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LEADING FROM BELOW: TURNING GREATER SUDBURY INTO AN EXPORT HUB OF MINING INNOVATION AND SUSTAINED PROSPERITY

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1. Introduction[1]

The expected boom in demand for minerals and metals, significant investments in the production of electric vehicles (EVs) and batteries in Canada, and declarations from the Canadian and American governments on the need to become less dependent on other countries for 'critical' minerals, present a once-in-a-century opportunity for Sudbury, Ontario, and other mineral rich communities. This opportunity raises this white paper's two strategic questions.

1. **How capable are Sudbury's homegrown small- and medium-sized (SME) supply and service-providing companies as well as the region's mining ecosystem in spurring mining innovation to meet these demands**?

2. **What can be done to maximize both the scaling-up and participation of Sudbury's companies in transforming the global mining industry**?

Answers to these questions will be crucial to Sudbury's future prosperity and to future sustainability of its mining ecosystem.

Greater Sudbury is in an enviable position compared to many other mining-rich jurisdictions. Not only does the city and nearby surroundings have the unique circumstance of nine operational mines, these mines and related operations are in turn serviced by competitive and innovative local companies that specialize in different parts of the hard-rock mining value chain.[2] Additionally, Sudbury has an active local government, an impressive array of education institutions, as well as extensive interpersonal networks that all contribute to promoting the industry's continued growth.

Mining innovation in Greater Sudbury must also work within several constraints. First, even if mining output will grow in years to come, this growth will no longer directly translate to a significantly greater number of new jobs in mining due to the incorporation of new technologies or improvements of those already in operation. Second, the financial and operational control of Sudbury's biggest mines will remain under foreign-based operators for the foreseeable future, which means major decisions about investments, research, financing, hiring and sourcing equipment are made outside the region. Third, the industry continues to face labour and skills shortages, though these are industry-wide and not especially unique to Sudbury. Fourth, the straightforward gaps in the mining value chain, many of which Sudbury's entrepreneurs have skillfully filled to create and grow the mining supplier industry have already been filled. This means that future growth—of established SMEs and start-ups alike—will require skills and specializations that either do not exist or in sufficient quantity in the region. Finally, the cohort of homegrown small- and medium-sized

[1] The authors would like to acknowledge the support provided by the Greater City of Sudbury to the underlying research on which this working paper is based.

[2] Vale operates six (Clarabelle, Coleman, Copper Cliff North, Creighton, Garson, and Totten) while Glencore operate three (Nickel Rim South, Fraser and Strathcona).

enterprises is squeezed by the recent acquisitions of several successful homegrown companies by foreign-based companies on the one hand and by the slowing rate of new mining-focused upstarts being created on the other.

2. The objectives

This white paper attempts to address several pressing matters. What can be done in, and by, SMEs, government, and supporting institutions in Sudbury to amplify the growth of established mining supply and service companies as well as to spur the creation of new ones, while also keeping their ownership in Sudburian hands? What measures can be taken to ensure Sudburians gain well-paid and safe employment? Finally, how can local institutions—governmental, education and non-profit—stay relevant in fostering this continued growth and sharing this prosperity?

In answering those questions, this white paper puts forth the ambitious goal of **Greater Sudbury becoming a leading export hub for hard-rock mining solutions, equipment, and knowhow**. To achieve this, we propose four interrelated recommendations.

1. **Encourage and assist Sudbury-based mining supply and service companies to significantly expand their exports,** actively embracing the global nature of mining and specific technologies as opportunities for profit, growth, and further innovation.

2. **Expand the skills base of the region's workforce,** with special emphasis on skilled trades, research in materials science, integrating information and communications technologies (ICT) into mining operations, as well as greater learning of international business and languages.

3. **Develop 'shared assets'** that bring together the major operators, certain suppliers, as well as government and public institutions to pursue capital-intensive initiatives while also dispersing risk between them, with the goals of capturing more value from mining operations and making Sudbury the go-to place globally to develop new-to-the-industry technologies and approaches.

4. **Connect Sudbury's mining resources and skills base to the national security of Canada and its allies**, which would not only commit more resources to the region toward the goal of securing 'critical minerals' for Canada and its allies, but can also result in unexpected mining innovations with Sudbury-based companies as active participants in those efforts.

All four recommendations seek to transform Greater Sudbury into a world-leading export hub for hard-rock mining solutions, technologies, and expertise. This ambitious target imparts vital roles to be played not just by individual companies but also by different levels of government, education institutions like Laurentian University, Cambrian College

and Collège Boréal, as well as for quasi-public entities like NORCAT, CEMI, MIRARCO, and MineConnect (Table 1).

Sudbury serves as a valuable Canadian test-case for harnessing the established and up-and-coming local mining SMEs that could generate widespread prosperity beyond the minerals that are extracted from the region's mines. By successfully becoming a world-leading exporter of mining equipment and expertise, business opportunities for Sudbury's mining-focused SMEs could expand by several orders of magnitude. Furthermore, this export-oriented approach would ensure that the local industry stays best-in-class, at the forefront of the global industry's latest trends and drivers thereof, while also spreading the gains of this prosperity to Sudbury more broadly.

