



Innovating for a Strong Canadian Energy and Mining Sector

Energy and Mines Ministers' Conference

Halifax, Nova Scotia

July 2015



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Executive Summary

Innovation has always been at the forefront of discussions on the future of the Canadian economy as it is the ultimate source of productivity growth, long-term competitiveness and improved living standards. Fortunately, Canada can count on strong enabling conditions for innovation across business sectors, including in natural resource industries.

The objective of this report is to present an overview of the current state of innovation leadership in Canada's energy and minerals and metals sectors. The report also highlights the importance of innovation in order to maintain Canada's competitive edge in these sectors. A few key observations are offered at the end of the report.

A. Canada's natural resource advantage

Canada is fortunate to have one of the largest, most diverse natural resource endowments in the world. Beyond these world-class reserves, expertise and knowledge are key elements contributing to Canada's position as a leading commodity producer and exporter. In particular, Canada is recognized globally for its innovative resource value chain that extends into other parts of the economy (e.g., the engineering and environmental services industries). These allied industries supply leading-edge technologies and services that are critical in helping Canadian resource firms stay competitive in the global economy.

B. Canada's innovation leadership in the energy and mining sectors

Over time, strong innovation leadership has contributed to the competitiveness of the energy and the minerals and metals sectors in Canada. While innovation is often directed towards minimizing costs by way of improved processes in upstream industries, technological breakthroughs in recent years have also helped to enhance the management, transportation, transformation and use of natural resources in all aspects of the Canadian economy. The development and adoption of these technologies and products have contributed to Canada's strong innovation record in the energy and minerals and metals sectors.

Collaboration is a key aspect of innovation leadership in Canada's energy and minerals and metals sectors. For natural resource companies, managing all technology needs in-house has become nearly impossible as a result of the high level of complexity of resource production and use. In this context, partnerships across the private and public sector have helped to focus limited capacity and resources on areas where Canada has an opportunity to excel, or where the challenges are the greatest. Collaboration can also ensure ongoing innovation, despite the currently challenging global economic conditions.

C. Looking ahead: The importance of innovation

Natural resources are at the centre of transformative changes occurring at a global scale. A number of medium- to long-term trends highlight the importance for Canada's energy and mining companies to be nimble and innovative in order to maintain their competitive edge.

More specifically, continued innovation efforts are important although the current business environment can represent a challenge (i.e., lower commodity prices, and reduced profit margins). Firms that are the most successful now in achieving cost reductions through

innovation will be well positioned to take advantage of opportunities when the growth in global demand for resources picks up. More efficient processes will also help Canadian firms to cope with increasing competition from low-cost producers.

The existing and future technical challenges that Canadian energy and mining firms face also highlight the role played by new technologies and solutions. For example, in a context of harder-to-access resources, energy and mining companies operating in Canada and abroad face growing pressures to improve environmental performance and meet public expectations. Innovation in new technologies and services has, however, helped to minimize the perceived tension between economic and environmental considerations associated with the development and use of natural resources. New energy technologies and services, for example, have improved efficiency and reduced the environmental impact of resource development, generated economic growth, and created jobs for Canadians.

1. Introduction: Innovation in a Changing World

Innovation has always been at the forefront of discussions on the future of the Canadian economy as it is the ultimate source of productivity growth, long-term competitiveness and improved living standards. As noted in Canada's 2014 Science and Technology Strategy, Canadian businesses in both traditional and emerging sectors must innovate to compete and survive in response to globalization, disruptive technologies and demographic change.¹

Fortunately, Canada can count on strong enabling conditions for innovation across business sectors, including in natural resource industries. For example, the federal, provincial and territorial governments help to maintain an attractive climate for business investment in research and development (R&D) through targeted investment and strategic support. Canada also ranks first among G7 nations in spending on R&D in universities and colleges as a share of gross domestic product (GDP).² More specifically, the natural resources sector's strong innovation performance is grounded on a diverse set of public support programs, a novel stock of technologies and the consistent collaborative effort of firms.³

The reports *Our Resources, New Frontiers*⁴ and *Mobilizing Canada's Energy Advantage*⁵, both released at the 2014 Energy and Mines Ministers' Conference (EMMC), highlighted that supporting a business environment which fosters productivity and innovation is critical to ensure the competitiveness of Canada's energy and minerals and metals sectors in a changing global economy. For example, growing pressures to improve environmental performance in a context of harder-to-access resources highlight the importance of developing innovative technologies and solutions. At the same time, companies need to contain costs in a challenging economic environment characterized by lower commodity prices and increased competition. Companies that are successful in addressing these challenges will be well positioned to take advantage of opportunities in the medium and long term.

Textbox 1 – Approach

This report will assess the importance of innovating for strong Canadian energy and mining sectors. The report is divided in three sections:

- **Canada's natural resources advantage**, particularly the elements that have contributed to making Canada a competitive, reliable and responsible supplier of natural resources to North America and the world.
- **Canada's innovation leadership** in the energy and mining sectors, including an overview of the role of industry, governments and universities in supporting innovation, from basic research to commercialization. This section also examines the key factors shaping innovation in the energy and minerals and metals sector.
- **The importance of continued innovation** in order for Canadian energy and mining firms to maintain their competitive edge in a global economy characterized by lower commodity prices and increased competition. Recent progress has also helped companies to respond to growing pressures to improve environmental performance.

Examples of public and private initiatives that support innovation in Canada's resource industries are highlighted in textboxes throughout the report.

Textbox 2 – National Policy Symposium on Energy Delivery and Management

Across Canada, there are important innovations happening in the energy delivery and management sector (electricity, natural gas, thermal and storage). By sharing insights, solutions, and best practices, opportunities and challenges were identified to accelerate innovation in this sector to enable it to become more innovative, competitive, and efficient.

The National Symposium on Energy Delivery and Management took place on April 15, 2015 and was delivered by QUEST – Quality Urban Energy Systems of Tomorrow, in partnership with this year’s Energy and Mines Ministers’ Conference hosts, Nova Scotia Department of Energy and Natural Resources Canada. Sponsorship was in part provided by the Canadian Gas Association and Canadian Electricity Association. The Symposium drew over 80 senior executives from government, industry, utilities, regulators, and other organizations from across Canada.

