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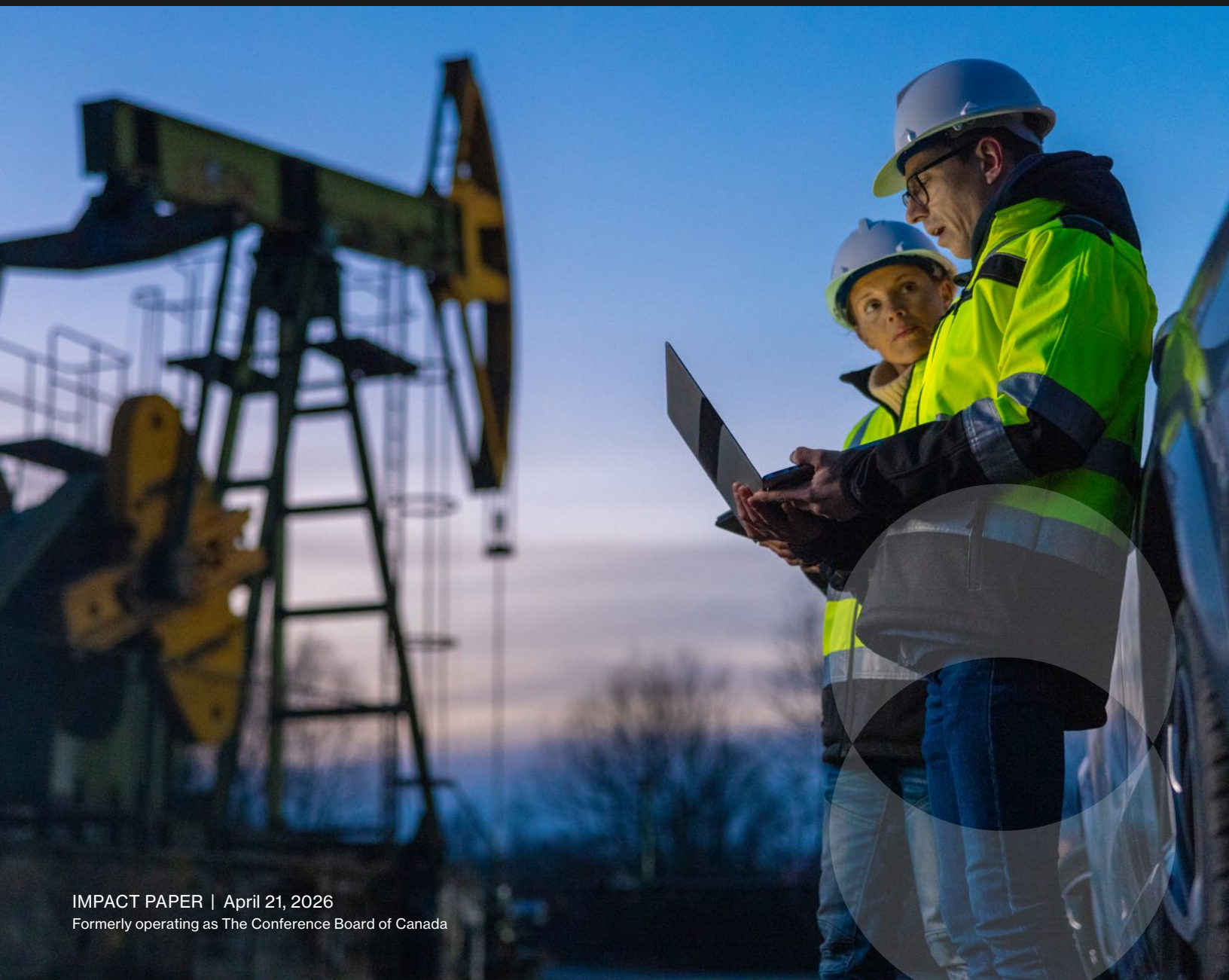
Fuelling Our Future

Talent and Technology in Canada's Mining and Oil & Gas Industries



IMPACT PAPER | April 21, 2026
Formerly operating as The Conference Board of Canada

Future Skills Centre | Centre des Compétences futures

The Future Skills Centre (FSC) is a forward-thinking centre for research and collaboration dedicated to driving innovation in skills development so that everyone in Canada can be prepared for the future of work. We partner with policymakers, researchers, practitioners, employers and labour, and post-secondary institutions to solve pressing labour market challenges and ensure that everyone can benefit from relevant lifelong learning opportunities. We are founded by a consortium whose members are Toronto Metropolitan University, Blueprint, and Signal49 Research, and are funded by the Government of Canada's Future Skills Program.

In partnership with: Toronto Metropolitan University, Signal49 RESEARCH, Blueprint

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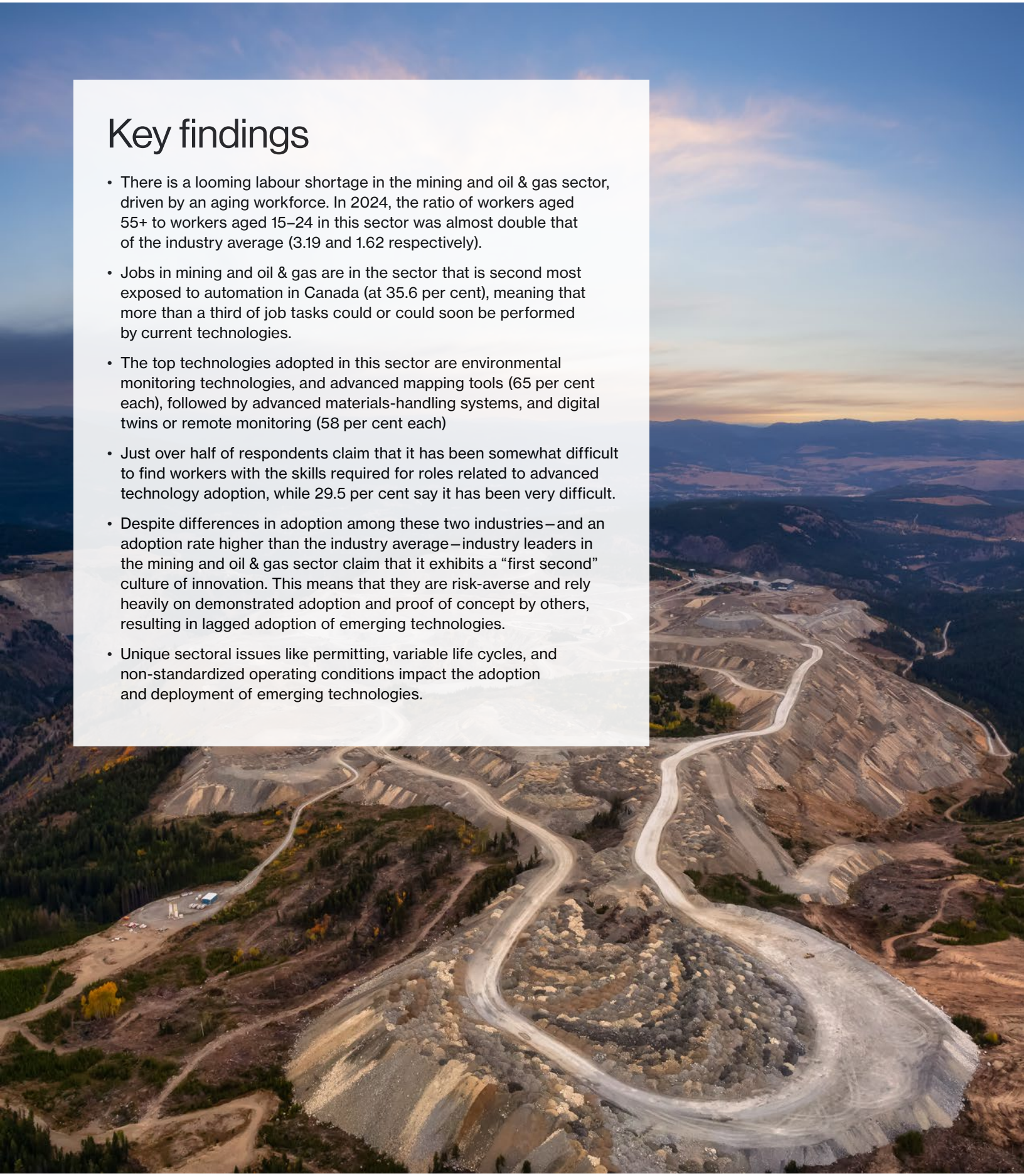