The findings and recommendations of this white paper emerged from field-level research in the region, including 40 interviews across the industry from the major operators to multiple company founders and high-level managers, officials in government and industry associations, as well as mining-focused staff and researchers in college and university. These semi-structured interviews took place in March, April, May, and July 2024. This paper also makes use of data from multiple sources such as National Resources Canada (NRCAN), Statistics Canada, and the International Energy Agency.

3. Sudbury's assets: Building on a strong base

Sudbury is in a competitive position compared to other mining-rich jurisdictions. Most obviously, the city and nearby surroundings are home to nine operating mines, which are serviced and supplied by a range of **competitive and innovative local companies** that specialize in different parts of the hard-rock mining value chain. Sudbury's long history of mining also means that the region is now endowed with multiple unique factors for future industrial success as well. The city boasts a robust **skills base** with people in different trades and professions able to actively participate in future innovations. Moreover, the local **government, universities and colleges as well as supportive institutions**—public and quasi-public—are active and interested in the industry's continued growth.

3.1. Competitive and willing to compete

Greater Sudbury has become home to a series of competitive and innovative local companies that provide equipment, technological solutions, and services in different parts of the hard-rock mining value chain.[3] Their continued existence is impressive given that mining supply chains are open to global competition and dominated by mostly foreign-based multinationals and original equipment manufacturers (OEMs).

[3] Invest Sudbury estimates that there are about 300 mining supply and service firms (Invest Sudbury, 2024a).

Many of Sudbury's homegrown companies have proven themselves in solving specific problems, whether in engineering (Technica, McLean), manufacturing or designing specialized equipment for the harsh underground mining environment (Rock-Tech, Hard-Line, Kovatera, Jannatech, Wipware, Railveyor), modernizing mine ventilation through hardware or software solutions (Maestro, PSL), among other activities. Many of these companies have continued to innovate and grow to the point of becoming established small- and medium-sized enterprises with employees based in and out of the region. Similarly, some have gained competitive advantages in manufacturing and design that have allowed them to defy pressures to move to lower-cost jurisdictions (Rock-Tech, Hard-Line) or to embrace more than just narrow elements of manufacturing and assembly (Kovatera). Some of these companies and their founders' visions had their origins in crises and external shocks, like collapses in the price of nickel, painful layoffs and major labour disruptions. Other companies emerged as responses to organizational and technological changes within the major operators like Vale (formerly Inco) and Glencore (then Falconbridge) or other OEMs like Komatsu, Epiroc (formerly Atlas Copco) and Sandvik. Greater Sudbury also boasts a host of serial entrepreneurs who have formed several successful companies and start-ups, and now regularly serve on boards of different relevant mining organizations or act as mentors to younger SME leaders in what has come to resemble a sort of 'Sudbury nationalism'.

There is no easy categorization of Sudbury's mining supply and service companies. This diversity is a testament to an underlying entrepreneurial spirit that has shown on many occasions capable of seizing on different growth opportunities, as well as to the robust knowledge and skills base that comes from a century of mining experience. The common origin of these successful SMEs has been the exceptional ability of founders to identify and act on potentially profitable gaps in the mining value chain in what has often amounted to 'user-based innovation' (Von Hippel, 2009). To this, we can add the general receptiveness of Sudbury's SMEs to innovate by adapting gadgets and practices from other industries.

On the other hand, many of our interviewees have expressed concerns about the tendency of the region's SMEs to exhibit a 'first to be second' mentality; in other words, to adopt a technology or practice only once it has been proven and deployed by others. This mindset is not exclusive to Sudbury's SMEs, but is common throughout the mining industry at large. Nonetheless, this reluctance to be bold and move first naturally extends into a related problem: the absence of homegrown companies seeking to expand, to acquire competitors—either vertically or horizontally—and to list on publicly traded exchanges. This white paper therefore suggests what can be done for Sudbury's mining SMEs to more actively become leading global suppliers.

3.2. A skilled, experienced and diversifying workforce

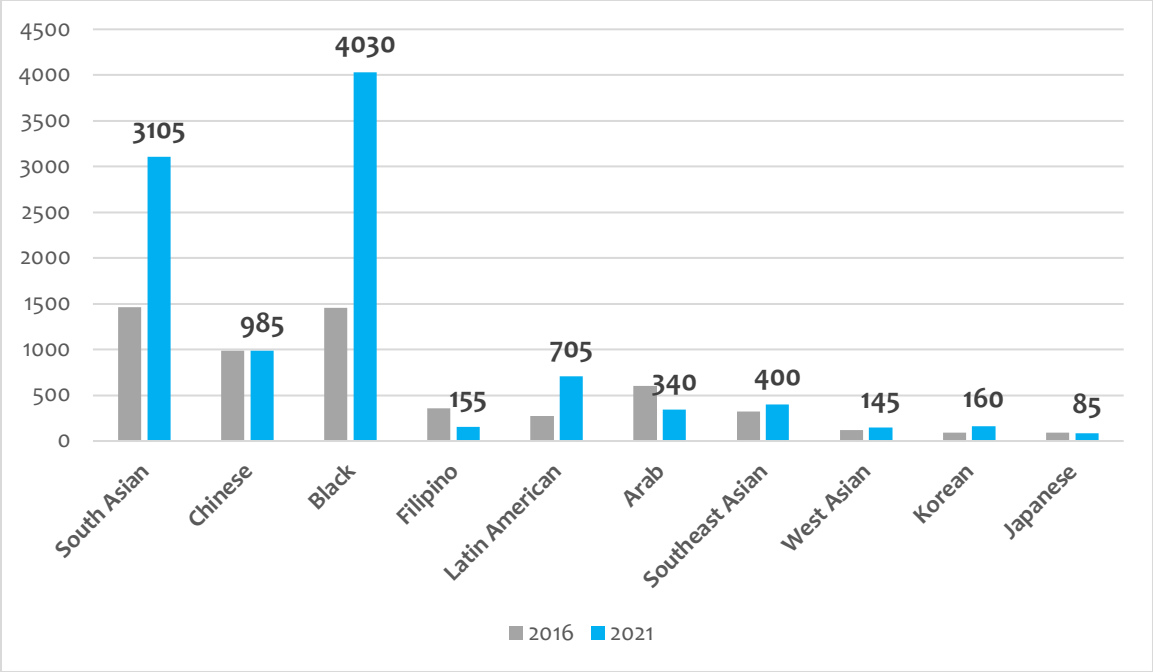
Greater Sudbury is richly endowed with human capital across a range of mining-focused and mining-adjacent trades and professions, with extensive practical experience in the mining industry. These skills have generally evolved with changes in the industry, with work increasingly focused on high-skilled and high-paying trades as well as technology-centric white-collar jobs aboveground.[4]

