

National Collaboration Strategy for the Mining Industry

Driving Innovation in the Canadian Mining Industry



Energy and Mines Ministers' Conference

St. Andrews by-the-Sea, New Brunswick

August 2017

National Collaboration Strategy for the Mining Industry

Driving Innovation in the Canadian Mining Industry

Energy and Mines Ministers' Conference

St. Andrews by-the-Sea, New Brunswick

August 2017



KPMG LLP developed this report in conjunction with the Government of Canada's Department of Natural Resources (NRCan) and the Green Mining Initiative Intergovernmental Working Group (GMI-IGWG) for the 2017 Energy and Mines Ministers' Conference (EMMC).

The information and opinions contained in this report reflect feedback received from stakeholder discussions and are to be used for the purposes of addressing the collaboration strategy. The statements contained herein do not necessarily reflect the opinions of KPMG nor those of the Government of Canada. KPMG has not sought to independently verify those sources unless otherwise noted within the report. Although KPMG endeavours to provide accurate and timely information, there is no guarantee that such information is accurate as of the date it is received or that it will continue to be accurate in the future.

KPMG LLP is a Canadian limited liability partnership and a member firm of the network of independent firms affiliated with the KPMG International Cooperative ("KPMG International"), a Swiss entity. All rights reserved.

The KPMG name and logo are registered trademarks of KPMG International.



Aussi disponible en français sous le titre : Stratégie de collaboration nationale pour l'industrie minière - stimuler l'innovation dans l'industrie minière canadienne

Cat no. M4-158/2017E-PDF (Online)
ISBN 978-0-660-09056-6

Table of Contents

Section I. Executive Summary	1
Section II. Introduction	3
Section III. Barriers to Collaboration	4
Case Studies and Lessons Learned	5
Section IV. National Collaboration Strategy	9
Section V. Recommendations to Achieve the Strategy	11
Section VI. Conclusion	13
Appendix	
A. Stakeholder Input From the Consultations and GMIAC/GMI-IGWG Workshop	14
B. List of GMI-IGWG Members	16
C. List of GMIAC Members	17
D. Reference Sources	18

Section I. Executive Summary

KPMG LLP (KPMG) developed this report in conjunction with Natural Resources Canada (NRCan), the Green Mining Initiative Intergovernmental Working Group (GMI-IGWG), and the Green Mining Initiative Advisory Committee (GMIAC) for the 2017 Energy and Mines Ministers' Conference (EMMC).

The objective of this report is to review the current mining ecosystem in Canada and provide a strategy to improve collaboration between various sector stakeholders for the purposes of supporting mining innovation and the adoption of green mining technologies by Canada's mining industry.

Approach

In preparing this report, KPMG performed a review of current literature and engaged mining ecosystem stakeholders from across Canada to gather their input on the current state of collaboration in the mining sector in order to identify barriers, define the National Collaboration Strategy, and outline actions for implementation.



Barriers to Collaboration

One of the primary goals of the collaboration strategy, set by the GMIAC and GMI-IGWG, is to achieve an innovation culture through engagement, collaboration and the removal of barriers to collaboration. Our research identified eight barriers for the mining sector that the collaboration strategy will aim to address.

Organization and communication between sector stakeholders	Optimization of resources	Building an innovation culture
<ul style="list-style-type: none">Awareness of Current R&D EndeavoursOpenness to Sharing and Intellectual Property ConsiderationsPublic Perception and Supply of Talent	<ul style="list-style-type: none">Private and Public Sector Funding and Resource AccessibilityMarket Cycles and the Mining Sector	<ul style="list-style-type: none">Regulatory EnvironmentPartnership ChallengesIndustry Culture of Risk Aversion

National Collaboration Strategy

In order to address the barriers identified above, the National Collaboration Strategy has been developed based on three strategic objectives to help drive collaboration and innovation in the mining ecosystem:

Support the strategic objectives set by NRCan, GMI-IGWG, and GMIAC in order to realize the innovation imperative through increased collaboration across the sector

by setting a direction that aligns with the priorities of the Canadian mining ecosystem, creating a culture of resource sharing and open communication, and coordinating resource and funding efforts to support shared priorities and collaborative opportunities.

1

Support a culture of communication and collaboration

Create a single platform that communicates the direction for the sector and coordinates the activities taking place among stakeholders. A unified platform will also minimize duplication of efforts by creating awareness of existing efforts, encouraging trust through increased collaboration opportunities, and driving transparent, open communication. Additionally, greater communication between sector participants will increase the potential for collaboration and increase the supply of high quality people for collaborative initiatives.

2

Share resources and leverage existing strengths, tools and organizations

Leverage existing public innovation funding opportunities, tools, and expertise to support efficient sharing of resources by ecosystem stakeholders for the purposes of increasing collaborations (e.g. collaborative consortiums of innovators) and highlighting areas of value relevant to the mining sector. This will help to ensure opportunities, time, and resources are committed toward green mining priorities.