Key findings

- There is a looming labour shortage in the mining and oil & gas sector, driven by an aging workforce. In 2024, the ratio of workers aged 55+ to workers aged 15–24 in this sector was almost double that of the industry average (3.19 and 1.62 respectively).
- Jobs in mining and oil & gas are in the sector that is second most exposed to automation in Canada (at 35.6 per cent), meaning that more than a third of job tasks could or could soon be performed by current technologies.
- The top technologies adopted in this sector are environmental monitoring technologies, and advanced mapping tools (65 per cent each), followed by advanced materials-handling systems, and digital twins or remote monitoring (58 per cent each)
- Just over half of respondents claim that it has been somewhat difficult to find workers with the skills required for roles related to advanced technology adoption, while 29.5 per cent say it has been very difficult.
- Despite differences in adoption among these two industries—and an adoption rate higher than the industry average—industry leaders in the mining and oil & gas sector claim that it exhibits a “first second” culture of innovation. This means that they are risk-averse and rely heavily on demonstrated adoption and proof of concept by others, resulting in lagged adoption of emerging technologies.
- Unique sectoral issues like permitting, variable life cycles, and non-standardized operating conditions impact the adoption and deployment of emerging technologies.

Achieving our promise

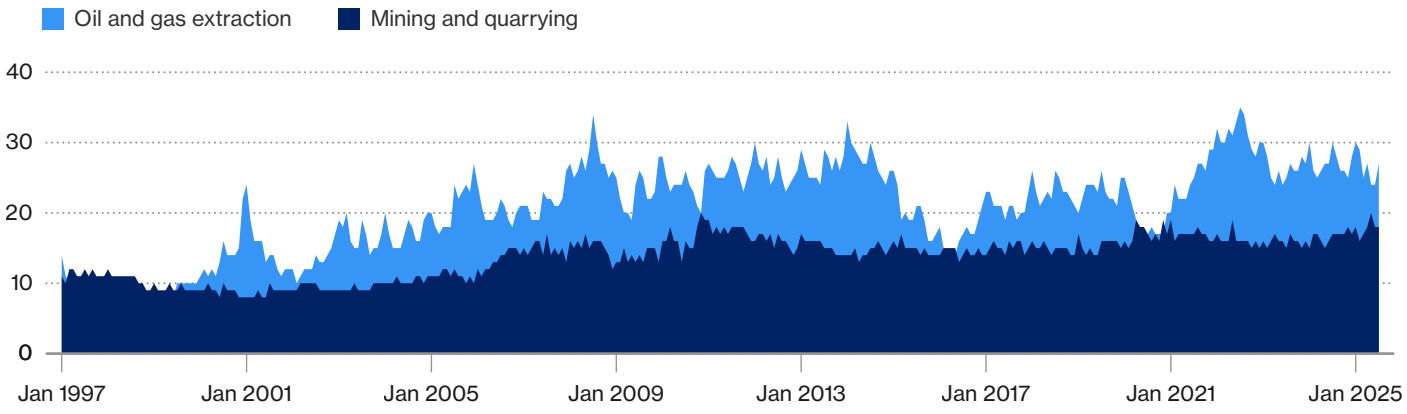
Mining and quarrying (hereafter referred to as mining in the text) and oil & gas extraction (hereafter referred to as oil & gas in the text) are two of Canada's most productive and strategically important industries.[1]

They comprise approximately 5.2 per cent of our GDP (as of August 2025)[2] and help establish national sovereignty in the face of geopolitical turbulence. Notably, their share of Canada's exports has approximately doubled from 1997 to 2008 and remained around that level since. (See Chart 1.)

The oil & gas industry is poised to play a central role in securing our energy future and is an important driver of developing technologies around carbon capture and reduction.[3]

For its part, the Canadian mining industry is essential in supplying critical minerals, such as lithium, nickel, and cobalt, all necessary for clean-energy technologies, electric vehicles, and battery storage.[4] As global demand for these resources accelerates, Canada's ability to sustainably and competitively extract and process them will be a key determinant of its future economic resilience and geopolitical influence.

Chart 1
Primary industries' share of goods exports increased over time
(percentage share)



Sources: Statistics Canada; Signal49 Research.

1 We refer to mining and oil & gas collectively as a primary sector and individually to each of them as a mining industry or oil & gas industry.
2 Statistics Canada, "Gross domestic product (GDP) at basic prices."
3 Canadian Climate Institute, "Concentrated-stream carbon capture."
4 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*.

Underscoring the sector's potential, these two industries featured prominently in the federal government's 2025 budget,[5] which includes a broad Critical Minerals Sovereign Fund ($2 billion), focusing on helping critical minerals projects (e.g., Ontario's Ring of Fire, British Columbia's Golden Triangle) expedite the investment process through the First and Last Mile Fund ($371.8 million). The budget additionally proposes reinstating accelerated capital cost allowances (CCA) for liquefied natural gas (LNG) equipment and low-carbon LNG facilities.

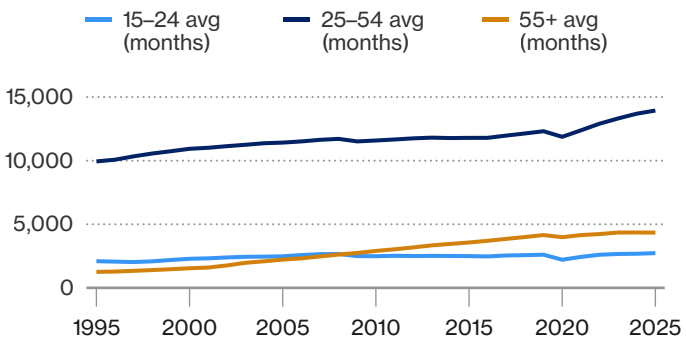
But these industries face a substantial challenge: there's a shortage of workers now, and the talent pipeline is narrowing further. Given the growing challenge, we explored how firms are responding by speaking with 33 industry and post-secondary leaders, collecting over 200 survey responses, and conducting an automation-exposure analysis for core occupations within the sector. We find that automation may help address labour shortages and, at the same time, create higher-skilled roles in technology, maintenance, and systems integration that can attract a younger, tech-savvy workforce.

The narrowing talent pipeline

Fewer young Canadians are pursuing careers in mining or oil & gas. Over the last 30 years, the age profile of workers in the mining and oil & gas sector has changed substantially. Looking at Statistics Canada's Labour Force Survey,[6] 2008 marked an inflection point where the monthly average number of individuals aged 55 years and older surpassed the monthly average number of 15–24 year-olds in Canada's labour force. (See Chart 2.) For all industries, the ratio of older to younger workers, 1.17 (2,904,500 jobs/2,488,400 jobs), increased slightly from 2010 to 1.52 (4,353,900 jobs/ 2,682,500 jobs) in 2024. But when we look at the mining and oil & gas sector, the gap widened. With a low of 1.31 (30,800 jobs/23,600 jobs) in 2010, the age gap for mining and oil & gas reached its highest peak in 2024 at 3.19 (52,700 jobs/16,500 jobs) (see Chart 3), nearly double the industry average.