Key insights from the Symposium:

- Efficient collaboration is critical, and intergovernmental working groups and agencies can advance the energy innovation agenda;
- Identify regional priorities within a national framework to accelerate innovation and enable Canadian leadership in global supply chains;
- Coordinate/streamline federal, provincial and innovation funding processes;
- Support community level innovation and community energy planning;
- Technology, policy and regulation drive each other;
- Many innovations happen at the local level and result in lower energy costs, enhanced reliability, better environmental performance and local economic benefits;
- How we deliver and manage energy is becoming as important as how we produce it; and
- Canada can be a global leader for energy delivery and management solutions by harnessing local solution experience as an export market opportunity.

Sources: QUEST, Government of Nova Scotia, Natural Resources Canada.

The objective of this report is to present an overview of the current state of innovation leadership in Canada’s energy and minerals and metals sectors. The report also highlights the importance of innovation in order to maintain Canada’s competitive edge in these sectors. It has been developed collaboratively by Natural Resources Canada and the Energy and Mines departments of the provinces and territories.

2. Canada’s Natural Resource Advantage

Canada is fortunate to have one of the largest, most diverse natural resource endowments in the world which positions the country favourably in meeting the world’s growing demand for energy, minerals and metals. For example, Canada is one of the leading mining nations in the world, producing more than 60 minerals and metals. More specifically, the country is the global leader in the production (by volume) of potash, and ranks among the top five global producers of strategic minerals and metals such as aluminum, cobalt, diamonds, nickel, uranium and

platinum-group metals. Similarly, in the energy sector, Canada is the fifth-largest producer of crude oil and natural gas, accounting for over 4 percent of global production in both cases, and is positioned as a global leader in terms of hydroelectricity.

Canada has been successful in translating this tremendous resource advantage into a key pillar of the country's economy. Today, the natural resource sectors are significant components of the national, provincial, and territorial economies (Figure 1). The energy, minerals and metals, and forest sectors directly and indirectly support close to 1.8 million jobs across Canada and account for almost one-fifth of the country's nominal GDP. In 2013, natural resource exports totalled close to \$260 billion. There are also hundreds of major resource projects currently underway or planned over the next ten years, worth approximately \$711 billion in investment.

Expertise and knowledge have been key factors contributing to Canada's position as a leading commodity producer and exporter. In particular, Canada is recognized globally for its innovative resource value chain that extends into other parts of the economy. For example,

Figure 1 – Contribution of the Natural Resources Sector to Provincial & Territorial Economies

	Nominal GDP, 2014 (%)*	Jobs, 2014*	Exports by province of origin, 2014 (\$ million)*	Major projects, 2015** (\$ billion)
Newfoundland & Labrador	33%	12,000	\$12,032	\$44
Prince Edward Island	3%	1,000	\$30	\$0.1
Nova Scotia	7%	11,000	\$1,679	\$26
New Brunswick	12%	20,000	\$11,014	\$4.5
Quebec	10%	178,000	\$33,101	\$67
Ontario	7%	237,000	\$49,701	\$39
Manitoba	9%	24,000	\$3,587	\$11
Saskatchewan	31%	39,000	\$20,294	\$27
Alberta	31%	210,000	\$98,015	\$204
British Columbia	11%	111,000	\$27,035	\$248
Yukon	14%	2,000	\$110	\$7
Northwest Territories	33%	3,000	\$2,081	\$5
Nunavut	21%	1,000	\$1	\$3
Multi-regional projects				\$26
Total - Direct	14.5%	851,000	\$258,681	\$711
Total - Indirect	4.7%	946,000		
Total - Direct and Indirect	19.7%	1,800,000		

Sources:

* Natural Resources Canada calculations based on Statistics Canada data.

**Natural Resources Canada, Provincial and Territorial Governments. As of June 2015.

Notes:

Energy, minerals and metals, and the forest sector are included. Totals may not add up due to rounding.

over 3,200 suppliers in a wide range of industries serve the minerals and metals sector. A growing clean technology sector is supported by world-class research provided by Canada's engineering and environmental sectors, and academic institutions. These allied industries contribute to resource development across Canada, for example by supplying leading-edge technologies and services that are critical in helping Canadian resource firms stay competitive in the global economy.

3. Innovation Leadership in the Energy and Mining Sector

Over time, innovation leadership has contributed to the competitiveness and environmental performance of the energy and the minerals and metals sectors in Canada. Collaboration and partnerships between firms, governments and academic institutions have been critical in developing innovations that have contributed to making Canada a competitive, reliable and responsible supplier of natural resources to the world. Innovation also extends to the transportation, management and use of energy, minerals and metals.

This section highlights examples of innovation leadership in the energy and minerals and metals sectors, including an overview of the role played by government, industry and academic stakeholders. Some of the factors that are shaping innovation in Canadian resource industries are also examined.

3.1 An innovation system founded on collaboration and partnerships

As a result of the high level of complexity of resource production, collaboration plays a critical role in the innovation process of the energy and the minerals and metals sectors.⁶ For resource companies, managing all technology needs in-house has become nearly impossible. In this context, partnerships across the private and public sector can help to focus limited capacity and resources on areas where Canada has an opportunity to excel, or where the challenges are the greatest.⁷ Collaboration can also ensure ongoing innovation, despite the currently challenging global economic conditions.

The mining houses don't exist in glorious isolation. There is an ecosystem of suppliers and vendors and people who provide technology.

Source: John McGagh, Head of Innovation, Rio Tinto, 2013 (in an interview with Mining IQ).

Textbox 3 – Canada's Oil Sands Innovation Alliance (COSIA)

COSIA is an industry-led alliance launched in 2012 which focuses on accelerating the pace of improvement in environmental performance in Canada's oil sands through collaborative action and innovation with other industries, governments and academia.

Through COSIA, participating companies capture, develop, and share the most innovative approaches and best thinking, focusing on four priority areas: tailings, water, land and greenhouse gas emissions. To date, COSIA member companies have shared 777 distinct technologies and innovations that cost over \$950 million to develop.

COSIA has 13 member companies, which represent almost 90 percent of the oil sands production in Canada.

Source: COSIA.

Textbox 4 – Canada Mining Innovation Council (CMIC)

The Canada Mining Innovation Council (CMIC) is the only national organization in Canada with a 20-year vision focused on innovation to address pre-competitive challenges in the industry. Its strategy (Towards Zero Waste in Mining) is focused on reducing waste in the minerals industry (productivity, energy, environmental) to zero in 20 years. CMIC's ability to execute on this strategy lies in the very active membership of mining companies, service providers, research, development and innovation organizations and universities within and outside of the minerals sector.