Education institutions like Laurentian University, Cambrian College and Collège Boréal, as well as mining-focused units within them (e.g., MIRARCO and the Centre for Smart Mining) have played important roles in formally training workers for the industry and fostering collaborations between academics, students, and industry partners.

Another emerging advantage of the region's workforce is its fast-growing diversity (Figure 1). There are now increasing contributions from women, 'new' Canadians, and First Nations to the labour and corporate ranks of the mining industry. Several factors have facilitated this diversity such as the need to acquire new skills and changes in company hiring policies; Impact Benefit Agreements (IBAs) with clauses to hire or contract First Nations' labour and companies; the growth of administrative and technical capacity of First Nations communities; immigration policies like the Rural and Northern Immigration Pilot (RNIP); the possibility and normalization of remote and hybrid work; as well as the sheer necessity to hire beyond the traditional demographics as the industry struggles to attract sufficient labour.

Figure 1: Population of visible minorities in Greater Sudbury, 2016 and 2021

[4] 'Today's mining industry embraces really any kind of people and skillset'. Interview with R&D head at a Sudbury-based SME.



Source: Census Profile 2016 (Statistics Canada, 2016) and Census Profile 2021 (Statistics Canada, 2021).

Another benefit and emerging competitive advantage has come from the much greater emphasis on safety among the region's operators and SMEs. This has resulted in increasingly safer jobs, as well as market opportunities. Several companies have already found this nexus of technology and safety as a lucrative gap in the market (Sofvie, Jannatech, Technica, Maestro). Furthermore, the creation of non-profit entities (NORCAT) to improve safety has made Sudbury a leading location in the teaching, development, and utilization of those skills and practices. These improvements have also come about due to a change in corporate culture, where company executives and managers are now held accountable for worker safety in the mines.

3.3. Supportive governments and institutions

Greater Sudbury also benefits from capable institutions that are active in fostering the industry's growth and developing the skills base of the local population.

For one, Greater Sudbury's municipal government has proven itself both interested in and capable of promoting the mining industry. For example, Greater Sudbury Economic Development (GSDC), a development agency within the city government, devises and executes projects to spur the industry's growth by leading trade expos and industry-focused conferences, facilitating connections between industry and institutions, among other activities.

Support from other levels of government has generally been less direct. Various Sudbury-based companies have received federal government support through long-standing policies like SR&ED tax incentives and the Ontario Ministry of Energy, Northern Development and Mines, as well as from agencies like Export Development Canada (EDC). This support may not be exclusive to mining and may only be beneficial or available only to companies at particular stages of development.[5] Furthermore, the launching of headline-grabbing 'critical minerals' strategies by both the Canadian and Ontario governments in recent years has on the surface been positive for the industry and region, though has been followed up with few tangible actions or concrete details on implementation.[6] Ontario's Bill 71 or the 'Building More Mines Act'[7] represents a more business-friendly amendment to the Mining Act, though it has run into legal complications with several First Nations.[8] The mining legislation has generally been interpreted positively by industry, though its facilitation in achieving the ever-elusive 'social license to operate' is yet to be determined.

Table 1: Select list of public institutions and their objectives in Greater Sudbury

Name of institution	Objectives
Centre for Excellence in Mining Innovation (CEMI)	CEMI develops innovative solutions to improve safety, productivity, and environmental performance in the mining sector. It helps mining companies achieve faster results and higher returns by accelerating the adoption of commercially viable technologies and enhancing the innovation capacity of mining service providers.
Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCO)	MIRARCO is North America's largest non-profit research firm dedicated to the global natural resources sector, with the goal of transforming knowledge into profitable, innovative solutions. MIRARCO develops cutting-edge technologies, practical solutions, and highly skilled professionals to support a safe, productive, and sustainable global mining industry.
Northern Centre for Advanced Technology Inc. (NORCAT)	NORCAT is a non-profit organization, home to the NORCAT Underground Centre, a facility for training and testing new automated mining equipment. Founded in 1995 by business and academic leaders, NORCAT was established to promote, educate, and support entrepreneurs, tech innovators, and skilled workers, driving long-term economic and social prosperity in Northern Ontario. Today, NORCAT has grown into a global company, offering programs and services that equip clients with the skills, competencies, and confidence to achieve their diverse career goals.