The gap highlights a worrying trend of the persistent lack of young (15–24 year-old) recruits in the mining and oil & gas sector who are needed to sustain the workforce.

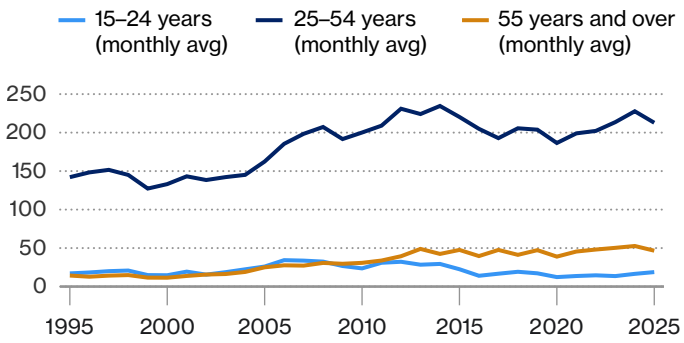
Chart 2
Employment in all industries
(employment, 000s)



Source: Statistics Canada; Signal49 Research.

5 Department of Finance Canada, *Budget 2025*, "Building a stronger Canadian economy."
6 Statistics Canada, "Employment rate by age group, October 2025."

Chart 3
Employment in mining and oil & gas (1995–2024)
(employment, 000s)



Sources: Statistics Canada; Signal49 Research.

Enrolment and expression of interest

Post-secondary institution leaders told us that they are concerned that there is an aversion to careers in mining and oil & gas. For instance, the Mining Industry Resources Council reported that a 2020 survey showed 42 per cent of young Canadians (ages 15-20) "definitely would not consider" working in mining, and 38 per cent "definitely would not consider" working in oil & gas.[7]

The public perception paradox

Studies of public perception show that both mining and oil & gas industries have high public support.[8] For instance, a mining industry professional reflecting on studies of the public perception of mining claimed that "people generally have a good opinion of mining but that doesn't mean they want to work in the industry. That's the paradox: strong public support, but low interest in mining careers."

Additionally, a national survey conducted by Nanos for the University of Ottawa in August 2025 reported that 84 per cent of respondents say that oil & gas is important for Canada's current economy, and 67 per cent of respondents say that oil & gas is important to Canada's future economy (up from 41 per cent recorded in 2020).[9]

8 Transfert Environnement et Societé, "Social Acceptability Barometer: Canadian Mining Sector"; Mining Association of Canada, "Public Opinion Polling"; Environics Research, *Canada 2025: The Next Energy Superpower?*

9 University of Ottawa Positive Energy Program, "Agreement that Canada should expand oil and gas exports."

7 Mining Industry Human Resources Council, "From Classroom to Mine Site: A Review of Canada's Postsecondary Education Pipeline for the Mining Sector."

Adjacent to the decreased interest from Canadian-born students in mining and oil & gas is the tighter caps on accepting international students into the pipeline.[10] This further constricts the talent pool as international students have two key effects in the sector—they help keep programs alive, and they offer an alternative source of talent to the Canadian workforce.

In their own words

"Enrolment was good in the mid-2000s, then slowly dropped, and hit a low during COVID."
Post-secondary education professional

"Where will my talent come from? Industry stats show about 10,000 mining jobs open each year for the next decade, just from retirements."
Post-secondary education professional

"International students have kept some programs alive when domestic enrolment was low. Without them, these programs could be at risk."
Post-secondary education professional

"If we are really serious about rebuilding our nation for the future, then we need to invest in these types of programs. If we don't do any of that, then it's the same old, same old, and less Canadian companies will be able to compete on the international market."
Mining industry professional

Industry and post-secondary institutions

Nearly 50 per cent of our survey respondents cited credentialism (overemphasis on formal credentials over practical experience) as a strong institutional barrier, and almost one-quarter of respondents think that post-secondary programs are not aligned with industry needs.

During interviews, respondents noted that the disconnect is with universities, not with polytechnic institutions.

In their own words

"There's a gap in how we train people. Universities aren't aligned with industry needs, but polytechnics are doing an excellent job."
Support industry professional

"All our [polytechnic] programs have advisory committees with industry representatives. We aim to include a broad mix of industry voices. We constantly adjust our curriculum and training tools based on their feedback."
Post-secondary education professional

10 Immigration, Refugees and Citizenship Canada, "2026 provincial and territorial allocations under the international student cap."

Extracting the future workforce

In addition to the difficulties of a dwindling talent pipeline, work in mining and oil & gas is often located in remote areas of the country. This work condition adds to the challenge of securing employees; remote sites and fly-in fly-out camp lifestyles deter many potential workers from pursuing a career in mining and oil & gas. For instance, of the top 100 exploration projects, the most southern mining operation in Canada is at Crean Hill in Sault Ste. Marie, while most oil & gas projects are in Alberta outside of city centres.[11]

To address the difficulty of bringing workers to remote sites, post-secondary and industry professionals have suggested increasing Indigenous participation in these industries. Both the Mining Association of Canada and the Canadian Association of Petroleum Producers have produced reports that highlight work partnerships with Indigenous communities[12] and the representation of Indigenous workers in both mining and oil & gas.[13] This call for increased participation aligns with our survey findings; one-quarter of survey respondents reported under-representation of Indigenous people. Additionally, Indigenous-led partnerships for both mining and oil & gas projects can provide lasting benefits for communities going forward.[14]

In their own words

"Not enough people are entering mining because they don't want to live outside big cities. They say, 'I can't live in Vancouver or Toronto? I have to go to Timmins or Flin Flon?' That turns them off. In the U.S., mining schools have dropped to a fraction of what they used to be because there aren't enough students, and jobs weren't steady. But the bigger issue is that people don't want to live in remote areas."
Mining industry professional

"Industry wants to hire and do business, but they're unsure who to contact and don't want to say the wrong thing. So, instead of risking a mistake, they wait for Indigenous workforce partners to reach out."
Post-secondary education professional

11 Natural Resources Canada, "Canada's Minerals and Mining Map."
12 Mining Association of Canada, "Indigenous and Community Relationships."
13 Canadian Association of Petroleum Producers, "Indigenous people's involvement in economic contribution and reconciliation in Canada's oil and natural gas industry."
14 Canadian Institute of Mining, Metallurgy and Petroleum, "Mining and Reconciliation: Reflecting on the National Day for Truth and Reconciliation."

Opportunities born of innovations

Canada's mining and oil & gas industries face a dual reality: automation offers a powerful lever to address labour shortages, boost productivity, and appeal to a new generation of workers drawn to high-tech careers. But automation also poses sizable risks for workers whose roles are highly exposed to technological substitution. This tension underscores why workforce transition planning is critical.

Without proactive strategies, a "business as usual" approach will not suffice. Attracting and retaining talent remains essential, and firms are increasingly turning to automation and advanced technologies to fill gaps, improve efficiency, and address talent pipeline issues. For example, initiatives like "This Is Mine Life"[15] showcase the industry's technological transformation, highlighting roles that combine software development and engineering with resource extraction, helping to reframe mining and oil & gas as innovation-driven sectors.