3

Build a culture of innovation

Minimize the risk for first movers in order to accelerate the adoption of green mining technologies. Innovation projects must develop a long-term focus that looks beyond market declines, while targeting quick gains for early adopters and incorporating lessons learned from failed endeavours.

Actions for Implementation

Finally, in order to begin to realize the National Collaboration Strategy, certain actions should be undertaken in the short, medium, and long term.

SHORT TERM

- Enhance the existing Assistant to Mining Innovation (AMI) portal to map existing capabilities and expertise in the sector
- Leverage existing working groups from government, industry, and supporting stakeholders

MEDIUM TERM

- Release publications about trends, challenges, innovations and collaborations in the sector
- Assess public and private funding and resource sources to seek alignment with initiatives that support collaborative opportunities

LONG TERM

- Consolidate existing technology road maps that highlight collaborative opportunities
- Communicate leading practices regarding working within the regulatory environment
- Address challenges with the sector's public perception

Section II. Introduction

The Canadian government and NRCan, through the formation of the GMIAC and GMI-IGWG, have supported the pan-Canadian mining sector through initiatives to improve the sector's environmental performance and to create green technology opportunities for Canadian mining businesses. Insights gained through engagements and consultations with mining sector participants and other affected stakeholders indicate a sentiment that the Canadian mining sector is becoming less competitive in the global market, requiring measures to be taken to both mitigate the sector's global standings and encourage the sustainability of the sector.

It has been identified through this research that the Canadian mining sector is facing an "innovation imperative" and requires stakeholders from all areas of the mining ecosystem to collaborate to drive innovative solutions to solve the sector's challenges. In order to accomplish this, NRCan, GMIAC, and GMI-IGWG have engaged in a workshop and studies to develop a **National Collaboration Strategy** for the mining sector, with the objective of accelerating innovation across the Canadian mining ecosystem, encouraging the adoption of green mining technologies, and reinforcing Canada's position as a global leader in the sector.

The collaboration strategy presented in this report will address three strategic objectives to mitigate the innovation imperative:

- **Improve Organization and Communication:** Develop and communicate a coordinated, clearly defined ecosystem map that can *communicate innovation priorities*;
- **Optimize Resources:** *Leverage strengths* and *share resources* to accelerate the adoption of innovation through a streamlined, collaborative and coordinated process; and
- **Build a Culture of Innovation:** Achieve an *innovation culture* through engagement, sharing of risk and removal of barriers.

Stakeholder Groups

For purposes of this report, we have defined the **Canadian mining ecosystem** as being comprised of stakeholders from three primary groups:

- **Government**, including federal departments and provincial/territorial (PT) ministries, responsible for identifying public priorities, coordinating objectives across the sector, and supporting collaboration
- **Industry**, including mining companies and industry associations, responsible for establishing industry priorities, communicating needs and objectives to other ecosystem stakeholders, supporting and adopting new innovations, and championing the sector
- **Supporting Stakeholders**, including academia, researchers, not-for-profit organizations, special interest groups, suppliers and service providers, and other groups or individuals with a vested interest in the mining industry, responsible for delivering the necessary research and innovation to address sector priorities, and playing an important catalytic role in the innovation continuum

While these groups each have their own priorities, they are all tied to the success of the sector. It is this mutual benefit that highlights the importance of collaboration, bringing together stakeholders from across the ecosystem to leverage expertise and share ideas to create value for all parties involved.

This report builds upon an understanding of the barriers that impede collaboration (Section III), develops a clear and understandable **National Collaboration Strategy** to address these barriers and challenges (Section IV), and presents a recommended action plan (Section V) to achieve a strategy that reflects the roles and responsibilities of all stakeholders within the mining innovation ecosystem.

Section III. Barriers to Collaboration

One of the primary goals of the collaboration strategy, as originally identified by the GMIAC and GMI-IGWG during their November 2016 workshop, is to achieve innovation through engagement and collaboration, and to remove barriers to the open exchange of ideas. In order to understand the barriers to collaboration in the current ecosystem, KPMG conducted a series of stakeholder interviews (Appendix A), as well as a review of recent sector publications (Appendix D) and case studies. This research identified eight barriers for the sector that must be addressed by the collaboration strategy going forward.

Barriers impacting organization and communication between sector stakeholders

Awareness of Current R&D Endeavours

- There is a general lack of awareness across government, industry and supporting stakeholder groups of the breadth of research and development (R&D) programs underway at any given time. This results in research activity silos and possible duplication of efforts that could be reduced through open collaboration.

Openness to Sharing and Intellectual Property Considerations

- Given the competitive nature of the mining sector, there is a lack of transparency and a closed culture of sharing information, including valuable intellectual property (IP), between industry and the supporting stakeholder groups. This results in a preference to develop ideas in-house or with a small group of partners, rather than sharing information and cross-pollinating ideas across the broader mining ecosystem.