Sources: CEMI (2024), MIRARCO (2024), NORCAT (2024), Invest Sudbury (2024b).

[5] Scientific Research and Experimental Development (Government of Canada, 2024).
[6] The Canadian Critical Minerals Strategy (Natural Resources Canada, 2022). Ontario's Critical Minerals Strategy (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2022).
[7] Bill 71, Building More Mines Act, 2023 (Legislative Assembly of Ontario, 2023).
[8] 'Ontario's Mining Act Facing Constitutional Challenge from 6 First Nations' (Liguid, 2024).

There is also considerable institutional support for Sudbury's mining SMEs at the local level (Table 1). These may not formally fall under the category of government entities, with each having different areas of focus and promoting different facets of the industry, such as technological (CEMI, MIRARCO); applied research (Centre for Smart Mining at Cambrian College); financing and scaling up (Northern Ontario Angels, the Foundry at Laurentian University); trade shows and export support (CAMESE; MineConnect; City of Greater Sudbury; Ontario Ministry of Energy, Northern Development and Mines); safety training (NORCAT); and education and learning (Laurentian University, Cambrian College, Collège Boréal, Dynamic Earth, Science North), among different areas of support.

This varied institutional support will be necessary for further growth and development. Likewise, the deepening of networks connecting industry, academia, and government will be important to convey shortcomings and opportunities for policy to policymakers, with the ultimate goal of transforming Greater Sudbury into a global export hub of mining and innovation.

4. Growing within constraints

Despite the achievements of Sudbury's mining SMEs and workforce, we identify five major constraints that may hinder future growth. First, the 'golden era' of employment in Sudbury's mining industry when large numbers of locals were employed directly in the mines and when local influence over financial and operational decisions was significant, has passed. Second, the most obvious gaps in the mining value chain have already been filled. This leads to the third constraint: the significantly reduced rate of mining start-ups being formed on the one hand and the sale of several established homegrown companies (Hard-Line, Jannatech) to larger foreign-based companies on the other raises concerns about the future health of homegrown mining supply ecosystem. Another source of concern may come from technological transformations within the mining industry—either underway or on the horizon—such as the push to reduce carbon intensity, to mine at greater depths, to harness the predictive power of computing, and so on. It isn't entirely clear whether the skill base and knowledge domains within Sudbury are sufficient to innovate and take advantage of these opportunities.

4.1. Mining production as a base for growth, not as generator on its own

Strong demand for Sudbury's ores in industries like steelmaking, aerospace, and increasingly in EVs, will ensure that significant mining activities continue in Sudbury. However, mined output, even with marginal increases in the future, will not necessarily translate into significant increases in revenues or employment numbers. For example, in 2022, Sudbury's mining industry directly employed 7,260 people, a sharp fall from highs of

about 18,000 workers in 1971.[9] Likewise, 64,900 tonnes of nickel worth CAD$1.045 billion in 2020 and just under 124,000 tonnes of copper worth about CAD$890 million were produced from Ontario's mines, a large portion of which came from Sudbury's mines.[10] We see no reason to expect this ratio of labour per production to change in the foreseeable future, especially as innovation and technology continue to enhance productivity, as tends to be the case in other extractive industries. Another brake on greater employment relates to the foreign-owned nature of the operators and OEMs, which would likely translate to growth in 'back office' employment outside the region and not necessarily in Sudbury.

Accordingly, any policy interventions should view mining as an anchor for growth in other related industries, not as the main direct generator of jobs for the region.

4.2. Limited local influence over operations and investments

No 'large cap' mining operator in Greater Sudbury is presently under Sudburian or even Canadian ownership and control.[11] Major decisions about investments, research and financing, hiring and promoting upper-level managers, as well as sourcing equipment and contracting tend to be made in headquarters far from sites of production in Sudbury. Furthermore, these multinational operators based outside Canada are fiduciarily responsible to their shareholders, whose corporate interests and strategies may not necessarily align with those of the local industry, region, or Canada more broadly.[12]

This constraint of limited operational decision-making control must be taken into account in any of the region's mining-related innovation policies.

4.3. Labour and skills shortages

Labour and skills shortages are not exclusive to Sudbury's mining ecosystem, and indeed are industry-wide, spanning a range of jobs as diverse as mining engineers, geologists, drillers, heavy equipment operators, diesel mechanics, health and safety coordinators, as well as managers of various types. These shortages persist despite mining

[9] *Financial Post* in 1971 wrote 'Sudbury remains basically a mining town with two nickel companies providing 50% of the employment' (Wallace & Thomson, 1993). Statistics Canada (2021).
[10] *Facts & Figures 2021* (Mining Association of Canada, 2022), p. 99.
[11] A 'large cap' company has a market capitalization value of more than US$10 billion, a category to which both Glencore (roughly $70bn) and Vale ($50.5bn) qualify. Poland-based KGHM's estimated market cap of US$9.5bn is close to qualifying (GlobalData, 2024).
[12] This translates even to decisions on which ores are mined in Sudbury. For example, some local industry leaders expressed distress at what they see as major operators 'dumbing down' their operations, focusing almost exclusively on nickel and copper, while ignoring some smaller though potentially strategic minerals like vanadium and cobalt.