> "We participated in something called 'This Is Mine Life', telling stories of the cool tech you'll be able to use, and your work-life balance. You could live your life as a software developer and work in that industry."
> **Post-secondary education professional**

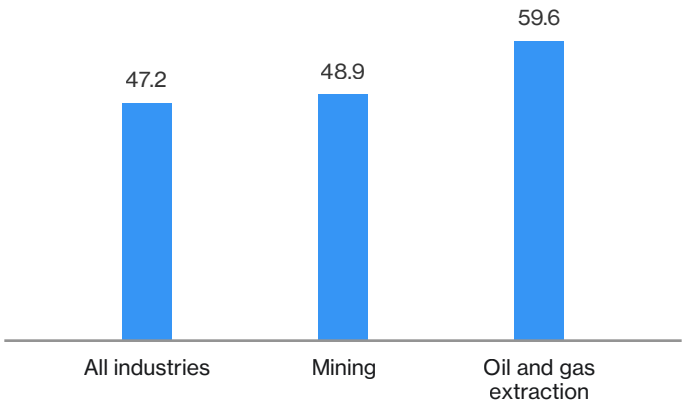
Yet the opportunity comes with responsibility. High-exposure scores in core occupations mean that automation could displace thousands of workers if adoption accelerates without parallel investment in skills development. Technology adoption therefore needs to run concurrently with reskilling programs, job transition pathways, and partnerships with post-secondary institutions to ensure that workers transition into emerging roles rather than exit the labour force entirely.

In short, automation is not only a solution to labour shortages, but also a catalyst for structural change. Harnessing its benefits while mitigating its risks will define the sector's ability to remain competitive, inclusive, and resilient in the decades ahead.

Automation's untapped potential

Exposure scores (i.e., a measure of how susceptible occupations are to automation) help identify where disruption is most likely and where reskilling efforts should be prioritized.[16] Mining and oil & gas are among the most exposed sectors to automation technologies in Canada.[17] But, despite having higher-than-industry-average adoption of advanced technologies (see Chart 4), they still have unrealized productivity potential from automation.

Chart 4
Oil & gas firms use advanced technology more often than mining firms
(percentage share of firms that use given advanced technology, 2022)



Sources: Statistics Canada, "Survey of Advanced Technology"; Signal49 Research.

15 Ontario Mining Association, "This is Mine Life."

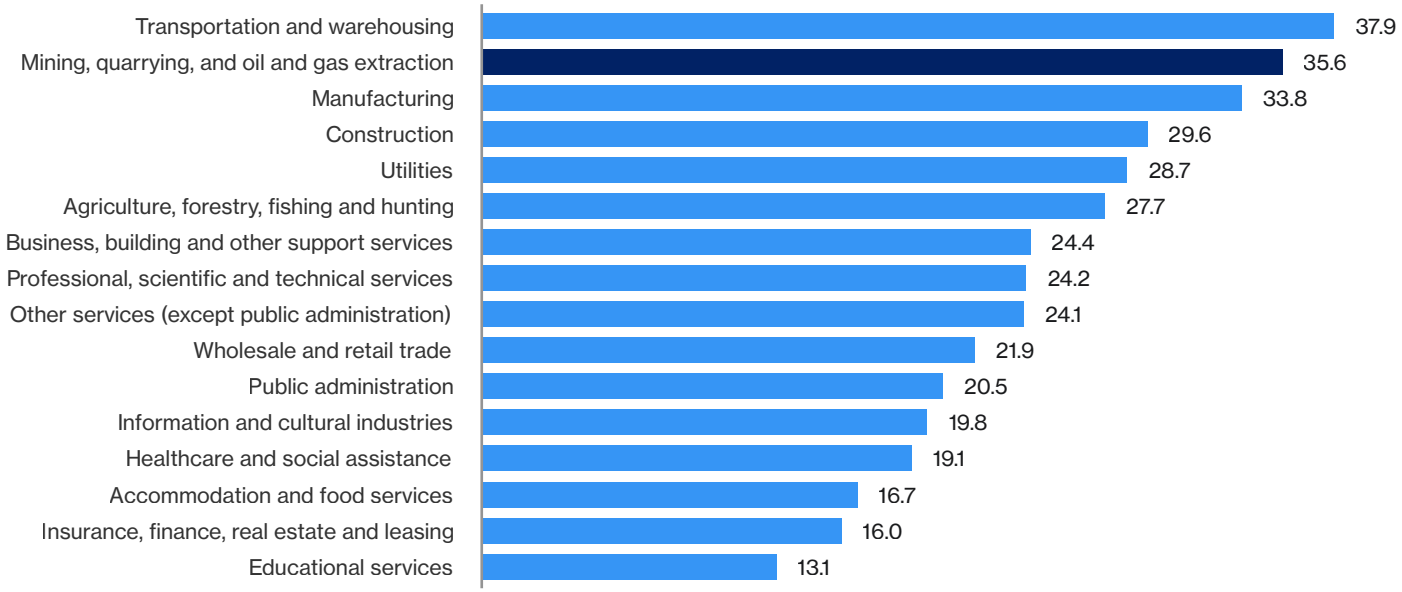
16 Automation score is the percentage share of tasks in an occupation that could be automated with current technologies.

17 More than one-third of job tasks in mining and oil & gas could be automated with existing technologies. Mining and oil & gas is just behind transportation and warehousing in terms of automation exposure.

Our estimates show that the mining and oil & gas sector has an average automation-exposure score of 35.6 per cent (see Chart 5 and Appendix A for details on calculation),[18] meaning that more than one-third of the tasks performed in these industries could be automated using technologies available today. To put this in perspective, only the transportation and warehousing sector ranks higher, with an exposure score of 37.9. These scores signal how deeply automation could reshape work in these sectors. A score of 35.6 suggests that routine, mechanical, and process-driven tasks make up a considerable share of the work, making them prime candidates for automation through robotics, AI, and remote-controlled systems.

This creates both risk and opportunity for both workers and firms: risk for workers because working in highly exposed roles may result in displacement; risk for firms in the cost of innovation and automation (especially in a capital-intensive sector, which will be explored later); simultaneously, opportunity for workers to both upskill and work off-site (contingent on the technology); and opportunity if firms can unlock major productivity and efficiency gains through automation.

Chart 5
Primary industries are the second most exposed sector to automation
(percentage of job tasks that can be automated)



Sources: Signal49 Research.

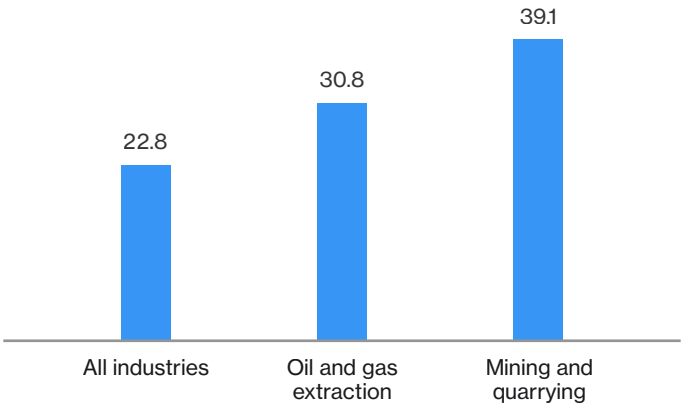
18 Automation exposure is defined as the percentage share of tasks within occupations estimated to be automatable, aggregated to sectors using employment-weighted occupational distributions so that exposure reflects both task-level susceptibility and the concentration of exposed occupations within each industry.

Chart 6 reveals that mining has higher automation potential (39.1 per cent) than oil & gas (30.8 per cent), both well above the economy-wide average of 22.8 per cent. The distinction is critical for workforce planning, as it suggests that even within the sector, the degree of automation exposure can vary substantially, requiring industry-tailored strategies for adoption and reskilling.

Chart 6

Automation potential is higher in mining sector than the oil and gas sector

(percentage of job tasks that can be automated)



Sources: Signal49 Research.