Public Perception and Supply of Talent

- Shortfalls in the supply of trained professionals available to participate in collaboration initiatives have been attributed to challenges with public perception and awareness of the mining sector. This has been particularly relevant in recent years as academic programs are turning away from the sector, thus reducing the number of mining-focused professionals available to collaborate, innovate, and help set the direction for the sector.

Barriers inhibiting the optimization of resources

Private and Public Sector Funding and Resource Accessibility

- Limited accessibility of funding and resources often places pressure on individual organizations to adopt a self-interest, rather than collaborative and sharing, approach when selecting R&D initiatives to undertake. This limits the scope for collaboration as it results in misaligned priorities between groups. While this approach may address specific financial and resource issues of individual stakeholders, it is not effective for the sector as it fails to leverage the collective resources and expertise and may result in duplication of efforts.

Market Cycles and the Mining Sector

- The mining sector is inherently tied to global commodity prices, resulting in long-term cycles of economic increases and decreases. While these trends are understood by the sector, they limit the appetite of industry to enter into long-term R&D commitments where the end product may not be certain or financially viable given volatile market conditions.

Barriers that limit building a culture of innovation

Regulatory Environment

- The current regulatory environment set by federal and PT government policies, which seek to support green mining practices, is not necessarily designed to support collaboration and may impose a barrier to partnerships and the emerging technologies. These issues disincentivize collaboration and innovation, resulting in a lack of alignment between the high-level outcomes-based objectives and the processes in place to implement them.

Partnership Challenges

- Current agreements for partnerships and related funding opportunities slow collaborative initiatives by requiring complex formalization of partnerships in order to receive research funding. These processes are often overly burdensome and have been identified as reasons for the dissolution of some partnerships.

Industry Culture of Risk Aversion

- Industry is generally risk-averse when adopting new and unproven technologies and processes, as there can be uncertainty around regulatory approval and their reliability. As a result, industry is less collaborative with other stakeholders in the ecosystem, requiring supporting stakeholders to bear the majority of the risk.

Case Studies and Lessons Learned

The following five case studies have been presented to provide examples of actual collaborative initiatives that were undertaken by the sector and to highlight key lessons learned in light of the above-mentioned barriers to collaboration that the industry faces.

CanmetMINING Energy Efficiency and Water Management Pilot Projects

CanmetMINING piloted a new and innovative business model where industry collectively identified priority areas that are critical for their operations and for the government (i.e. CanmetMINING) to provide the resources to deliver on those priorities in close collaboration with industry stakeholders. It was also proposed that any intellectual property generated from the R&D work would be shared between the government and the companies involved in the pilot study. In a 2014 workshop held for mining stakeholders, energy efficiency and water management were the two identified priority areas for the pilot projects.

Energy efficiency project: Results led to the evaluation of different technologies to replace the standard ball mill technologies with a more energy-efficient technology.

Water management project: The pilot project led to a larger scale project that is currently subject for funding by Sustainable Development and Technology Canada.

LESSONS LEARNED

Collaboration: Goal alignment between government and industry was crucial to advancements in the identified priority areas.

Leveraging resources: Sharing ideas, human capital, equipment and processes accelerated the development of green technologies, leading to faster results and a greater overall impact.

Discover Abitibi Initiative (DAI)

The DAI, a mineral exploration initiative in northeastern Ontario, received an initial investment of \$14M from industry as well as from federal and provincial/territorial governments.

Over the course of 10 years, the DAI leveraged the initial \$14M and spurred over \$38M of activity by providing relevant data and insights to stakeholders through surveys and exploration. Additionally, the DAI completed 29 exploration-related projects that brought together members from various areas of the mining ecosystem.

LESSONS LEARNED

Regular Communication: Ongoing discussions with members ensured that each successive phase of the initiative became more refined in terms of R&D focuses, data collection and investment decisions.

Available and Measured Funding: The DAI built successful partnerships between government funding agencies, industry and research. In addition, numerous volunteers helped evaluate proposals for technical soundness and coordinated efforts relating to project completion.

International Mining for Development Centre (IM4DC)

Completed in June 2015, the IM4DC was a \$31M investment forming part of the Australian government's \$127M commitment in the Mining for Development Initiative. From 2011 to 2015, the program delivered 105 courses and workshops across the world, 90 research and institutional capacity building projects and supported 27 fellowships.

Overall, the program surpassed established goals set by the Australian government and encouraged greater collaboration across the industry. The program facilitated collaborations and provided support to over 2,726 participants from 789 institutions across 65 countries.

LESSONS LEARNED

Comprehensive Platform of Information Sharing: Collaboration spanned across industries and countries on a range of topics of interest to the mining sector. This provided an extensive network for communication and idea sharing for stakeholders.

Regular Communication and Interim Reviews: The IM4DC program framework was continuously reviewed and refined over the life of the centre, helping to create a responsive stakeholder collaboration network.

