining industries?

Community Engagement and Acceptance:

- How are mining industries engaging with local communities to address concerns and develop support for technological innovation ?

- What strategies exist to ensure that the benefits of technological innovations are shared with local communities?

- What are the opportunities and challenges arising from technological innovation for mining industries for Indigenous people, communities and businesses/organizations ?

- What is the impact of mining industries and technological innovations impact on traditional practices, and the cultural fabric of indigenous communities?

Costs and Return to Stakeholders:

- What are the upfront costs associated with implementing technological innovations, and how do they compare to long-term operational savings?
- What is the expected return on investment for investing in technological innovation ?
- Does technological innovation in mining industries support economic diversification and resilience for Indigenous communities?
- What are the externalities associated with technological innovations in mining industries ?

Employment and Workforce:

- How will innovations in mining industries impact employment levels?
- What measures are being taken to address potential job displacement, and how can workers be reskilled for new roles?
- Are there strategies to ensure a fair and just transition for affected communities?
- How does access to education and resources impact on how Indigenous community members participate in and benefit from technological innovation ?

Ethical Considerations:

- What are the ethical considerations associated with technological innovations for mining industries, particularly in relation to decision-making and accountability?
- How can responsible and ethical practices be promoted throughout the supply chain and through the value chain for mining industries ?

Environmental Considerations:

- How can technological innovation contribute to minimizing the environmental impact of mining industries ?
- What innovations exist to address concerns related to land reclamation and ecosystem restoration following the abandonment of mining projects?
- For technological innovations related to environmental observation, how can Indigenous communities benefit in terms of early detection of environmental risks, improved mitigation

approaches, enhanced environmental stewardship and improved relationships between Indigenous communities and extractive industries.

- Does technological innovation related to environmental impact assessments process involve collaboration with indigenous communities and incorporate traditional ecological knowledge to comprehensively understand the potential risks from mining industries.

Regulatory and Policy Frameworks:

- Are there clear regulatory frameworks in place to effectively govern the introduction and use of technological innovations in mining industries ?
- How can regulatory bodies adapt to technological innovation and ensure its responsible and ethical use?
- How do regulatory systems provide clear legal frameworks that protect the land rights, cultural heritage, and environmental interests of indigenous communities as a result of technological innovation ?

Technology Integration:

- What challenges are faced in integrating technological innovation into existing mining industry operations and infrastructure?
- How can mining industries balance the need for innovations with the limitations of certain geological or physical conditions?

Data Security and Cybersecurity:

- What safeguards are in place to protect emerging technological innovations from cyber threats ?
- How is sensitive data, such as geological information and operational data, being secured against unauthorized access ?
- How is Indigenous and traditional knowledge protected ?

Answering these questions will help with the integration of technological innovations into operations in a manner that is technologically sound as well, as socially responsible and sustainable.

While many of these questions are unanswered in the research literature, there are ongoing *practices* in many regions that could be studied to improve understanding and to develop advantageous policies,

practices and strategies. Our research program will study such practices as part of our broader effort to contribute to the literature and to develop those much-needed policies and strategies.

Methodology

To address the knowledge gap questions and to generate policy and strategy ideas to spur rapid and responsible growth in the mining industry, a suite of interdisciplinary, collaborative projects organized around **six key themes** is proposed:

1. ***Sector Capacity and Coordination***: To identify and clarify constraints on innovation and growth in the sector (including capital constraints, network failures, and collective action problems), so as to identify and develop solutions.

2. ***Technology***. To understand the opportunities and challenges to developing and diffusing automation, digital and other technologies across the sector to support innovation, productivity and growth.

3. ***Local Communities***: To understand local impacts and perspectives, and developing strategies to generate greater inclusion and benefits, while also reducing the negative impacts of mining processes on local communities.

4. ***Labor, Skills and Good Jobs***: To understand the evolving labor and skills needs for the sector's innovation and rapid growth, and to identify strategies for meeting those needs while improving job quality across the sector and supply chain.

5. ***Greening the Sector Supply Chain***: To understand the opportunities and challenges to reducing the carbon footprint of globally fragmented and dispersed mining sector supply chain activities.

6. ***Simulation of Mining Projects***: To provide a tool that a variety of public and private sector stakeholders can use to model the choice of specific technology innovations in specific areas to illustrate the distribution-related outcomes from those choices. The model will assess the costs and benefits of specific innovations in terms of metrics that are important to the mining companies (profits, project net present value, rate of return) and to the communities (taxes, royalties, supply and service sector development, employment and other externalities).

Within each theme, subsets of the research team will design and execute projects with a view of generating insights that help answer the core research questions. Different **methodological approaches** will be used for each project, suited to what is being investigated. Projects will involve:

- ***Case studies***. Cases from a number of jurisdictions will be selected for their potential to illuminate the challenges and opportunities facing mining companies and communities, highlighting innovations that contribute to growth, and embody strategies for ensuring activities are conducted in environmentally sustainable, locally beneficial and socially responsible ways.

- ***Data collection, analysis and simulation***. Some projects will involve the collection and analysis of existing or original data and use of such date in simulation models to illuminate sector capacity issues; efforts to measure efforts to reduce the carbon intensity of supply chains; labor

and skills market trends; technology adoption, use, and impact; and trends in benefits and impacts on local communities.

- ***Comparable sector scan and analysis.*** Other projects may involve examining the experiences of comparable extractive industries that have faced or currently face similar challenges in order to identify policies, practices and strategies (McKnight, 2021) that could be adapted to the critical minerals and metals sector.

Research Outputs and Knowledge Transfer

The research program will generate a variety of outputs, relevant to the academic research community, governments and policy-makers, the critical minerals and metals sector, and local communities. These include:

- **Academic outputs**. The team will produce and publish ***research articles*** in high-quality, peer-reviewed journals; present findings at academic conferences; and aim for at least one book published by team members after project completion. The program will also help ***develop new researchers*** by employing graduate and postdoctoral researchers in projects.

- **Policy outputs**. The team will present insights and options to governments and policy-makers by publishing ***policy papers*** and ***commentaries*** (with relevant think tanks and media outlets) based on the research, and providing ***briefings to key decision-makers*** when and where relevant.

- **Industry outputs**. As the ultimate aim of the program is to spur responsible innovation and growth in the critical minerals and metals sector, the team will share insights with industry audiences, including ***presenting at sector-relevant conferences***, publishing ***short pieces in industry publications***, and providing ***briefings to key industry decision-makers*** when possible.

- **Community outputs**. The biggest "output" for local communities is an opportunity to be included in the research itself and to utilize the research outputs, including the simulation tool, to develop insights into the issues that are the focus of the research. As the team works on local issues, we will ensure robust ***opportunities for local community residents and stakeholders to share their perspectives***, and ensure that these ***perspectives are included in research and dissemination activities***.

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