In the mining industry, 9.7 per cent of occupations are classified as highly exposed to automation, but these roles account for 40.2 per cent of total employment. (See Table 1.) This means that a relatively small set of jobs, those most vulnerable to automation, represent a large share of the workforce. This concentration of employment in high-exposure roles highlights a big opportunity. Automation can help alleviate labour shortages when applied to routine, physically demanding tasks that are increasingly difficult to staff. At the same time, it creates space for new, higher-skilled roles in technology, maintenance, and systems integration, roles that can attract a younger, tech-savvy workforce.

Equally important is the medium-exposure category, which accounts for 39.7 per cent of occupations and 33.2 per cent of employment. These roles are not likely to be fully automated, but many of their tasks can be augmented by technology. This suggests that the largest workforce impact may come not from job replacement, but from job transformation, where workers increasingly combine domain expertise with digital, technical, and analytical skills.

Table 1

Nearly three-quarters of employment is exposed to automation in mining and quarrying

Automation exposure	Number of occupations	Share (%)	Employment	Share (%)
High exposure (>50)	26	9.7	30,955	40.2
Medium exposure (25–49)	106	39.7	25,555	33.2
Low exposure (<25)	135	50.6	20,520	26.6
Total	**267**	**100.0**	**77,030**	**100.0**

Sources: Signal49 Research.

In the oil & gas industry, 9.8 per cent of occupations are classified as highly exposed to automation, representing 17.5 per cent of total employment, while medium-exposure roles account for 35.4 per cent of occupations and 32.4 per cent of employment. (See Table 2.) This distribution signals a considerable opportunity for the industry. While half of current employment is in low-exposure roles, the notable share of medium- and high-exposure occupations means that automation can help alleviate labour shortages by taking on repetitive, physically demanding tasks that are increasingly difficult to staff. At the same time, automation creates demand for new roles in technology integration, predictive maintenance, and remote operations, jobs that can attract a younger, digitally skilled workforce.

As automation continues to reshape these industries, coordinated action will be essential. Governments, educational institutions, and industry all have roles to play. Firms can identify emerging skill needs and invest in technology adoption, while public policy and training providers can ensure accessible reskilling programs and regional workforce planning. This collaboration matters because automation affects more than individual jobs; it influences productivity, economic inclusion, and competitiveness at a national level.

Table 2
Half of employment is exposed to automation in oil and gas extraction

Automation exposure	Number of occupations	Share (%)	Employment	Share (%)
High exposure (>50)	24	9.8	12,615	17.5
Medium exposure (25–49)	87	35.4	23,325	32.4
Low exposure (<25)	135	54.9	35,990	50.0
Total	**246**	**100.0**	**71,930**	**100.0**

Sources: Signal49 Research.

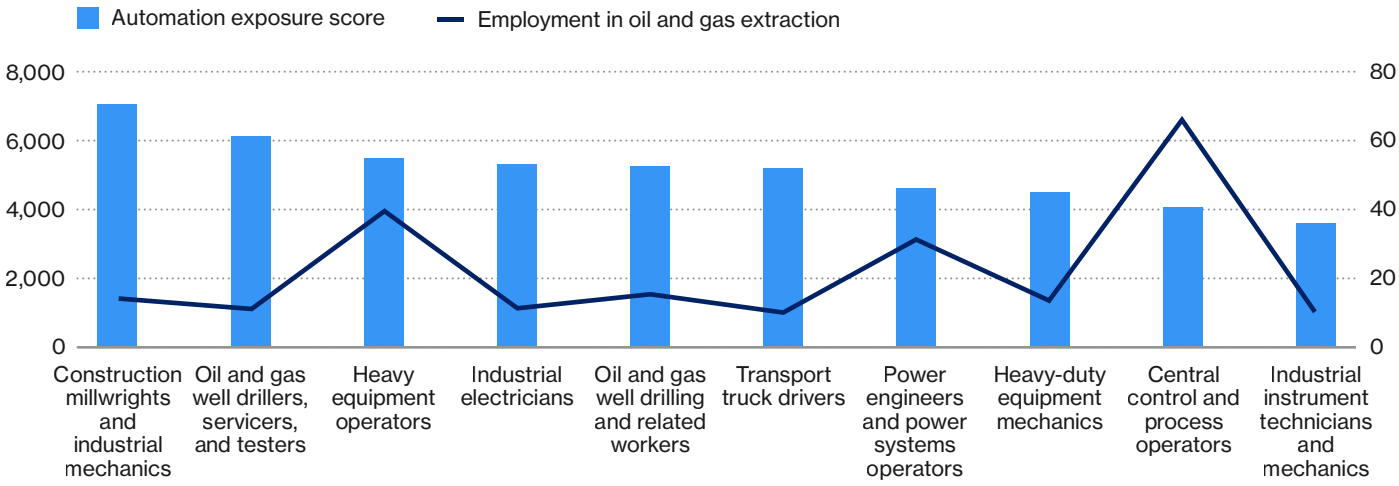
Oil & gas

In oil & gas, occupations such as construction millwrights and industrial mechanics (automation-exposure score of 70.6), oil & gas well drillers (61.3), and heavy-equipment operators (55.0) are among the most exposed. (See Chart 7.) These roles typically involve repetitive, physical tasks that are increasingly being automated through robotics and remote-controlled machinery. Notably, central control and process operators (individuals who monitor, adjust, and maintain processing units[19]), with a score of 40.8, represent the largest employment group, indicating that even moderately exposed roles can have a substantial impact on employment prospects.[20]

Chart 7

Top 10 exposed occupations are routine- and mechanical-tasks-intensive in oil and gas extraction

(Left axis: employment; right axis: automation exposure score)



Note: Occupations with an employment of 1,000 and higher as of 2021.
Sources: Signal49 Research.

19 Canada, National Occupational Classification, "9232.0 – Central control and process operators, petroleum, gas and chemical processing."

20 Automation exposure scores indicate the share of tasks within an occupation that could be automated using current technologies. Occupations with scores greater than 50 per cent are classified as highly exposed; those with scores above 25 per cent and up to 50 per cent are moderately exposed; and those with scores of 25 per cent or less are considered minimally exposed.

Mining

The mining industry shows a similar pattern, with construction millwrights and industrial mechanics again topping the exposure scale at 70.6, followed by welders and related machine operators (65.7) and underground mine service and support workers (56.7). (See Chart 8.) These roles are central to mining operations and are increasingly being replaced or augmented by automated systems. Importantly, underground production and development miners (score of 54.9) and heavy-equipment operators (55.0) together account for over 16,500 jobs, making them essential targets for workforce transition planning.