National (Canadian) Diamond Strategy

In 2003, provincial and territorial premiers expressed the need for a National Diamond Strategy to assess the opportunities and constraints to growth in the Canadian diamond industry. Guiding the initiative were four principles:

- (1) Maximizing benefits to Canadians
- (2) Developing cooperation between all stakeholders
- (3) Encouraging participation in the industry
- (4) Encouraging investment in all sectors of the industry

The strategy was identified by stakeholders to be unsuccessful in meeting its objectives and facilitating a collaborative environment due to several key failings.

LESSONS LEARNED

Stakeholder Representation: The Multi-Stakeholder Coordination Board (MSCB) adopted an open membership framework that was unsuccessful in attracting the required representation to form an effective and focused MSCB.

Clearly Communicated and Coordinated Objectives: The strategy lacked an effective mechanism to communicate the national objective and coordinate the activities of its members.

Incentivized: Jurisdictions had little reason to align their priorities with the national level priorities, and maintained a vested interest in advancing their own agendas.

Mining 3 (M3)

Mining3 is an industry-focused Australian-based research organization, formerly Cooperative Research Centre (CRC) Mining, which recently transitioned to an entirely industry-funded partnership in 2016–2017. The organization is directed by its global mining industry members to develop and deliver transformational technology to improve productivity, sustainability and safety.

Mining3 comprises all CRC Mining's activities and Commonwealth Scientific and Industrial Research Organization's (CSIRO) hard rock mining research capability. The partnership brings together significant mining research capabilities to effectively deliver research and innovative technologies for the members and the global mining industry.

The organization's mission involves developing industry solutions, which provide both incremental and step-change productivity increases for the major global mining challenges. Mechanisms and guiding principles include:

- A research vision based on the needs of the mining industry in a 10–20+ year time frame
- Research road maps focused to deliver industry technology needs in an 8+ year time frame
- A technology transfer plan to identify and deliver valuable industry outcomes from each 8-year research road map
- Ongoing incremental outcomes delivered at project milestones

In order to achieve innovative outcomes, Mining3 partners with members from industry, universities, and supply and service providers to develop industry solutions.

LESSONS LEARNED

Focused Research: The research program activities are coordinated to solve overarching mining challenges. Mining3 will partner with non-members on a specific research or commercialization project as necessary to resolve a specific need. This is an example of how the mining sector has come together in Australia to build the critical mass of commitments to achieve innovative results.

Mechanisms and Incentives: Members sign for an 8-year term, where they have control of the direction of the research vision and research road map, which is revised every two years. Members also receive benefits through being in the network, such as particular Mining3 IP and leveraged R&D investment.

Selective Leadership: Mining3 selects board members, executive team members and specialists to form a diverse set of relevant backgrounds. This design provides various stakeholder groups with a voice and provides relevant expertise to support members. Representation includes universities, investors, former mining company and OEM executives, and professional services (e.g. lawyers).

Section IV. National Collaboration Strategy

The proposed collaboration strategy is intended to support the collaboration principles set by NRCan, GMI-IGWG and GMIAC during the November 2016 workshop in order to address the innovation imperative through increased collaboration across the mining sector in Canada, as follows:

- Align priorities and direction for the Canadian mining ecosystem driven by common needs;
- Coordinate efforts and resources to more efficiently and effectively support shared priorities; and
- Create a culture of sharing and openness amongst the various stakeholder groups.

Through an assessment of the barriers and lessons learned presented in Section III, and in consideration of these collaboration principles, the proposed collaboration strategy recommends the following strategic objectives as a strategy to improve collaboration.

1. Improve Organization and Communication: Develop and communicate a coordinated and clearly defined ecosystem map that can *communicate innovation priorities*.

- Awareness of Current R&D Endeavours
- Openness to Sharing and Intellectual Property Considerations
- Public Perception and Supply of Talent

The mining sector's strategy and direction requires central coordination, allowing for alignment of work and full capitalization on the strengths, experiences and capabilities of sector stakeholders.

2. Optimize Resources: *Leverage strengths* and *share resources* to accelerate the adoption of innovation through a streamlined, collaborative and coordinated process.

- Private and Public Sector Funding Accessibility
- Market Cycles and the Mining Sector

Open communication and sharing of information is required to effectively leverage the human and financial capital available in the sector to target long-term strategic goals and mitigate volatile market cycles.

3. Build a Culture of Innovation: Achieve an *innovation culture* through engagement, sharing of risk and removal of barriers.

- Regulatory Environment
- Partnership Challenges
- Industry Culture of Risk Aversion

Industry and supporting stakeholders must be encouraged rather than dissuaded by regulatory and cultural forces to become early adopters of new innovative green technology.

The recommended **National Collaboration Strategy** will focus on improving organization and communication across the Canadian mining ecosystem, optimizing resources available to support the Canadian mining ecosystem in the development of innovation, and building a culture of innovation that creates an environment that is receptive and collaborative to supporting new green mining innovations.