The impact of this strategy will include:

- Significant leveraging of existing assets and expertise nationally and from the provinces and territories;
- Significant leveraging of investments from the federal, provincial and territorial governments and the private sector;
- Avoiding duplication of existing programs;
- Enhancing of existing programs through connection to a longer-term strategy;
- The ability to discover new resources faster and with less cost;
- Helping non-viable mines become viable, accelerating the development of mineral properties, and increasing jobs and development (e.g. Ring of Fire);
- Decreasing footprint and environmental impact; and
- Developing the north through the discovery of new deposits and more mines.

Source: NRCan, CMIC.

The focus of firms towards containing costs by way of improved process innovation (e.g., adoption of more efficient technologies) also highlights the significant role that suppliers of technology and technical services play in helping Canada's energy and minerals and metals sectors stay on the "leading edge." The advanced technologies and other machinery and equipment (M&E) implemented to improve productivity and contain costs typically embody considerable R&D performed in other sectors of the economy. Canada's rich tradition of excellence in these allied industries has given rise to strategic competitive clusters in all regions of the country. For example, according to the Mining Association of Canada, over 30 mining clusters can be found across Canada, with suppliers of goods and services being key players.⁸ Cluster networks help innovators commercialize technologies that respond to the needs of the industry.

Through their research and collaboration with industry, universities also play a critical role in supporting innovation in Canada's energy and mining sector. Academic research generates discoveries that underpin new products, processes and policies and that help address some of the most pressing challenges faced by Canadian resource companies.⁹ Applied research collaborations with colleges and universities are particularly important to small and medium-sized enterprises, which often lack the resources to invest in innovation projects. Academic institutions also develop young talent and business leaders, providing them with the specific skills and knowledge required to support Canada's competitive advantage in the energy and the minerals and metals sectors.

Textbox 5 – International Minerals Innovation Institute (IMII)

IMII, formed in 2012, is a partnership composed of industry, government and post-secondary education and research institutions. IMII is a leader to inform, facilitate, coordinate, and financially support innovative industry-driven research and skill development that enhance the growth and global competitiveness of Saskatchewan's minerals industry.

In the area of skills development, IMII is funding a number of initiatives that have enabled post-secondary institutions (e.g., University of Saskatchewan, Saskatchewan Polytechnic, Northlands College, Cumberland College) to develop and launch new courses and programs.

Current research initiatives that are being facilitated include:

- Funding to support a team from the Industrial Psychology Department of the University of Saskatchewan and the Nursing School of Saskatchewan Polytechnic undertake a collaborative research project on “Enhancing Cultures of Safety in the Mining Industry;” and
- Support to a cross-functional team of graduate students and research scientists under the leadership of a professor from the Civil and Geological Engineering Department of University of Saskatchewan, in collaboration with Canadian Light Source, to start a research project on “Removal of Cationic Salts from Brine Effluent.”

Further research and training initiatives are in development.

Source: Government of Saskatchewan.

Through a wide range of policy instruments – from tax incentives and regulations to direct funding programs – the federal, provincial and territorial governments in Canada support an environment that favours innovation throughout the resource economy.¹⁰ All jurisdictions have implemented policy instruments that support innovation, with the responsible development of natural resources and environmental protection being common areas of focus. This includes the support of innovations related to the extraction, production, transportation, transmission, storage, management and use of natural resources. However, Canada's provinces and territories differ in terms of their mix of energy, mineral and metal resources, and each has distinct priorities and capabilities. For example, the Government of Canada is a major driver of energy technology innovation and is investing in areas such as energy efficiency, fossil fuels and renewable energy. Federal investment alone represented 14.5 percent of total spending on energy research, development and demonstration in 2009-10.¹¹ In the minerals and metals sector, the Green Mining Initiative brings together various stakeholders, under the collaborative leadership of Natural Resources Canada, to develop green technologies, processes and knowledge for sustainable mining. Through the GMI, the Government of Canada aims to improve the mining sector's environmental performance, to promote innovation in mining and to position Canada's mining sector as the global leader in green mining technologies and practices.¹²

Governments not only support innovation in the energy and mining sectors, but also undertake R&D in their own laboratories. For example, through work at its Canmet laboratories, Natural Resources Canada contributes to innovations that enhance the competitiveness of the Canadian energy and mining industries (Textbox 6). By making innovations accessible to a wide range of stakeholders, public R&D helps to advance innovations that give Canada a competitive edge in today's global market.

Textbox 6 – Innovation leadership in Canmet labs

Through work at its Canmet labs, Natural Resources Canada contributes to innovations that enhance the competitiveness of the Canadian energy and mining industries.

CanmetENERGY

CanmetENERGY is the Canadian leader in clean energy research and technology development, employing over 450 scientists, engineers and technicians. The organization works with partners in industry and academia, as well as with environmental stakeholders, to develop more energy efficient and cleaner technologies in a number of areas such as building and communities, clean fossil fuels, bio energy, renewables, industrial processes, oil sands, and transportation.

CanmetMATERIALS

CanmetMATERIALS is the largest research centre in Canada dedicated to the fabrication, processing and evaluation of metals and materials. CanmetMATERIALS strives to develop technologies to improve the reliability of energy production and energy efficiency, reduce greenhouse gas emissions and other environmental impacts, result in innovative products for a green economy, and enhance health, security and safety. Its research focuses on three industrial sectors: transportation, energy, and metal manufacturing.

CanmetMINING

In addition to the Green Mining Initiative, CanmetMINING has been a leader or a participant in many mining and innovation-related national collaborations. For instance, the Deep Mining Research Consortium was initiated in the early 2000s to solve problems related to mining at depth in Canada. CanmetMINING also meets with the Chief Inspectors of Mines from every province and territory annually to discuss emerging issues, challenges and areas of R&D that can help promote productivity, sustainability and health and safety in mining, and uniformity in regulation across Canada.

Source: NRCan.

3.2 Strong innovation record in the energy and minerals and metals sectors

Innovation leadership has shaped Canada's energy and minerals development over time. There are several examples of innovations that have improved the sectors' economic and environmental performance.