The future is now

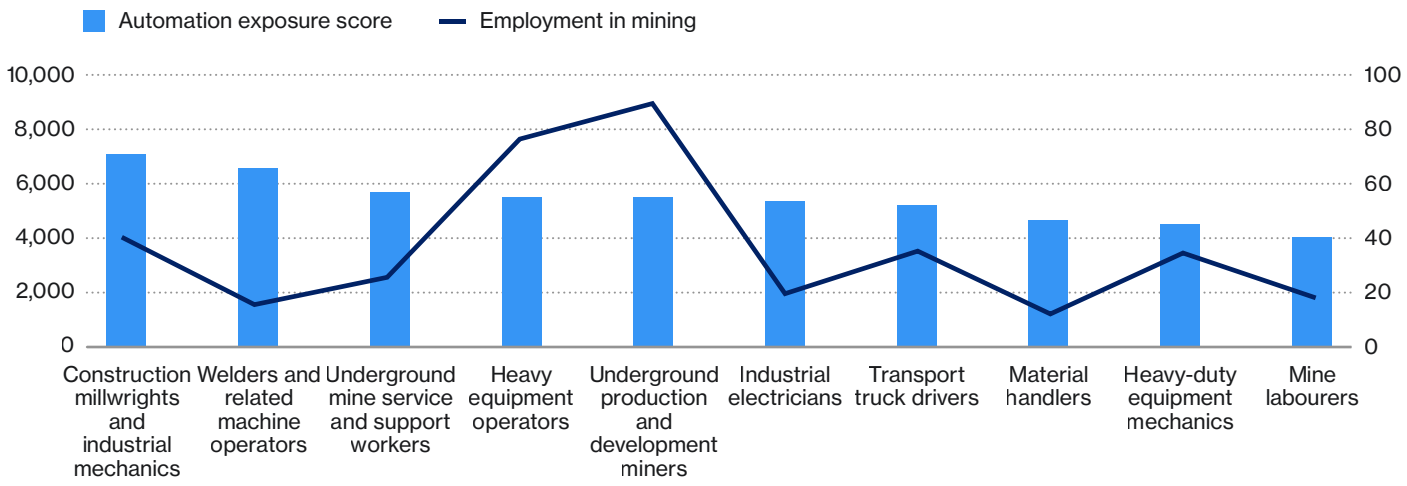
Automation is no longer a distant possibility; it is already shaping work in mining and oil & gas. High-exposure scores across key occupations combined with substantial employment figures highlight an opportunity: automation can help address persistent labour shortages by taking on routine, physically demanding tasks, while creating new roles in technology, maintenance, and systems integration.

This shift requires occupation-specific strategies that focus on skills upgrading and mobility pathways, ensuring workers transition into emerging positions rather than exit the workforce.

It is important to note that automation potential does not always translate into immediate adoption. For example, 59.6 per cent of oil & gas extraction firms report using advanced technologies, well above the economy-wide average of 47.2 per cent, while mining firms report an adoption rate of 48.9 per cent—only slightly above average. This contrast reveals a critical insight: oil & gas firms are leveraging technology more effectively despite having lower automation exposure than mining. Meanwhile, mining's higher automation potential, paired with moderate adoption, suggests untapped opportunities for productivity gains. Given the high potential for automation in the sector, what technologies are they currently using, and how can they take it to the next step?

Chart 8

Top 10 exposed occupations are routine and mechanical tasks intensive in mining and quarrying
(Left axis: employment; right axis: automation exposure score)



Note: Occupations with an employment of 1,000 and higher as of 2021.
Source: Signal49 Research.

Technology at work

The top technologies adopted within the sector are environmental monitoring and advanced mapping tools (both at 65 per cent adoption). Other technologies are also widely adopted, including digital twins, battery-electric vehicles (BEVs), IoT, wearable safety sensors, 5G/LTE-enabled operations, and advanced materials-handling systems. (See Chart 9.) Looking at firms that are "exploring" technology, AI is the technology with the highest rate of "exploration" (at 35.2 per cent), closely followed by predictive maintenance systems (31.1 per cent). Given that AI as a technology is the highest in "exploring" and among the lowest in "not used," it is likely that AI adoption will increase in the coming years especially as Natural Resources Canada (NRCan) has engaged in several AI projects for the sector.[21]

Use cases of advanced technologies in mining and oil & gas

Predictive maintenance

"Most of our equipment now uses predictive systems, trucks, pipelines, valves, all instrumented. Computing power has caught up, so data helps us make decisions, sometimes automatically. It ties into AI: we've taught operational equipment using machine learning and have used neural networks for over 20 years. Applying them gave us over 95 per cent understanding of plant inputs and enabled feed-forward process control, what people now call AI, but it's really just math."

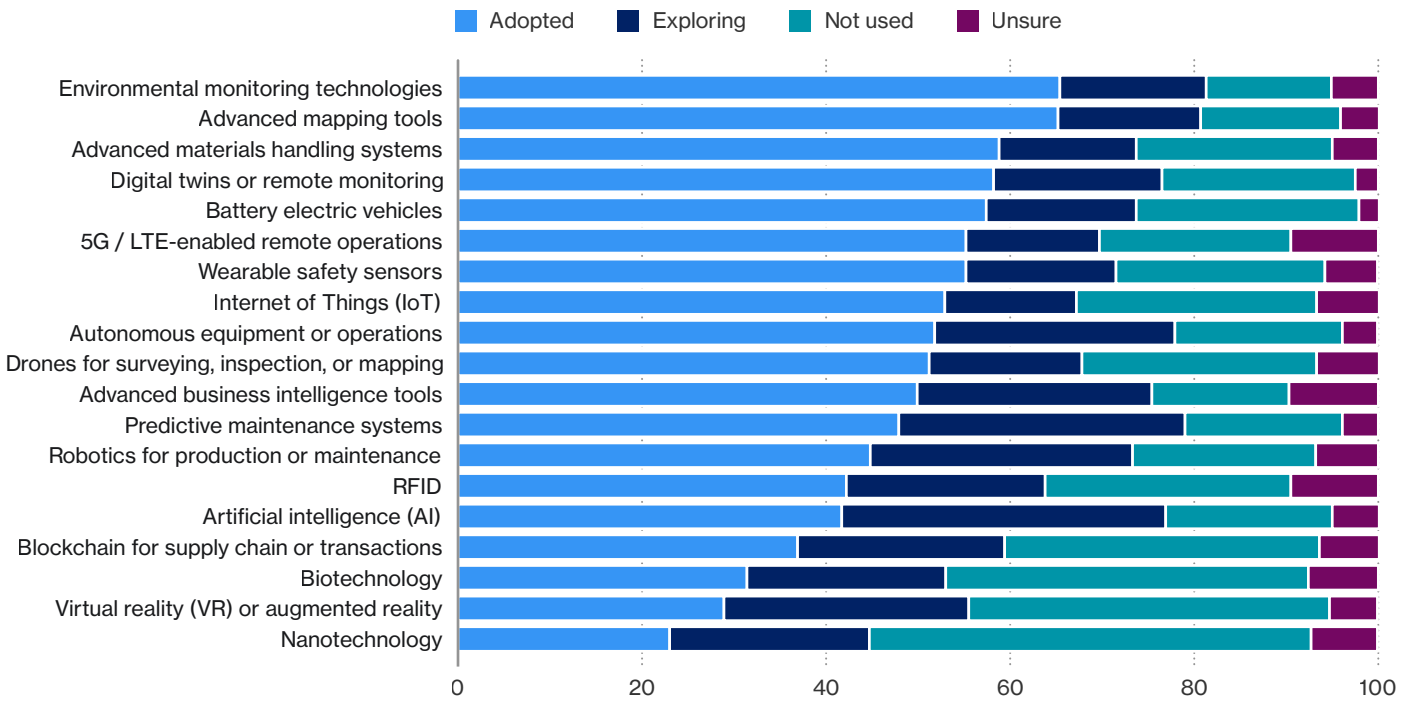
Oil & gas industry professional

Chart 9

Adoption of emerging technologies

Q: Over the past five years, to what extent has your organization used the following technologies?

(per cent, N = 204)



Source: Signal49 Research.