wages in Ontario being on average 63% higher than the province's industrial average.[13] Similarly, yearly salaries in mining, smelting and refining in Canada averaged CAD$123,000 in 2020, considerably higher than the average of CAD$100,000 paid to those working in forestry and logging, which is the next highest-paying industrial sector, and considerably more than manufacturing ($86,000) and even finance and insurance ($94,200).[14]

Despite these high wages, impressive improvements in worker safety, considerably fewer jobs requiring working underground as well as much greater demographic and gender diversity in the workforce (Figure 1), the mining industry continues to struggle to attract and retain people. A recent McKinsey study found the mining industry to be the least appealing industry among those under 30 years-old old, with 42% of respondents answering that they 'definitely would not' considering work in mining, while another 28% 'probably would not' work in mining.[15] Policies like Rural and Northern Immigration Pilot (RNIP), while helpful, have only partially and temporarily filled labour gaps in the sector.[16]

Any policies to stimulate this industry must also find ways to increase interest among the workforce, especially among young people.

4.4. Where are the next market gaps?

The entrepreneurialism of many Sudbury- and northern Ontario-originated companies that enabled them to successfully identify market gaps and provide industry-specific solutions bodes well for future growth of the region's mining ecosystem. However, correctly identifying the next market gaps will demand greater innovation, ingenuity and resourcefulness among both established Sudbury-based companies and new upstarts joining the fray.

The mining industry is already undergoing significant technological changes, with plenty more ahead. Mining at ever greater depths, electrifying operations and transport through battery-powered equipment, fully or partially automating processes, harnessing 'big data' analytics and artificial intelligence, recovering metals from mineral-rich tailings—these are just a few of the major transformative changes already underway, with the potential to transform the industry in the not-so-distant future. Likewise, the mining industry will continue to experience further incremental innovations in blasting, drilling, hauling, processing, worker safety, and so on. Indeed, some of Sudbury's mining SMEs are already actively participating and driving these changes. Both radical and incremental innovations

[13] Mining jobs in Ontario paid on average CAN$1,951 per week in 2022 (OMA, 2024).
[14] Statistics Canada Table 36-10-0489-01 and Natural Resources Canada cited in *Facts & Figures 2021* (Mining Association of Canada, 2022), p. 110.
[15] 'Has mining lost its luster? Why talent is moving elsewhere and how to bring them back?' (McKinsey & Company, 2023).
[16] 'The north isn't for everyone', one interviewee said. The Rural and Northern Immigration Pilot ended in August 2024.

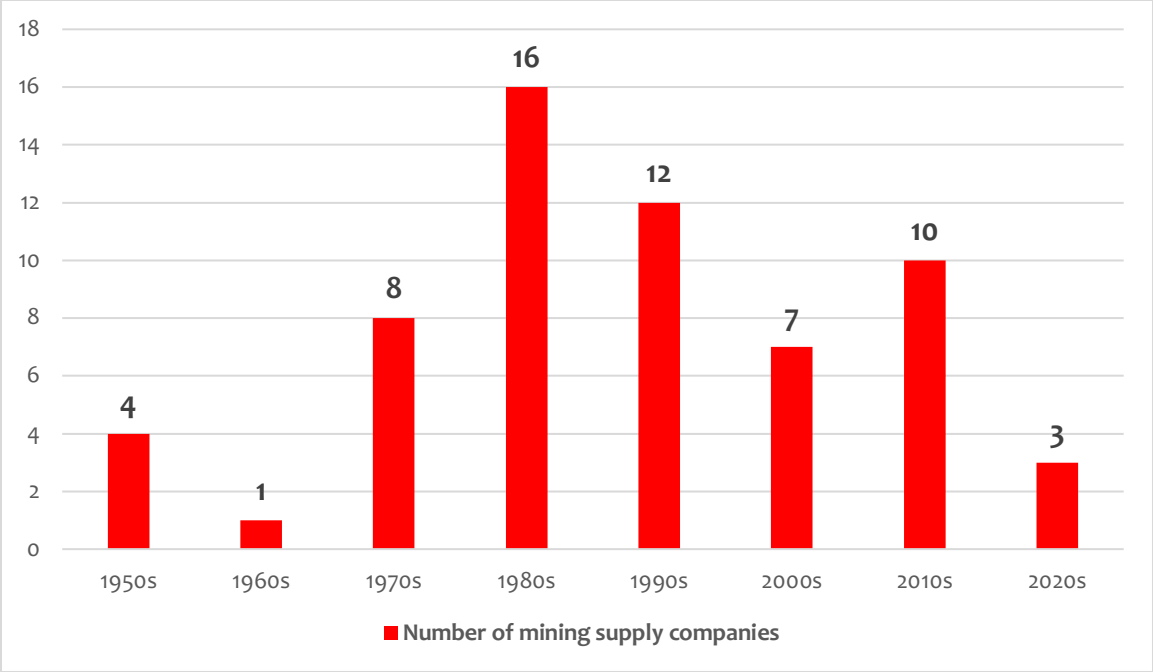
present significant opportunities for Sudbury-based companies and its workforce, though these unfolding and potential changes present enormous commercial opportunities as well as significant risk and uncertainty. This will put a premium on developing new areas of strength among its SMEs and new skills among its workforce, such as growing the pool of chemical engineers, computer engineers and software programmers, while also providing the latest skills and industry practices to its mining and metallurgical engineers, mechanics, millwrights and industrial electricians among others.