In the upstream industries of the energy sector and the minerals and metals sector, these include significant advances in exploration and extraction technologies, pipeline safety, the production of renewable energy, and environmental monitoring methods for the reduction of greenhouse gas emissions and the protection of water resources and soil. For example, Canada

Textbox 7 – Innovation in renewable electricity in Nova Scotia

Nova Scotia has a strong record of innovation in the energy sector, with various projects currently underway. One of the most notable local companies is LightSail Energy, which is recognized internationally for their compressed air energy storage system allowing for grid-scale storage of energy.

The province is also home to innovative projects in the area of tidal energy. For example, the Fundy Ocean Research Centre for Energy is currently undertaking two research projects to monitor specific areas and advance resource characterization in the Bay of Fundy.

The Nova Scotia Government, in partnership with the Offshore Energy Research Association (OERA) has developed ties with the United Kingdom “Innovate UK” program. In October 2014, the OERA and Innovate UK announced a joint-call competition seeking innovative technologies or research related to in-stream tidal development. Project funding is awarded to those who can either produce technologies or research that evaluates the environmental impact of in-stream tidal energy.

Source: Government of Nova Scotia.

is recognized as a world leader in carbon capture and storage (CCS) with four large-scale projects under construction or in operation. Working collaboratively, the governments of Canada, Alberta and Saskatchewan have invested over \$1.8 billion in funding for CCS to date.¹³ In the mining industry, beyond technological breakthroughs in mineral and metal extraction (Textbox 9), new techniques and tools are transforming exploration activity. A good example is Groundtruth Exploration, a Yukon-based company, which has developed innovative technologies that are not only more effective and efficient at finding deposits, but that have also helped to reduce the impact of exploration on the environment.

In addition, several innovations developed over recent years have helped to enhance the use of natural resources in all aspects of the Canadian economy. Pulse Energy, for example, is a company that was founded in 2006 with support from the Government of Canada and the Government of British Columbia and that has since gained recognition as a leader in the fast-

Textbox 8 – The Dawson Creek Reclaimed Water Project in British Columbia

Shell and the City of Dawson Creek opened the Dawson Creek Reclaimed Water Project in the fall of 2012. The facility virtually eliminates Shell’s need to draw on local fresh water sources for the operation of its Groundbirch natural gas venture in Northeast British Columbia. The multi-million dollar facility, which has a capacity of 4,000 cubic metres a day (i.e., enough water for almost 16,000 Canadian households*), provided a new source of revenue for the City of Dawson Creek and additional water for industrial and municipal uses.

Shell pipes its share of the water from the treatment plant to its natural gas operations in the prolific Groundbirch gas field. The water is then stored in ponds and later mixed with recycled production water to be used in drilling and well completions. Piping the water to Groundbirch rather than trucking it has meant a reduction in traffic, noise and dust, which are among the top concerns of local landowners.

*Assumes Canadians with water meters use 251 litres of water each day per household, based on data from Environment Canada. **Source:** Government of British Columbia.

Textbox 9 – The Ultra-Deep Mining Network (UDMN)

The UDMN is a \$46million business-driven initiative championed by Ontario’s Centre of Excellence in Mining Innovation in Sudbury. Its mandate is to help the mining industry to adopt commercially viable R&D project results, and to deploy proven innovative technologies.

Projects funded through the UDMN must have an end user as a partner and a well-defined path to commercialization. The UDMN currently has 29 active projects under four themes:

- 1) Rock stress risk reduction: To improve the control of stability in deep underground excavations.
- 2) Energy reduction: To improve the energy consumption profile and cooling of deep mines.
- 3) Novel methods of material transport and productivity: To increase the rates of development and production in mines.
- 4) Improved human health: To enhance the human environment in deep mines.

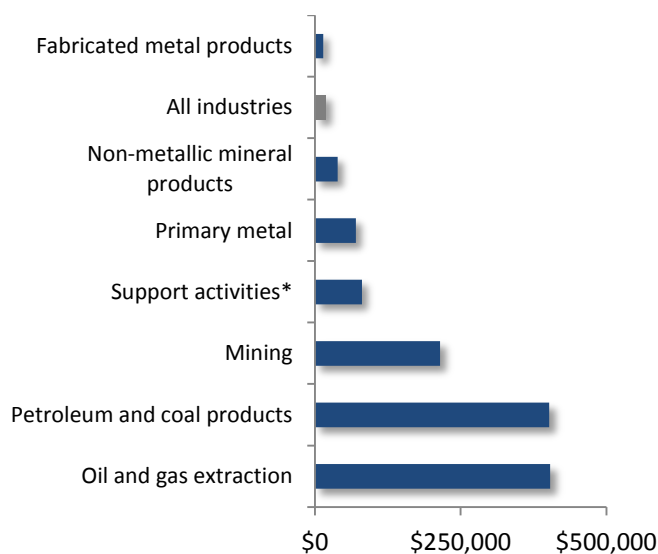
The UDMN also engages a solution team consisting of SMEs and academia. This partnership facilitates knowledge and technology transfer by SMEs, most of which are within Canada’s mining supply and service sector.

Sources: UDMN, Government of Ontario.

growing market of building-performance improvements and innovation. The technology and expertise developed over the years by Pulse Energy have helped to reduce costs and emissions in British Columbia’s communities, including remote communities that rely on diesel generators and where the cost of power is very high.¹⁴ Annex 1 provides additional detailed examples of recent innovation that are transforming the energy and minerals and metals sectors in Canada.

The development and adoption of these technologies and products have contributed to Canada’s strong innovation record in the energy and minerals and metals sectors. In 2012, the Centre for the Study of Living Standards (CSLS) published the report *Innovation in Canadian Natural Resource Industries: A Systems-Based Analysis of Performance, Policy and Emerging Challenges* which assessed the innovation performance of resource industries by looking at a variety of indicators that represent the innovative efforts of firms. The main conclusion of the report was that the overall innovation performance of the Canadian energy and minerals and metals sectors is strong as measured by most indicators, and has improved in recent years. For example, these sectors outperform the Canadian business sector in terms of productivity levels, M&E capital intensity (Figure 2), adoption of new technologies, collaboration efforts between firms, and R&D personnel.

Figure 2 – M&E Capital Intensity, 2013
M&E Capital Stock per worker



* Support activities for mining and oil and gas extraction

Source: NRCan calculations based on Statistics Canada data.