21 Natural Resources Canada, "Artificial intelligence for mining."

Use cases of advanced technologies in mining and oil & gas

Artificial Intelligence

"We were ahead of the curve; as soon as GPT came out and it was available on Open AI, and models were available on Azure, we were early adopters. Some of our bright minds in the company convinced senior leaders to invest in it and made the technology accessible to our team."
Mining industry professional

"There's AI-assisted ore sorting right now; that's with AI trying to recognize the rock and determine what it is. That's a big one."
Mining industry professional

Battery-electric vehicles (BEVs)

"We use electric battery vehicles on our sites. They're great—small trucks go out daily, come back, plug in, and are ready for the next day."
Oil & gas industry professional

Environmental monitoring

"We developed a process that has a zero-waste footprint. There are no legacy materials that must be left on the site after we're done. Everything that we bring in becomes a product for sale going out."
Mining industry professional

Autonomous equipment

"We've looked at autonomous equipment for 15 years, from small mine machines to full-size trucks. For now, we focus on Lean Six Sigma improvements. Autonomous trucks only pay off if the efficiency gain is big enough, and we're not there yet. We revisit it every year, especially when replacing fleet components."
Oil & gas industry professional

"I was just at a mine two days ago. They replaced 100 truck drivers with 20 completely autonomous trucks, and the truck weighs 200 tons. These things are bigger than a house, and there are no people on them. But now they have 20 people in the control room."
Mining industry professional

Drones and mapping

"Drone mapping is essential. The technology is mature, easy to deploy, and we'd like to use it even more."
Mining industry professional

Business intelligence (BI)

"We use BI tools like Power BI and Tableau, plus direct ERP [Enterprise Resource Planning] reporting. Our setup is customized because we've acquired many companies and sometimes kept their ERPs. We're moving to a core ERP [supplier], SAP, which makes future migrations easier since our acquiring company also uses SAP."
Oil & gas industry professional

Digital twins

"We've used digital twins for years and now have digital triplets with AR/VR added for training. They let us do virtual walkthroughs, design work, and problem-solving. I can even climb virtual towers. AR/VR has been a great addition. Digital tools boost productivity, but they need disciplined implementation."
Oil & gas industry professional

To better understand the broader technology ecosystem and how organizations in this sector access and adopt technologies, we asked respondents about partnerships in technology development, and both enablers and barriers of technology adoption.

Through interviews, we found that adoption often seems to be a collaborative effort, from proof of concept to industry standard. Since the sector is so capital intensive and there are multiple knock-on effects and each site is different, trial stages and early results are critical, even if adoption ultimately lags.

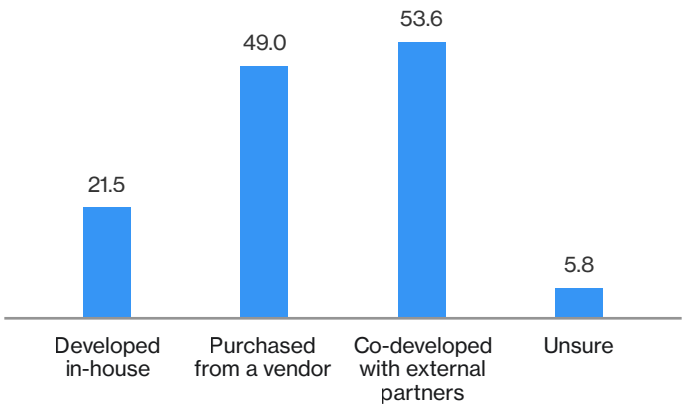
We asked respondents about the different ways they access technology, allowing for multiple responses. Over 50 per cent of survey respondents claimed that they co-develop technology with external partners, almost 50 per cent of survey respondents indicated purchasing from vendors, and 21 per cent developed technologies in-house. (See Chart 10.) In short, these responses point to the prevalence of bespoke solutions developed alongside vendors and even government partners[22] rather than a primary focus on internal R&D expenditures. For instance, in November 2025, the Government of Canada invested $1,050,000 to support Cambrian College's Centre for Smart Mining[23] that will support up to 145 mining technology SMEs with access to advanced equipment and expertise.

Chart 10

Method of access to emerging technologies

Q: How has your organization accessed or developed new technologies? Select all that apply.

(percentage of job tasks that can be automated)



Sources: Signal49 Research.

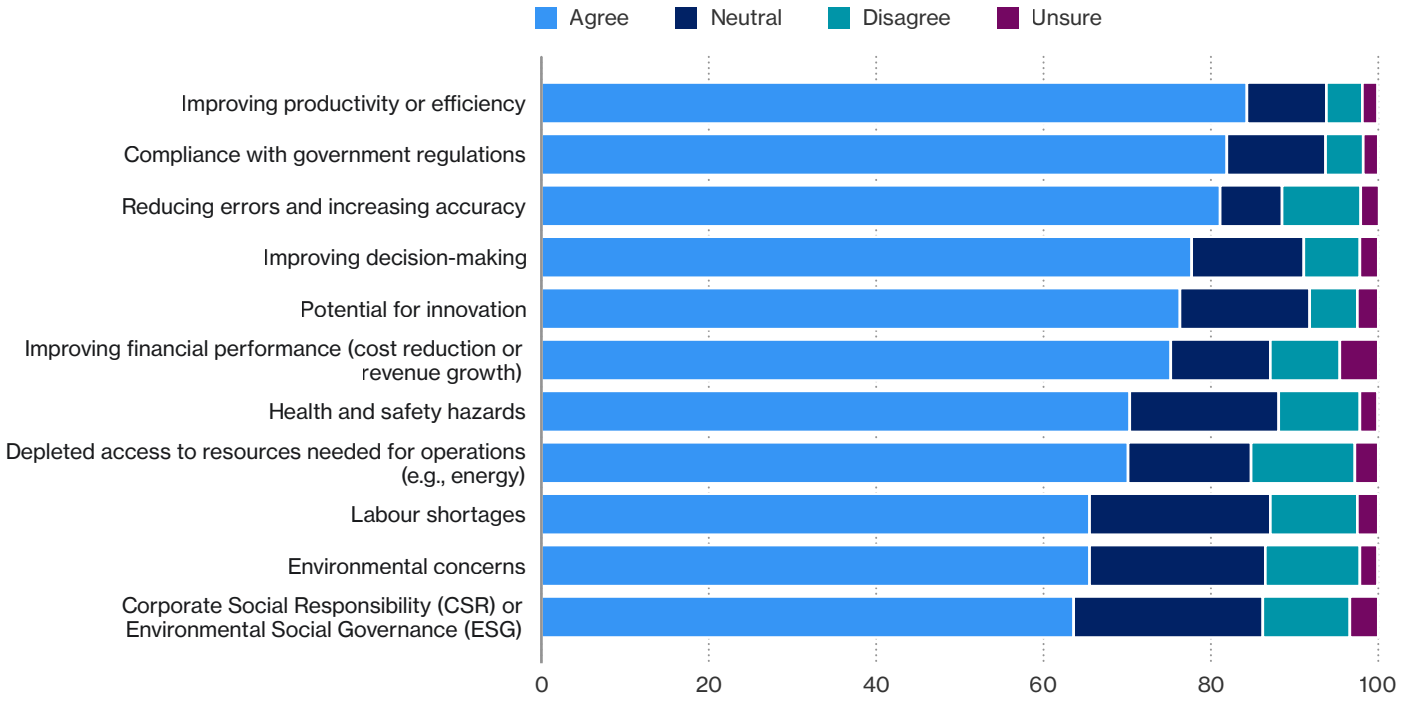
22 Natural Resources Canada, "CanmetENERGY research centres."

23 Canada, Federal Economic Development Agency for Northern Ontario – FedNor, "Government of Canada invests over $1 million to support mining innovation in Northern Ontario."

In terms of incentives for adoption, the top factors affecting decisions to adopt are productivity and efficiency (84 per cent), compliance (82 per cent), and error reduction (81 per cent). (See Chart 11). The top factors affecting ability to adopt are data security and privacy, uncertainty about business impact, and integration challenges (each cited by about 2/3 of firms). (See Chart 12.)