In continuation of the GMIAC and GMI-IGWG workshop report, the strategic framework laying out the goals, considerations, ways of working, and success factors has been adapted to align with the three strategic objectives for the National Collaboration Strategy and used to set the direction for recommendations and actions to achieve the strategy going forward.

Strategic Objectives	Goals	Considerations	Ways of Working	Measuring Success
Improve Organization and Communication	<ul style="list-style-type: none"> • Improve coordination activities • Accelerate the adoption of innovative technologies 	<ul style="list-style-type: none"> • Driven/informed by industry needs 	<ul style="list-style-type: none"> • Coordinating body/function • Senior level champions • Fora to facilitate dialogue 	<ul style="list-style-type: none"> • Industry buy in on innovative products/services • Increased awareness of ongoing innovative efforts pan-Canada
Optimize Resources	<ul style="list-style-type: none"> • Leverage strengths and share resources • Efficient use of funding 	<ul style="list-style-type: none"> • Commit time and resources • Recognize value and seek expertise 	<ul style="list-style-type: none"> • Mapping of expertise and capabilities • Technology road maps / tools / frameworks 	<ul style="list-style-type: none"> • Number of collaborative undertakings • Increased investment in innovation
Build a Culture of Innovation	<ul style="list-style-type: none"> • Collaborative and coordinated process • Identify unnecessary barriers 	<ul style="list-style-type: none"> • Demonstrate progress • Understand the regulatory and cultural environment 	<ul style="list-style-type: none"> • Private- and public-sector funding must have a common direction to achieve shared objectives. • Incentive mechanisms 	<ul style="list-style-type: none"> • Level of engagement/ collaboration • Technology progression and uptake

Section V. Recommendations to Achieve the Strategy

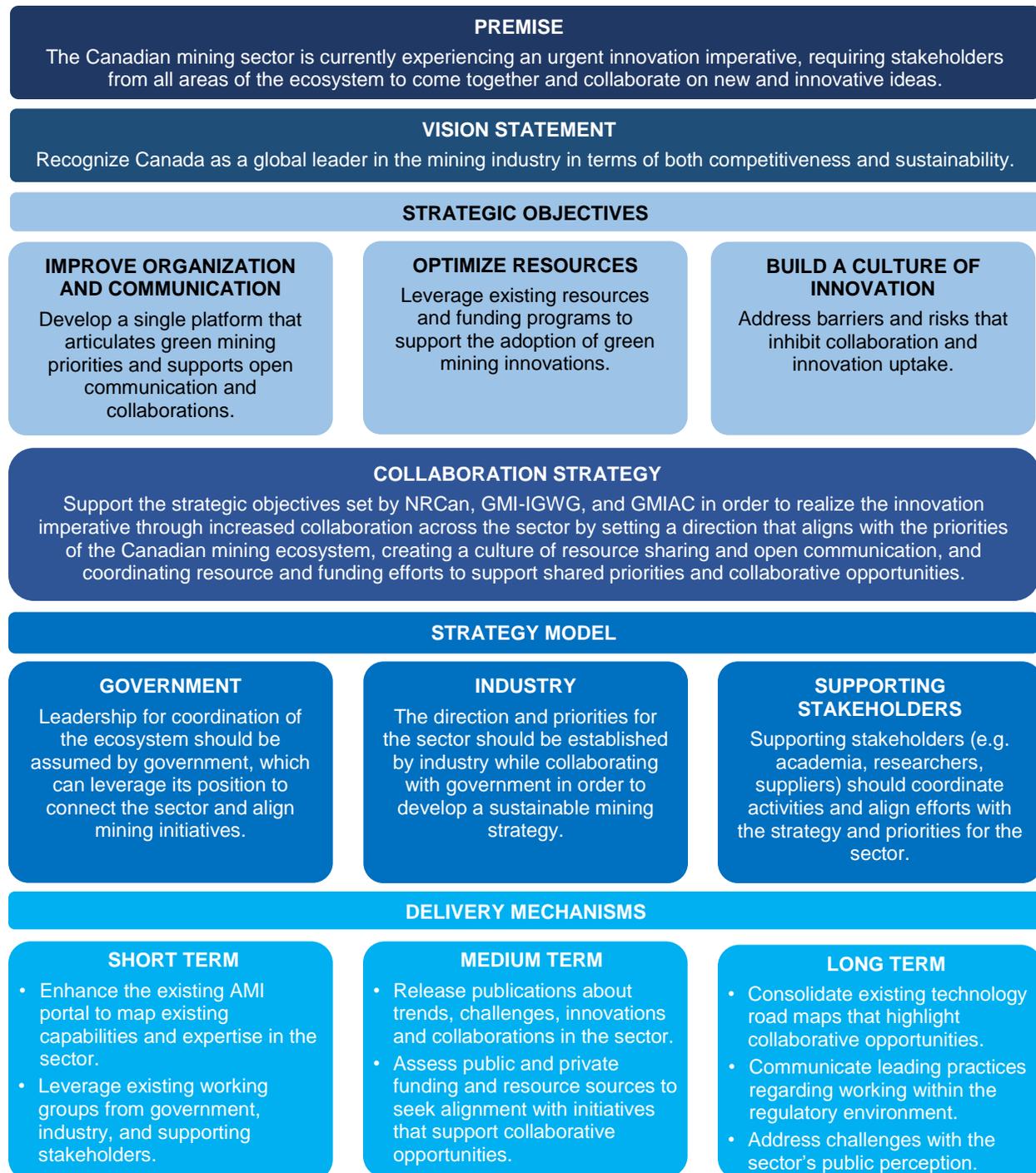
To support the goals and principles of the collaboration strategy outlined for the Canadian mining ecosystem, the following recommendation, actions, responsibilities and performance indicators will help guide decision making among the ecosystem stakeholder groups.