The report also showed that the sector’s innovation performance is grounded on a diverse set of public support programs, a novel stock of technologies and the consistent collaborative efforts of firms. The main exceptions were related to R&D intensity (Textbox 10) and average years of schooling. Poor labour productivity growth in recent years also represents an area of concern. After increasing for an extended period of time, labour and multifactor productivity in both mining and oil and gas extraction have been on a generally downward trend over the last 15 years. A key factor explaining this performance was rising commodity prices, which motivated companies to prioritize production growth, typically from harder to access lower-grade deposits (mining) or unconventional sources (energy), over investments and innovations that lead to productivity gains.

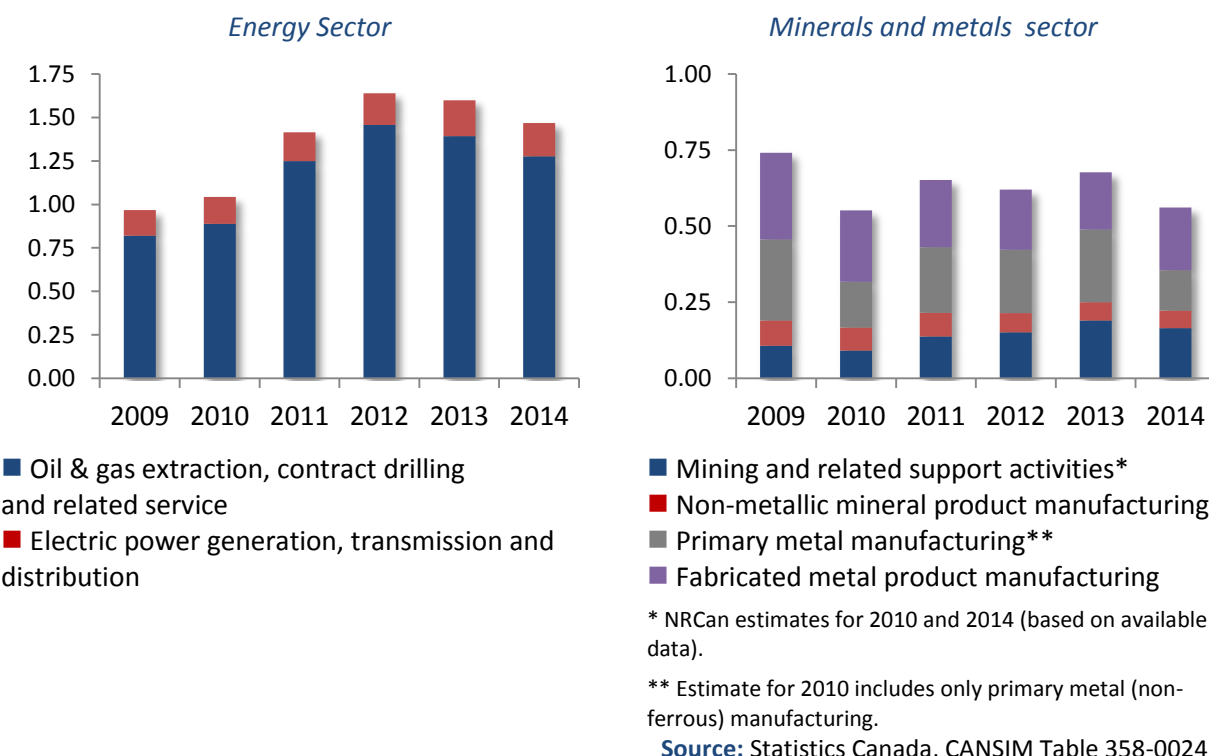
Textbox 10 – R&D trends in energy and mining

In 2014, business expenditures on R&D (BERD) totalled about \$1.5 billion in the energy sector, and over \$500 million in the minerals and metals sector. While significant, these expenditures have been on a downward trend. Available data also show that R&D intensity (BERD as a percentage of nominal GDP) of extractive industries has been lagging behind that of the business sector as a whole. These trends can be explained in part by structural characteristics specific to resource sectors. Among these is the focus of resource industries on containing costs by way of improved processes which, in turn, leads firms to acquire technologies that embody considerable R&D performed in other sectors of the economy (e.g., universities, other industries).

Sources: CSLS, NRCan.

Business expenditures on research and development, 2009-2014

Billions of dollars



Despite this strong innovation record, Canada is not alone in the innovation race. Industrialized and emerging economies around the world continue to invest heavily in science and technology. For example, public expenditures on energy research, development and demonstration (energy RD&D) by the International Energy Agency member countries have increased by 30 percent since the 1990s. More specifically, government expenditures on energy RD&D in nations such as the United Kingdom and Australia have more than tripled since the early 2000's, while spending in the United States and Germany has more than doubled during this same timeframe.¹⁵

3.3 Factors shaping innovation in the energy and minerals and metals sectors

The form and characteristics of innovation processes are unique to each sector of the economy and are shaped by the different drivers, constraints and opportunities. While the energy and the minerals and metals sectors in Canada are made up of industries with widely different characteristics, it is possible to identify a few common features that differentiate them from other sectors of the economy.¹⁶

- **Commodity production:** Many resource-based industries produce products differentiable only on the basis of price and sold on global markets. Few, if any, of the competitive conditions in these markets are determined in Canada, even when unique endowments are concerned. Energy commodities are also not valued for their inherent features or characteristics, but rather for the goods and services that they enable.
- **Wide range of production environments:** Energy and mining companies are operating in a wide range of production environments, which often precludes “one-size-fits-all solutions.” For example, specific innovations can be required to support the development of different types of reserves (e.g., conventional vs. unconventional) or production in certain regions of the country (e.g. the North).
- **Capital intensity and long-term pay-outs:** Resource operations, particularly in the extractive industry (i.e., mining, oil and gas), entail very large capital investments with projected payoff periods that are measured in decades. Initial investments in technology and structure often result in capital that remains in service for several years, and may be difficult to change once put in place. This feature can slow the development and adoption of new technologies.
- **Complexity and uncertainty:** The production processes of natural resource products are multidimensional and involve numerous activities such as exploration, resource management, extraction, manufacturing, and the prevention and mitigation of environmental impacts. Investments also occur in an environment that can include significant price volatility, shifts in global supply and demand, and a certain level of uncertainty related to policy directions and regulations. Complexity and uncertainty increase the level of risk and can represent a barrier to innovation.

Other features of the energy and minerals and metals sectors in Canada may also influence the innovation process. For example, Canada has a relatively small domestic market for emerging energy technologies, which means that innovative firms in this industry (e.g., clean technology small and medium-sized enterprises) must often rely on export markets to be competitive.