The trajectory of these innovations and their application will also be impacted by market changes, including metal prices, EV adoption rates, changing battery chemistries and the like, which will continually test the abilities of these companies to adapt to new technologies, modify existing ones, and to acquire new skills that fit these changes.

4.5. Declining rates of new business formation and acquisition of Sudburian SMEs by foreign companies

Going back to at least the 1950s, Greater Sudbury's mining supply chain has expanded, notably with many companies being formed and some growing to impressive sizes and levels of sophistication (Figure 2). However, a worrying trend has emerged. On one hand, several successful companies, including prominent companies like Hard-Line, Jannatech and Mining Technologies International, which were on the verge of becoming global suppliers, have been purchased by larger, foreign-based companies, interestingly from Sweden and Japan. On the other hand, Sudbury has experienced a slowdown in the number of mining-focused start-ups being formed.

Figure 2: Number of Sudburian mining supply and service companies formed by decade



Source: MineConnect (2024).

Note 1: The number of mining supply companies shown in the diagram above only include mining supply companies that are members of MineConnect.

Note 2: At the time of collecting the data (September 2024), the data for the 2020s was only available up to 2024.

Together those two trends are a reason to worry about the future of local ownership and control, as well as the sustainability of Sudbury's mining ecosystem itself, a gap that this white paper seeks to address.

5. Recommendations: Turning Greater Sudbury into a global export hub of mining innovation and sustained prosperity

This white paper seeks to transform Sudbury into a world-leading export hub of hard-rock mining solutions, equipment, services and knowhow. To do so, four recommendations are proposed:

1. **Encourage and assist Sudburian companies to export** their equipment and knowledge-based solutions, actively embracing the global nature of the mining industry and its lucrative possibilities.

2. **Deepen the skills base within the region,** with particular emphasis on skilled trades, integrating information-communications technologies (ICT) into mining operations, further research in materials science, as well as greater learning of international business and languages.

3. **Develop shared assets** that coordinate different types of local mining participants, including operators, SMEs, and institutions to partner in undertaking mining-related innovations while also dispersing risk, which would contribute to making Sudbury the global mining industry's go-to place for new and old companies seeking to learn, develop, and incorporate the latest technologies and solutions into their operations.

4. **Make explicit connections between Sudbury's skills and asset base to the national security of Canada and its allies**, which will commit greater resources to the region and its SMEs, which will help to ensure a steady supply of 'critical minerals' and likely generate mining innovations that very likely can be applied in other jurisdictions within and outside of Canada.

These four recommendations are interlinked, mutually strengthening, and should be pursued in tandem as part of the larger effort to transform Greater Sudbury into a global export hub of mining solutions, equipment, services, and know-how. As such, these recommendations aim to capture greater value from mining-related activities in the region.

5.1. Encourage exports

Mining supply and service companies that originated in Greater Sudbury have successfully responded to demands of the local and regional mining industries. However, they have tended to be much less active in pursuing opportunities abroad. We recommend measures that actively target foreign markets for sales. The aim should be to make future Sudbury's SMEs be 'born global,' while also giving established SMEs easier access to resources that both situate and to compete in a global market. This is an achievable goal specifically because Sudbury's SMEs have already shown some success in exporting. It is time to build on this success and make it the main metric for success.

This export-oriented pathway has vast potential to deliver sustainable growth and prosperity for multiple reasons. For one, Sudbury-based supply and service companies are so varied in their experiences and knowledge bases that they could provide various solutions and technologies to different hard-rock mining challenges in other jurisdictions, and not be dependent on any single niche for future business. Furthermore, Sudbury's mining-focused SMEs have already proven capable of supplying technologies and solutions to several of the world's largest operators like Vale and Glencore as well as to world-class OEMs like Epiroc, Komatsu and Sandvik. Another benefit of an export-oriented focus would help to break through the persistent and widely acknowledged 'first to be second' mentality among the region's SMEs and mining industry more generally.

Increasing exports will diversify the customer base of Sudbury's mining SMEs. This has the dual benefits of increasing their resilience to industry cycles while also diversifying the types of mined minerals and metals for which these SMEs will provide their equipment and technological solutions. As such, this more export-oriented approach will tap into the much larger global demand for metals, including and not exclusive to mined nickel, copper

and gold. This greater diversity—in clients as well as in mined minerals—will also help to shoulder some of the inevitable price fluctuations and changes in demand. Indeed, the existence of abundant though challenging reserves and mines outside Greater Sudbury will require durable and high-quality equipment as well as effective solutions—in engineering, software, management, among others—all areas where the skills and equipment of Sudbury-based SMEs could be widely applied and appreciated. One potentially high-growth area for Sudbury's mining SMEs could be in hard-rock lithium mining, as this metal is vital to lithium-ion batteries for EVs and stationary storage, and whose demand is expected to grow exponentially in years to come.