Recommendation	Actions	Responsibilities	Performance Indicators
1. Improve Organization and Communication: Support a culture of communication and collaboration			
<p>Create a single platform that communicates the direction for the sector and coordinates the activities taking place among stakeholders. A unified platform will also minimize duplication of efforts by creating awareness of existing efforts, encouraging trust through increased collaboration opportunities and driving transparent, open communication. Additionally, greater communication between sector participants will help to address the current supply shortfall of trained professionals available for collaboration initiatives.</p>	<ul style="list-style-type: none"> • Short term: Leverage the existing AMI portal to create an open communication platform that enables stakeholders to regularly update information. • Medium term: Release publications, aligned with initiatives regarding green mining, that create dialogue between all stakeholders about trends, challenges, innovations, and collaborations that are taking place in the sector. • Long term: Government and academia must work together to support existing mining-related programs (e.g. School of Mining and Petroleum Engineering) impacted by challenges with the sector's public perception. 	<ul style="list-style-type: none"> • AMI should be maintained at the federal level, specifically by NRCan, given the overarching role in facilitating communication and collaboration that will be undertaken by this level of government. Industry and supporting stakeholders must support the AMI portal through active sharing and updating of information. • NRCan to coordinate the dissemination of relevant information to be provided by industry and supporting stakeholders. • Industry and PT ministries to communicate needs and objectives to the broader ecosystem and promote collaborative tools. 	<ul style="list-style-type: none"> • Number of stakeholders, innovation activities and research projects included in the portal within year 1 and later assessed on an annual basis to identify changes year-by-year. • Number of daily, monthly and yearly unique visitors to the on-line portal, which indicates awareness of the portal among ecosystem stakeholders. • Number of stakeholders providing input toward publication content. • Increase in enrolment in mining-related programs and supply of professionals. • Alignment between industry communicated priorities and the activities being undertaken by supporting stakeholders.
2. Optimize Resources: Share resources and leverage existing strengths, platforms and organizations			
<p>Leverage existing public innovation funding opportunities, tools, and expertise to support efficient sharing of resources by ecosystem stakeholders for the purposes of increasing collaborations (e.g. collaborative consortiums of innovators) and highlighting areas of value relevant to the mining sector. This will help to ensure opportunities, time and resources, such as</p>	<ul style="list-style-type: none"> • Short term: Map the capabilities and expertise that exist in the mining sector as well as available funding, using the AMI portal to disseminate this information. • Medium term: Ensure that government funding is aligned with initiatives to support collaborative opportunities to incentivize industry and 	<ul style="list-style-type: none"> • NRCan to coordinate the development of the mapping exercise, with input and support from industry and supporting stakeholders. The long-term technology road map can leverage the data available in the AMI portal. • GMI-IGWG and GMIAC, PT governments and funding organizations to identify 	<ul style="list-style-type: none"> • Changes in industry performance and global standing (e.g. contributed revenue, international mine rankings). • Total investment in innovation and the number of different investors. • Return on investment (ROI) for innovations.