Similarly, access to private funding and venture capital is also lower in Canada compared to other countries like the United States.

Taken together, these features distinguish the energy and minerals and metals sectors from other sectors of the Canadian economy. As noted previously, innovation in Canada's resource industries is generally the result of collaboration and partnerships, and is often directed towards minimizing costs by way of improved processes. That being said, product improvements and diversification play a key role in the competitiveness of Canadian resource-based manufacturing industries (e.g., advanced materials manufacturing).

4. Looking Ahead: The Importance of Innovation

Natural resources are at the centre of transformative changes occurring at a global scale. A number of medium- to long-term trends are creating opportunities and challenges that highlight the importance for Canada's energy and mining companies to be nimble and innovative.

4.1 Opportunities in a changing global economy

Among the most important trends impacting the global economy is the rise of emerging economies, which are projected to account for most of commodity demand growth in the future. According to the International Energy Agency, for example, almost all energy demand growth to 2040 is expected to come from non-OECD countries, shifting the centre of gravity of energy markets decisively away from the Americas and Europe.¹⁷ In this context, emerging markets should continue to offer a tremendous opportunity to expand and diversify Canada's natural resource export markets.

As of today, however, Canada's overall market share of natural resource imports by emerging economies remains relatively small.¹⁸ This trend reflects the fact that other resource-producing nations have had more success in capturing natural resource export opportunities in emerging markets.

Canadian resource producers also face increased competition in the United States where new rivals, often counting on highly

To regain momentum, and lay a strong foundation for the next mining cycle, companies need to accelerate their efficiency programs and invest more significantly in innovation.

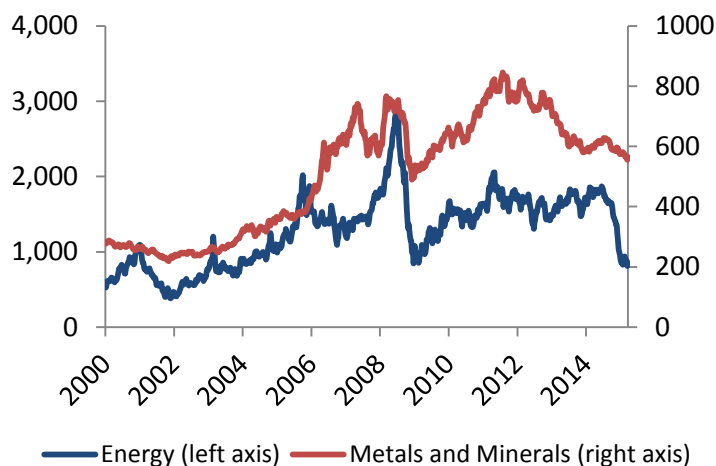
Source: Deloitte, Tracking the Trends 2015.

competitive cost structures, are rapidly gaining market share. In this context, innovation will remain a key driver of competitiveness for Canadian firms in the energy and minerals and metals sectors hoping to capture opportunities in both traditional and emerging markets.

Although long-term demand for natural resources is expected to rise, short-term pressures are forcing companies to examine their operations. For example, the recent decline in commodity prices highlights the need to contain costs through rationalization, productivity improvements or better supply chain management (Figure 3). Companies that are the most successful in achieving cost reductions, in particular through innovation, will be well positioned to take advantage of opportunities when the growth in global demand for resources resumes.

In light of growing global demand for alternative energy technologies, Canada also has an opportunity to leverage its expertise and leadership in areas such as distributed power generation and energy efficiency technologies.¹⁹ In turn, these energy technologies, as well as other high-tech equipment, offer an opportunity to turn Canada’s promising deposits of critical minerals and metals (e.g., rare earth elements) into a competitive advantage.

Figure 3 – Commodity Price Index, 2000-2015



Source: Bank of Canada.

Textbox 11 – Impact of recent technological progress on oil and gas development

Innovation and the increasing efficiency of horizontal drilling and multi-stage hydraulic fracturing technologies are unlocking vast unconventional shale and tight hydrocarbon resources in North America which were previously uneconomic to produce. This includes oil and gas plays in Saskatchewan, Alberta and British Columbia.

This technological change has had a profound impact on North American and global oil and gas markets. For example, crude oil production in the United States is near a 30-year high, and, by 2020, the United States could be a net exporter of natural gas. Growth in unconventional production has contributed to the decline in North American natural gas prices and is often cited as a factor in the oil price decline over the last year.

While technological advancements have allowed for new and abundant production of oil and gas in North America, the impact on prices emphasises the need for companies to contain costs through productivity improvements as well as the importance for Canada to diversify its energy export markets.

Sources: NRCan, U.S. Energy Information Agency.

4.2 Addressing technical challenges and improving environmental performance

The existing and future technical challenges that Canadian energy and mining firms face also highlight the role played by new technologies and solutions. In the mining industry, for example, untapped mineral and metal reserves are increasingly found in remote and northern regions where the lack of infrastructure, sparse population, and often extreme seasonal temperatures translate into higher costs (e.g., due to reliance on diesel for electricity generation).²⁰ The development of cost-effective technical solutions to economically mine remote and lower grade ore is important to ensure the competitiveness of Canada’s mining sector over the long term.²¹

Continued progress also helps to respond to growing pressures to improve environmental performance. For example, major resource projects have been a source of concerns in the population with regards to their cumulative impact on the environment as well as on public and worker health and safety. Internationally, companies seeking project financing are now required to apply rigorous environmental and social standards.²² In this context, innovation in new technologies and services has helped to minimize the perceived tension between economic and environmental considerations associated with the development and use of natural resources.

New energy technologies and services, for example, have improved efficiency and reduced the environmental impact of resource development, generated economic growth, and created jobs for Canadians. Growing global demand for such technologies and services can also provide Canadian companies with opportunities to contribute to improved environmental outcomes abroad and increase Canadian exports. For example, in its 2014 report on the Canadian Sustainable Technology Industry, Analytica Advisors estimated that the global market for clean technologies could more than double to \$2.5 trillion by 2022.²³

Textbox 12 – A first wind project supporting mining operations

For northern communities and mining sites, the use of diesel for electricity generation is commonplace and very costly.

In the Nunavik region of Quebec, adding wind generation and energy storage to diesel generation could provide stable energy supply and help to reduce emissions. A number of technological breakthroughs over recent years have helped the wind industry to adapt to conditions in Northern Quebec.