Several measures could help to encourage Sudbury's mining supply and service companies to export more. For one, grants and funding could be tied to export-oriented or export-viable projects. Likewise, greater funding could be made available for the region's several institutions that already promote export strategies of the region's SMEs, such as MineConnect; MSTA; Export Development Canada (EDC); and the Ontario Ministry of Energy, Northern Development and Mines. To this, entities like the Greater Sudbury Economic Development agency within the municipal government have made significant efforts to host events that both showcase the skills of Sudbury-based companies and to foster exchanges with foreign peers and operators. More programming of this sort, despite the lack of immediate and tangible benefits, are needed.

5.2. Expand the skills and knowledge base

Greater Sudbury boasts a robust skills base and experienced workforce, with expertise particularly in the upstream segment of exploring, extracting, and hauling in the very challenging underground hard-rock mining environment. This experience has been built over a century of mining in the region and has been sustained and improved upon within an ecosystem of companies capable of performing different specialized tasks or producing advanced equipment.

Amid the many changes in technologies and practices in underground mining, there are areas where the region's workforce could be made even more competitive. For one, we recommend greater emphasis on training across a range of skilled trades, such as for welders, millwrights, mechanics, electricians, instrumentation technicians, to name a few. This can be done through programs that publicize the importance and benefits of working in skilled trades to high-school and even grade-school students, as exhibitions and programs at Dynamic Earth and Science North have been doing.

Programs to retrain or to upgrade skills of those already in the workforce will also be valuable in helping to fill the gaping shortages across skilled trades and to prepare this workforce for a mining industry that is undergoing significant technological changes. For Sudbury's SMEs and the region more broadly to become a global mining export hub, including of the next generation's mining technologies and practices, priority should be on

developing this wide range of skills now, as this concerted effort would largely help to convert these daunting risks facing the industry into opportunities for the region.

We also suggest specialized programs that increase understanding and knowledge of information-communication technologies (ICT) since the importance of these technologies to mining, as evident in automation, digitalization and robotization, will only grow in years to come. Several Sudbury-based companies have already had substantial success in incorporating and adapting both software and hardware ICT to make workers safer and more productive in the harsh underground mining environment; to connect surface operations with the 'mine's face'; and overall to find greater efficiencies and productivity in extracting, moving and processing ore bodies. Deepening this ICT-centric knowledge base through multi-year programs as well as 'short courses' and seminars will likely enable Sudbury-based entrepreneurs and mining workers to identify further opportunities to integrate ICT-based solutions into their operations. These ICT-based solutions are also transferable, applicable to a substantially larger client base and mines outside of Greater Sudbury, and thus further serve the objective of increasing the global competitiveness of Sudbury's SMEs.

For another, in expanding the skills base of the workforce, we suggest greater efforts to finance and engage in advanced research and training in materials science, which builds on work currently underway at MIRARCO. This interdisciplinary field of researching and discovering materials as well as finding uses for materials in other fields and industries is a recurring theme in the history of the modern mining industry. It continues to hold significant promise, for example by yielding powerful breakthroughs in recovering metals from tailings and recycling, among others.

Building on the previous recommendation to encourage exports among Sudbury's mining SMEs, we also suggest more programming and training in particular subfields of international business and language training. This learning may come in the form of multi-year and short-term degrees or seminars and 'short courses'. Furthermore, this more international focus may also include greater training in foreign languages. To this, there are potentially vital roles that public institutions like Laurentian University, Cambrian College and Collège Boréal and even for semi-public institutions like NORCAT and Centre for Mining in Excellence Innovation (CEMI) could play as hosts or facilitators of this learning.

The region also boasts the advantage of being home to a large Francophone and French-speaking population. Estimated at nearly 62,000 people or nearly 38% of Sudbury's population, this population could be active participants in network- and business growth not just in Quebec but in French-speaking mining-rich jurisdictions abroad such as New Caledonia and parts of Africa.[17] To this skill base, we must also add the growing number of non-Anglophone and -Francophone peoples in Greater Sudbury. These groups, made up of permanent residents (PR), workers such as those brought by RNIP, and 'new' Canadians,

[17] Knowledge of the French language in Greater Sudbury from the 2021 Census of Population of Statistics Canada (2022).

may facilitate some of these connections and the building of networks abroad, with plenty of opportunities to become more actively engaged in Sudbury's newfound global orientation proposed in this white paper.

5.3. Develop 'shared assets'

The mining industry in Greater Sudbury and abroad has long faced nagging problems of coordination and collective action that have hindered more innovative approaches across the value chain. We suggest an approach that develops and possibly leads to shared ownership between stakeholders, such as a new smelter, processing plant or joint exploration and research into novel technologies and approaches (e.g. ultra-deep mining, tailings recovery, digitalization) as well as patents and other intellectual properties that emerge from that research. This collaborative approach toward 'shared assets' may bring together operators like Vale or Glencore, certain suppliers, as well as local government and public institutions, depending on the project and asset in question. This approach would bring together diverse viewpoints that could yield potentially novel solutions while also dispersing risk among the parties, allowing entrepreneurs and companies to engage with technologies and activities that otherwise would have been inaccessible due to the cost, uncertainty, or myriad other reasons. This approach of 'shared assets' also holds the potential promise of becoming a magnet for other mining companies, suppliers, start-ups and institutions eagerly searching for a location to develop and test nascent technologies.