<p>those available to Canadian mining superclusters (e.g. Sudbury), are committed toward green mining priorities.</p>	<p>supporting stakeholder involvement.</p> <ul style="list-style-type: none"> • Long term: Consolidate existing technology road maps that illustrate elements of ongoing collaborations (e.g. innovation timelines, resources, key industry groups). This can be an added feature in the existing AMI portal. 	<p>opportunities to align and coordinate funding and support, where possible.</p> <ul style="list-style-type: none"> • Industry to work with government to increase the level of industry support provided to sector-aligned activities. 	<ul style="list-style-type: none"> • Uptake of programs (e.g. NorCap) and tax incentives.
<p>3. Build a Culture of Innovation: Build a culture of innovation</p>			
<p>Minimize the risk for first movers in order to accelerate the adoption of green mining technologies. Innovation projects must develop a long-term focus that looks beyond fluctuations in the market while targeting quick gains for early adopters and incorporating lessons learned from failed endeavours.</p>	<ul style="list-style-type: none"> • Short term: Leverage existing working groups from all levels of government (e.g. GMI-IGWG and GMIAC), industry (e.g. MAC) and supporting stakeholders (e.g. CMIC), suppliers, regulators, and others to discuss regulations and cultural barriers that inhibit collaboration. • Medium: Government and regulators should work together to develop a “tool kit” of guiding maps, information sheets, and leading practices to aid the sector in working within the current regulatory framework and cultural barriers. • Long Term: Existing working groups (e.g. GMI-IGWG and GMIAC) should select and champion 2–3 “high technology readiness,” consortium-style projects in priority areas identified by industry and supporting stakeholders to reduce risk and identify leading practices for collaboration. 	<ul style="list-style-type: none"> • GMI-IGWG, GMIAC and other industry stakeholders to discuss barriers that limit collaboration. • PT ministries should work with the federal government and industry in establishing the regulatory tool kit and its supporting material. • NRCan, in conjunction with GMI-IGWG and GMIAC working groups, should identify potential pilot projects and oversee the potential development of the pilot projects in consultation with industry and supporting stakeholders. Identify leading practices and lessons learned based on these pilot projects. 	<ul style="list-style-type: none"> • Number of patents filed. • Number of approved innovation initiative grants. • Number of green mining technologies adopted. • Uptake in R&D, prototype development, and commercialization activities.

Section VI. Conclusion

Based on the findings of the stakeholder engagement process, literature review and the November 2016 GMIAC and GMI-IGWG workshop, the strategic model below details the necessary steps to drive collaboration and address the current innovation imperative. This model will allow NRCan, GMI-IGWG, GMIAC, and federal, provincial and territorial energy and mines ministers to communicate and drive forward the key goals, strategy, and actions required to accelerate the adoption of green mining technologies and processes across the Canadian mining ecosystem.



Appendix

A. Stakeholder Input From the Consultations and GMIAC/GMI-IGWG Workshop

Stakeholder Group	Organization
Academia, Research and Training	Cambrian College, Sudbury
	Canadian Mining Industry Research Organization (CAMIRO)
	Collège Boréal, Sudbury
	COREM
	Lakehead University
	Laurentian University (includes Laurentian Mining Innovation and Technology (LMIT)) / MIRARCO
	Northern Centre for Advanced Technology (NORCAT)
	Queen's University
	Research & Development Corporation of Newfoundland and Labrador
	Université Laval (Chaire de recherche et d'innovation Goldcorp en droit des ressources naturelles et de l'énergie)
	University of British Columbia (Norman B. Keevil Institute of Mining Engineering)
	University of Guelph
	University of New Brunswick (Economic Geology chair)
	University of Toronto
Government and Not-for-profit	Alberta Energy
	Canadian Mining Innovation Council (CMIC)
	CanmetMINING, Natural Resources Canada (NRCan)
	Centre for Excellence in Mining Innovation (CEMI)
	Department of Industry, Tourism and Investment (N.W.T.)
	Department of Natural Resources (N.L.)
	Energy and Resource Development (N.B.)
	Environment and Climate Change Canada (ECCC)
	Greater Sudbury Economic Development Council
	Hydro-Québec
	International Mineral Innovation Institute (IMII)
	Manitoba Mineral Resources
	Ministère de l'Énergie et des Ressources naturelles (Que.)
	National Research Council (NRC)

	New Brunswick Innovation Foundation
	Nova Scotia Department of Natural Resources
	Ontario Ministry of Northern Development and Mines (MNDM)
	Ontario Ministry of Research, Innovation and Science
	Sudbury Area Mining Supply and Service Association (SAMSSA)
	Sustainable Development Technology Canada (SDTC)
	Thunder Bay Economic Development
	Timmins Economic Development
Operators and Prospectors, Mining Industry Supply & Services, and Associations	Agnico Eagle
	Association de l'exploration minière du Québec
	Association minière du Québec
	Barrick Gold
	BESTECH
	Canadian Association of Mining Equipment and Services for Export (CAMESE)
	Canadian Institute of Mining, Metallurgy and Petroleum (CIM)
	Detour Gold Corporation
	Glencore
	Goldcorp
	Hudbay Minerals
	Kingston Process Metallurgy Inc. (KPM)
	Kirkland Lake Gold Ltd.
	McEwen Mining
	Mining Association of Canada (MAC)
	NORAM
	Noront Resources Ltd
	Ontario Mining Association (OMA)
	Prospectors & Developers Association of Canada (PDAC)
	Saskatchewan Mining Association
	Syncrude Canada Ltd.
	Teck Resources Ltd.
	Vale
	XPS Consulting and Testwork Services
	Yukon Mining Alliance

B. List of GMI-IGWG Members

Jurisdiction	Ministry or Department
Alberta	Alberta Energy
British Columbia	Ministry of Energy and Mines
Canada	Natural Resources Canada (NRCan) Environment and Climate Change Canada (ECCC)
Manitoba	Manitoba Growth, Enterprise and Trade
Newfoundland and Labrador	Department of Natural Resources
Nova Scotia	Department of Natural Resources
Nunavut	Department of Economic Development & Transportation
Ontario	Ministry of Northern Development and Mines (MNDM)
Québec	Ministère de l'Énergie et des Ressources naturelles
Yukon	Energy, Mines & Resources