Supported by Natural Resources Canada’s ecoENERGY Innovation Initiative, TUGLIQ Energy Co. installed a wind turbine at Glencore’s Raglan Mine in Nunavik. Combined with a three-stage energy storage system, the wind turbine has helped the mine to reduce its diesel consumption by one million litres and, in turn, to reduce its emissions.

Sources: Natural Resources Canada, Government of Quebec.

Textbox 13 – Potential extension of Rambler Metals’ Ming copper-gold mine

The Research & Development Corporation (RDC) and Rambler Metals have invested in a demonstration plant at the Ming Copper-Gold mine in Baie Verte, Newfoundland and Labrador. The project is aimed at reducing operating costs while processing previously unusable material, potentially making viable up to 18.2 million tonnes of copper ore.

If the demonstration plant is successful and operating parameters are optimized, the company may introduce this technology into its mining operations at the Ming Mine in order to access the Lower Footwall Zone (LFZ), an area that currently is not included in its mine plan. Thus, the demonstration technology has the potential to significantly extend the life of the Ming Mine beyond the current six years. The total value of the project is \$3.8 million.

Sources: Government of Newfoundland and Labrador.

Textbox 14 – Driving innovation into Canada’s energy and mining supply chains

As high grade and easy-to-access oil and mineral reserves in Canada and around the world are depleting, cost-effective technology solutions are needed to economically exploit remote resources and extend existing mining operations with lower grade ore. The National Research Council of Canada (NRC) is tackling these challenges through “High Efficiency Mining”, a multi-year R&D program that deploys a critical mass of expertise to help companies manage the risks and costs of introducing innovative technologies into every stage of the mining process.

The program establishes co-investment opportunities for stakeholders along Canada's mining value chain to develop and deploy new technology to increase production at lower cost. Targeted projects will help optimize mining processes, improve equipment durability, and reduce the risk of technology adoption and integration across mining operations. These collaborative activities will result in practical technology solutions to save companies hundreds of millions of dollars in operating and maintenance costs, while generating sustainable economic benefits to Canada through an increase in reserves (i.e., economically recoverable resources).

Sources: National Research Council of Canada.

5. Key Observations

Several public and private initiatives have contributed to the innovation leadership and competitiveness of Canada’s energy and minerals and metals sectors. However, the current global economic environment and the transformative changes that the sectors are facing also highlight the importance of innovation.

- The energy and mining firms that are the most successful in achieving cost reductions today through innovation will be well positioned to take advantage of opportunities when the growth in global demand for resources picks up. More efficient processes will also help Canadian firms cope with increasing competition from low-cost producers.
- Energy and mining companies operating in Canada and abroad face growing pressure to improve environmental performance in a context of harder-to-access resources. Innovation can, therefore, minimize the perceived tension between economic and environmental considerations associated with the development and use of natural resources.
- Collaboration between industry, governments and universities helps to focus limited capacity and resources on areas where Canada has an opportunity to excel, and where the challenges are the greatest. Collaboration can also ensure ongoing innovation in the energy and mining sectors, despite the current challenging economic conditions.
- Research and innovative solutions enable companies to take advantage of current and future opportunities. In this context, strong allied industries and cluster networks increase the resiliency of Canada’s energy and mining sector.

- Government programs and policies play a key role in providing a stable and predictable environment that supports innovation. The development of codes and standards has, for example, facilitated the entry of new technologies into the market in recent years.
- Current and future challenges may lead companies to accept greater technology risk. Waiting for fully-proven technology could otherwise translate into lower competitiveness for Canadian firms in both traditional and emerging markets. Adapting proven technologies from other sectors also represents an opportunity to lower the cost and risk of innovation to industry.

Supporting a business environment that fosters productivity and innovation is critical to ensure the long-term competitiveness of Canada's energy and mining sectors. Innovating will also help companies to remain nimble in order to adapt to conditions of a changing global economy.

Textbox 15 – Energy innovation roundtables

Five energy innovation roundtables and a national roundtable were convened by Natural Resources Canada between fall 2013 and summer 2014. These roundtables brought together more than 100 senior executives from industry, academia, associations, utilities, governments, non-governmental organizations and the financial community to solicit views on barriers and solutions to accelerating energy innovation in Canada.

A number of key messages emerged from these roundtables that will help guide future actions to support innovation in Canada's resources industries.

- Sustained leadership mobilized around shared objectives and common outcomes would help foster innovation. Governments have a strategic role to play in order to bring together stakeholders from across the innovation chain.
- A market-driven R&D portfolio, focused on key Canadian strengths, would deliver benefits in the medium to long term to help enhance Canada's competitiveness.
- Public R&D efforts could be better aligned with industry needs, mindful of jurisdictions, to ensure a level of coherence across priorities and innovation system players. Strategic partnerships and targeted funding can help to achieve this coherence, and an emphasis on demonstration is important to showcase innovations.
- A stronger enabling environment could help spur innovation and better ensure that technologies are not stranded along the innovation chain (e.g., procurement programs help de-risk innovations).
- Gaps along the innovation chain exist, and several companies struggle to access capital. Government-led initiatives (e.g., Sustainable Development Technology Canada) help to support industry, particularly small and medium enterprises.

Source: NRCan, *Energy Innovation Roundtables Report*, 2014.

Annex 1 – Examples of Innovations in the Canadian Energy and Mining Sector

A) Greater efficiency in oil sands extraction

CanmetENERGY recently completed a contract with the Canada's Oil Sands Innovation Alliance (COSIA) for the first phase of a multi-year development project to develop a direct contact steam generation technology. COSIA participants were Suncor, CNRL, Devon Energy, Shell Canada and Statoil. The overall objective of this program is to develop a high pressure oxy-fired direct contact steam generator (HiPrOx/DCSG) system capable of providing steam for oil sands steam-assisted gravity drainage (SAGD) plants. This technology is intended to replace conventional steam generation technology such as once-through steam generators (OTSGs).

The concept of the direct fired steam generator is to combust a fuel with pure oxygen at high pressure. Wastewater contaminated with hydrocarbons and solids can be used within this type of system to create the final product, a flue gas stream consisting mainly of CO₂ and H₂O. The resultant product stream will then flow underground sequestering a significant portion of the CO₂. Due to the fact that the combustion products are all converted to the useable product stream, the thermal efficiency of this device will be close to 100 percent.