These collaborations may also be vital in coping with looming technological change and uncertainty facing the mining industry, such as from advanced data collection, generative artificial intelligence (AI) as well as further advances in designing 'digital twins' and mapping of mines. To this list, we should also add wearable technologies for personnel, fully or partially autonomous operations, as well as battery-powered machinery and vehicles. Indeed, many innovations that have proven transformative to mining have originated outside the mining industry, but became transformative once tailored to the harsh conditions of mining. This puts an added premium on the above suggestions to deepen knowledge of info-communications technologies and to train and upgrade skills of workers.

The necessity both to mine greater quantities of minerals while also adopting more sustainable mining practices inevitably leads to a question with no easy answer: who would lead a radical transformation of the mining industry? Globe-spanning 'large cap' operators may have resources—human and financial—but are constrained by shareholders and make decisions through the prism of global portfolios. Similarly, OEMs are often locked into the dominant paradigm of the major operators, and this 'lock in' becomes even more pronounced further down the supply chain. Ultimately, the industry's players—large and small—all seem tied into the same model and modes of operation, notably the carbon-intensive and invasive model of blasting, tunneling, and load-haul-dump (LHD) operations. Conversely, those interested in 'disrupting' this paradigm lack the financial and human resources to do so.

Any pursuit of radical or potential radical innovations in mining, whether in the form of 'continuous' mining, deep mining, or for certain metals and geologies leaching or in-situ production, as well as greater use of rail, non-diesel-powered drivetrains, smaller and more numerous vehicles, and so on, would inevitably require manpower and financial might well beyond what Sudbury's companies and workforce alone could muster.

In the face of these daunting challenges, a more coordinated, risk-sharing approach which may yield potentially transformative results is necessary. To this, any significant endeavour into *any* of these technologies would require a much greater role for government, to which we now turn.

5.4. Connect Sudbury's resource and skills base with the national security of Canada and allies

Canada's Critical Minerals Strategy acknowledges a 'generational opportunity for Canada's workers, economy, and net-zero future,' and envisions a supply of 'responsibly sourced' critical minerals, while also supporting the development of both domestic and global value chains.[18] Recent calls to secure mineral supplies and 'friend-shore' global supply chains through initiatives like critical minerals strategies of both the Canadian and Ontario governments have yet to translate into much tangible action or even greater focus on mining- and mining skills-rich regions like Greater Sudbury. This white paper recommends explicitly connecting Sudbury's mineral and human capital base with strategically important mineral supplies of Canada and its allies.

A larger government presence could lead to greater cooperation between otherwise uncoordinated players, which include companies as well as public and semi-public institutions. It may also provide a clearer and sounder framework for sustained cooperation over a significant period. This would require a shift in both federal and provincial governments' previous 'light' touch, as in the form of SR&ED tax credits, to one that is more active and coordinating in nature.

These final two suggestions—to develop 'shared assets' between various parties and to tie Sudbury's resource and skills base to Canada's national security—could bring together operators, certain suppliers, as well as public institutions and governments at different levels to help solve nagging coordination and collective-action problems, while also committing much greater resources to the region and its mining industry.

[18] According to the Canadian Critical Minerals Strategy (2022), critical minerals deemed *critical* in Canada when a mineral is: 1) "essential to Canada's economic security and it supply is threatened"; or 2) "required for Canada's national transition to a low-carbon economy"; or 3) "a sustainable source of highly strategic critical minerals for Canada's partners and allies".

6. Conclusion: Beware of complacency

Greater Sudbury's mining economy has exhibited impressive staying power despite jarring changes in commodity prices, ownership handovers among operators, environmental devastation from previous mining practices, regulatory changes, as well as host of technological changes. This longevity can be attributed to the ample skills base, networks, homegrown companies in different parts of the mining value chain, supportive institutions as well as to major investments from big operators.

The continued demand for the high-grade nickel and copper that Greater Sudbury's mines yield—metals that will be vital to the world's decarbonization efforts—have revived interest in the mining industry and the region. But the temptation to fall into old habits will be strong. A status quo approach will only minimally tap the current once-in-a-century opportunity for the region's peoples and companies to actively contribute to making mining more innovative, inclusive and sustainable.

Events in recent years have sent out several warning signals of the turbulence ahead. For one, the much-heralded energy transition hasn't brought about the expected boom in commodity prices, especially for nickel and to a lesser extent for copper. There is considerable technological uncertainty as well, especially on end-use technologies and their metal intensities. The global EV battery market has seen the emergence of cost-effective alternative battery chemistries that require little or no nickel or cobalt at all, such as lithium iron phosphate (LFP) batteries.

There is no shortage of uncertainty and risk ahead—for the region, its companies, workforce and supporting institutions. This should only increase the urgency to prioritize and accelerate Greater Sudbury's transformation into a global export hub for industry-leading mining solutions, equipment and know-how.

To this end, this white paper made several recommendations, putting forth some measures to amplify the global competitiveness of its companies and workforce. These recommendations included greater training in various mining-related skilled trades, increased knowledge and incorporation of information communications technologies into mining and mining-related activities, greater funding and research in the interdisciplinary field of materials science, as well as greater training in international business and foreign languages.

These measures are mutually interlinked and should be pursued concurrently to bolster the global competitiveness and export-oriented push of Sudbury's SMEs, and to help transform Sudbury into a world-class mining export hub that can convert the many risks facing the industry and Sudbury into opportunities for profits and shared prosperity.

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