C. List of GMIAC Members

Organization
Association Minière du Québec
Barrick Gold
Canadian Association of Mining Equipment and Services for Export (CAMESE)
Canadian Institute of Mining, Metallurgy and Petroleum (CIM)
Canadian Mining Innovation Council (CMIC)
CanmetMINING, Natural Resources Canada (NRCan)
Centre for Excellence in Mining Innovation (CEMI)
COREM
Glencore
Hudbay Minerals
Hydro-Québec
McEwen Mining
Mining Association of Canada (MAC)
MIRARCO
Mitacs
National Research Council (NRC)
Ontario Ministry of Northern Development and Mines (MNDM)
Sustainable Development Technology Canada (SDTC)
Teck Resources Limited
Université Laval
University of Guelph

D. Reference Sources

- Canadian Mining Innovation Council, 2008. *The Pan-Canadian Mining Research and Innovation Strategy*, s.l.: Natural Resources Canada.
- Canadian Mining Innovation Council, 2016. *Towards Zero Waste Mining*, s.l.: s.n.
- Cobden, C., n.d. *Study on State of Commercialization of Canadian Green Mining Technologies*, Ottawa: Cobden Strategies Inc..
- Daignault-Simard, X., 2013. *Accelerating the adoption of Green Mining Innovation*, s.l.: Natural Resources Canada.
- Energy and Mines Ministers' Conference, 2016. *State of Commercialization of Canadian Green Mining Technologies*, Winnipeg: Energy and Mines Ministers' Conference.
- Environment and Climate Change Canada, 2015. *Government programs for canadian manufacturers*. [On-line]
Available at <https://www.ic.gc.ca/eic/site/054.nsf/eng/00078.html>
[Accessed May 2017].
- Forer, B., 2016. *Barriers and Incentives to Clean Technology Adoption in the Mining Sector*, s.l.: Natural Resources Canada.
- Forer, B., n.d. *Clean Tech Adoption in the Mining Sector: Barriers and Incentives*, s.l.: Natural Resources Canada.
- Government of Ontario, 2015. *Seizing Global Opportunities: Ontario's Innovation Agenda*. [On-line]
Available at <https://www.ontario.ca/page/seizing-global-opportunities-ontarios-innovation-agenda>
[Accessed May 2017].
- Green Mining Initiative, 2013. *Addressing Regulatory Barriers to the Adoption of Green Mining Technologies in Canada*, s.l.: Green Mining Initiative Intergovernmental Working Group.
- Intergovernmental Working Group, 2016. *Mining Sector Performance Report: 2006-2015*, s.l.: s.n.
- International Minerals Innovation Institute, 2016. *Developing an Innovation Ecosystem for Saskatchewan's Minerals Industry*, Saskatchewan: IMII.
- Marshall, B., 2014. *Facts & Figures of the Canadian Mining Industry*, s.l.: Mining Association of Canada.
- Marshall, B., 2016. *Facts and Figures of the Canadian Mining Industry (F&F 2016)*, s.l.: Mining Association of Canada.
- Minerals Council of Australia, 2016. *Review of the R&D Tax Incentive*, s.l.: s.n.
- Mining Association of Canada, 2017. *MAC welcomes several Budget 2017 measures*. [On-line]
Available at <https://mining.ca/news-events/press-releases/mac-welcomes-several-budget-2017-measures>
[Accessed may 2017].

Ministry of Research and Innovation and Science, 2017. *Ontario Research Fund: Research Excellence*. [On-line]

Available at <https://www.ontario.ca/page/ontario-research-fund-research-excellence>

[Accessed May 2017].

MNP, 2011. *Regulatory Barrier Identification and Analysis – Green Mining*, Regina: MNP.

Natural Resources Canada, 2013. *Program of Energy Research and Development*. [On-line]

Available at <http://www.nrcan.gc.ca/energy/funding/current-funding-programs/perd/4993>

[Accessed May 2017].

Natural Resources Canada, 2016. *Clean Technology in Canada's Natural Resource Sectors: A Discussion Paper*, s.l.: Natural Resources Canada.

Natural Resources Canada, 2016. *Key Facts and Figures on the Natural Resources Sector*. [On-line]

Available at

https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/files/pdf/10_key_facts_nrcan_2016-access_e.pdf

[Accessed May 2017].

Natural Resources Canada, 2016. *LetsTalkCleanResources.ca Online Engagement: Final Report*, s.l.: Natural Resources Canada.

Natural Resources Canada, 2017. *Green Mining Initiative Advisory Committee Workshop Report*, Ottawa: CanmetMINING.

Statistics Canada, 2017. *Employment by Industry*. [On-line]

Available at <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ40-eng.htm>

[Accessed May 2017].