An analysis conducted by Navius Research estimated that the technology could result in the potential benefits:

- Reduce per barrel bitumen production costs by \$1.5-3/bbl (natural gas) and \$4-8/bbl (Pet coke),
- Lower fresh water consumption by 50-100 percent,
- Reduce GHG emissions by 77-85 percent, and
- Make the lifecycle GHG intensity of oil sands produced gasoline competitive with conventional world crude.

The first phase of testing focused on using process water (with high solids and hydrocarbon contamination) directly fired with natural gas. Future phases may use solid waste fuels and tailings water.

Outcomes of the test work completed by CanmetENERGY have been very positive and have reduced the risk factors for this technology substantially, paving the way to accelerated development. These ground-breaking tests did not reveal any technological barriers, and with the successful completion of development work slated for the next 3 years, DCSG has a high probability of reaching commercial implementation.

Source: CanmetENERGY, COSIA, Navius Research.

B) Ventilation innovation for mines

a) Green mining initiative – environmental technology verification (ETV) pilot of BESTECH's NRG1-ECO automated ventilation control system

To address barriers to the adoption of green mining technologies, the Energy and Mines Ministers tasked officials in 2013 with piloting one green mining technology through Environment Canada's Environmental Technology Verification (ETV) Program. The technology that was selected for the pilot project is an energy management solution which includes an automated mine ventilation control system, BESTECH's NRG1-ECO® system.

A key objective of the pilot was to determine if technology verification would accelerate the uptake and commercialization of green mining technologies. Other objectives included verifying the performance claims of an existing technology with a view of promoting its uptake and providing support for the commercialization of green mining technology. The Canadian ETV Program offers an independent review that verifies environmental performance claims for innovative technologies, processes, and products. It is based on sound science, high-quality data, and recognized protocols. Third-party, independent organizations collect data to test performance claims and review performance results.

The performance claim made by BESTECH is that: "The NRG1-ECO® Ventilation Control System enables an underground mine to automatically control the ventilation system's air flow and volume to when and where it is needed. This allows a mine to reduce the fan's energy consumption by at least 20 percent while maintaining a safe working environment for the underground workers. The percentage of energy savings depends on the site's usage of the solution's five control strategies."

This performance claim was independently verified under the ETV Program. A verification certificate was awarded to BESTECH in November 2014, and the technology has been listed on the Canadian ETV Program website (etvcanada.ca).

To further advance green mining technologies, Natural Resources Canada's CanmetMINING will track pilot outcomes to determine whether ETV can accelerate deployment of green technologies, and will promote ETV to manufacturers and suppliers in the mining sector.

b) Automated ventilation-on-demand at Éléonore mine benefits employees and bottom line

"Éléonore is the mine of the future," say Pascal Morin, Manager, Technology and Communications at Goldcorp's Éléonore mine and Flynn McCarthy, the company's former Corporate Energy Manager. In addition to a number of previous energy efficiency projects that include the implementation of an energy management information system (EMIS) as well as the installation of variable frequency drives and high-efficiency motors and pumps, the Éléonore mine in Quebec now features a unique automated ventilation-on-demand (VOD) system.

In March 2014, the company installed a SmartEXEC ventilation system from SimSmart Technologies to conserve energy and improve air flow for the well-being of underground employees. "Éléonore is our pilot project for this technology and we are optimistic about applying the technology in other mines," says Morin.

“Once savings at Éléonore have been verified, Goldcorp’s other underground mining operations are feasible future candidates for implementations,” says McCarthy.

The automated SmartEXEC fan systems respond to signals emitted from AeroScout Wi-Fi radio-frequency identification (RFID) tags, tracking devices worn by all underground employees and installed on all 80 pieces of underground machinery. The technology tracks real-time locations of both employees and machinery, and measures air quality for optimum working conditions.

“The real-time monitoring allows us to determine carbon dioxide (CO₂) and other gas levels, all of which are now well below the thresholds issued by the Quebec Commission de la santé et de la sécurité du travail du Québec (CSST),” says McCarthy. Morin notes that this pilot was made possible through the collaboration of many departments, including staff from human resources, electrical and mechanical engineering, and operational sections to achieve an integrated system.

Morin indicates that in the first two months after implementation alone, “the system saved propane, improved air flow and increased employee comfort.” The system will be expanded to other levels of the mine and tunnels late in 2014 which will bring the total number of fans to 70 and about 15 air flow regulators. “With this expansion, the annual savings could reach between \$1.5 and \$2.5 million over conventional ventilation systems and would also represent a significant annual reduction in GHG emissions,” says Morin.

Flynn notes that future projects include automation and control for energy efficiency, the acquisition of electric vehicles and the implementation of compressor-less technology. “Goldcorp is committed to continuous improvement to support a sustainable future for our employees, the communities in which we operate, and our planet.”

Source: Gordcorp, NRCan, *Heads Up* CIPEC Newsletter - December 2014.

c) Ontario Smart Grid Fund – Canadian Solar Renewable Energy Microgrid Testing Centre

The Ontario Ministry of Energy’s Smart Grid Fund (SGF) is a \$50M energy technology demonstration program that is commercializing the next generation of advanced distribution system solutions. SGF currently supports 26 innovative projects and, together with external partners, has resulted in an over \$160 million investment in Ontario’s energy sector.

Microgrids are an identified priority technology for SGF. In April 2014, the program announced funding support for the Renewable Energy Microgrid Testing Centre (REMTC) in Guelph, Ontario. The REMTC, constructed and administered by major solar panel manufacturer Canadian Solar Inc., will provide testing and validation services for new microgrid system components and controls (including solar and wind generation, battery storage, and intelligent controller software) with the goal of maximizing the level of renewable energy penetration within a microgrid. As each microgrid system is unique, the REMTC will be able to simulate each proposed microgrid under near real-life conditions.

By demonstrating the potential of microgrid solutions, the REMTC will greatly reduce the risks and costs associated with adopting this localized approach to electricity distribution. More specifically, the REMTC will provide insight into the ability of remote communities and large industrial facilities like mines to avoid the high costs, low efficiency, and environmental risks

associated with the use of diesel generation through the adoption of microgrid systems. To this end, Canadian Solar is collaborating with the Keewaytinook Okimakanak Council of First Nations and their economic development affiliate NCC Development Inc. to ensure the REMTC is able to develop an applicable solution in advance of an expected real-world deployment in Fort Severn, Ontario.

Notes

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