Finally, over 59 per cent of firms say that demonstrated proof of concept and level of adoption in the industry influence their decision to adopt emerging technology. In interviews, participants voiced a variety of concerns when it comes to technology adoption, ranging from ROI to skills to infrastructure. Combined, these concerns suggest a cautious approach to innovation which we will explore in further detail in the next section.

Chart 11
Factors affecting decision to adopt
Q: To what extent do you agree or disagree that the following factors influence your organization's decision to adopt new technologies?
(per cent, N = 204)



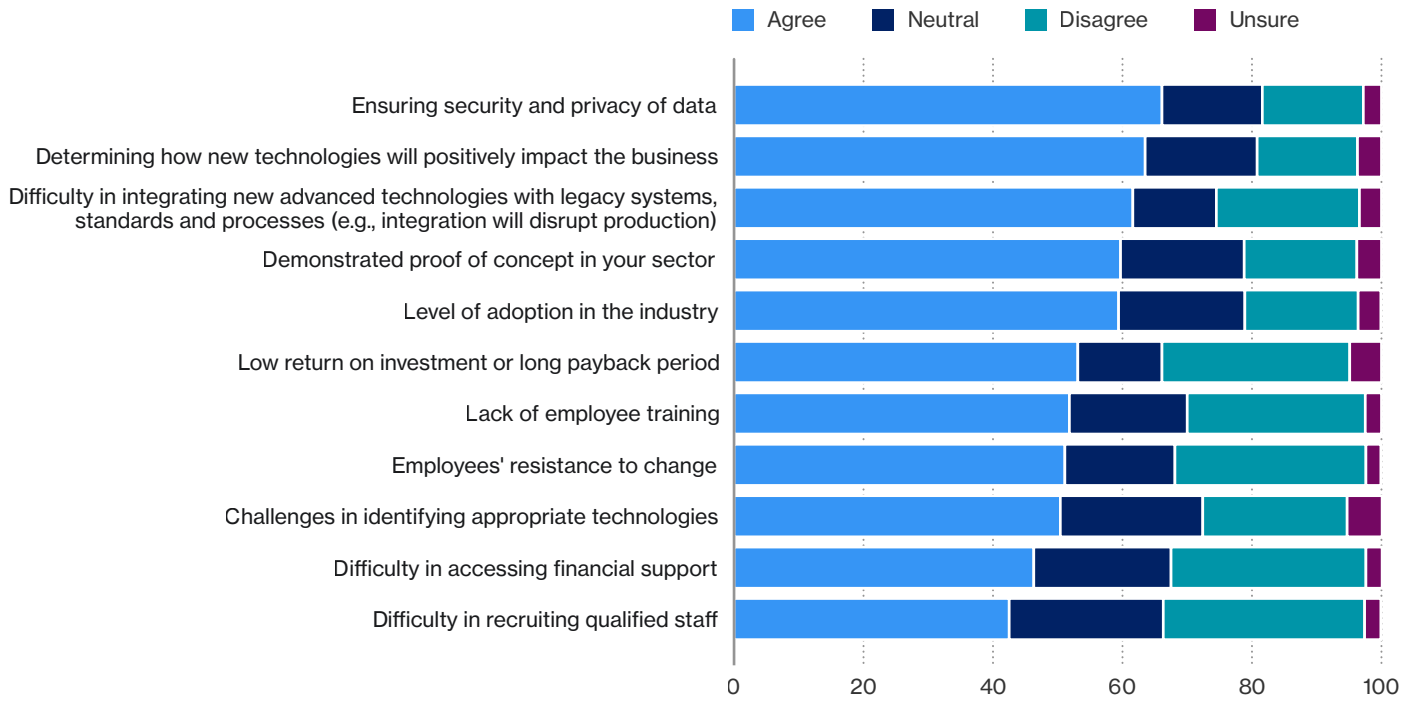
Source: Signal49 Research.

Chart 12

Factors affecting ability to adopt

Q: To what extent do you agree or disagree that the following factors affect your organization's ability to adopt new technologies?

(per cent, N = 204)



Source: Signal49 Research.

In their own words

"When developing or testing new tech, we start small and use trials to build confidence. For automation, operations decide what they need. We often work with other mining companies and test outside current operations to prepare. We start with smaller projects and mines."

Mining industry professional

"Oil & gas companies collaborate on tech development through joint partnerships like COSIA [Canada's Oil Sands Innovation Alliance]. They share pilot sites, such as one at Suncor, where all participants could test chemicals."

Oil & gas industry professional

"Adoption is hard because mining is capital intensive with long planning cycles, about 20 years to build a mine. You can't just flip a switch to automate. Infrastructure decisions were made a decade ago, so change is slow and rigid."

Mining industry professional

Avoiding obstacles

Thus far, we have presented technology adoption and automation as a means to offset the challenges in the talent pipeline and to boost productivity. However, there are systemic issues in this sector that are barriers to adopting more technology. These barriers are both internal in the culture of innovation, and external in terms of the sector's operational capacity. We consider these obstacles in this section.

A culture of caution

Our interviewees pointed to a culture of caution that stifles innovation. To paraphrase our participants, they claimed that firms avoid being early adopters, preferring instead to be the "first second," adopting technologies only once they have been proven elsewhere. Not only is this felt in the sector overall, but also in both industries individually. Despite having higher-than-industry-average levels of adoption of advanced technologies, recent independent reports highlight the aversion to change in the mining industry[24] and the slow movement of the oil & gas industry to deviate from established practices.[25]

While we have shown that both the mining and oil & gas industries have higher rates of advanced technology adoption than the industry average, there is a persistent aversion to risks that come with innovation.[26] Innovative efforts, such as switching from diesel-powered to battery-electric vehicles,[27] have knock-on effects that can reverberate throughout entire operations, impacting production and project management.

In capital-intensive industries, like mining and oil & gas, that have established methods and technologies, we heard from respondents that there is a tendency to opt for ways to minimize the amount of risk even at the cost of increased potential production. Ultimately, this means that industry leaders tend to be slower and more conservative when it comes to their adoption of new technologies, preferring to see successful use cases deployed by competitors or in other jurisdictions.

In their own words

"Clients want new tech but refuse to be first adopters. They'd rather wait until two others have successfully used it before buying."
Support industry professional

"Mining is a legacy industry driven by quarterly returns. It sticks to proven methods and remains conservative."
Mining industry professional

"Energy companies are slow and conservative. They avoid risk, which is natural for the industry."
Oil & gas industry professional

24 Porto, "Is aversion to change threatening the mining sector?"
25 Schulte, "Future of oil and gas through technology, leadership, and change management (Digitalization)."
26 Kokmuench, "Overcoming risk aversion in mining: The case for innovation."
27 Elbokl, "Juiced for the Job: Round up of BEVs powering the future of mining."

Unique challenges

In order to unpack the risk-averse mindset, it is crucial to recognize that both mining and oil & gas operations are also constrained by three important elements (aside from their capital-intensive nature): complex permitting processes, variable life cycles, and their unique geographic operations.

Complex permitting processes

To extract natural resources, both mining and oil & gas firms must acquire permits across multiple jurisdictions. For instance, if you are a mining firm operating in Ontario, you must comply with several provincial and federal acts that help oversee various aspects of the project, including (but not limited to) environmental protection, health and safety, and transportation.[28] Over 85 permits and approvals are required,[29] which means it could take up to 15 years to open a mine in Ontario. Since permitting can take such a long time, many prospective projects get delayed, and initial projections (even regarding technology usage) get disrupted. As a result, the provincial government has introduced the "One Project, One Process" framework[30] to streamline the approval process while retaining consultation with Indigenous communities and established environmental standards.

Similarly, if you are an oil & gas firm operating in Alberta, you need to file your plans with the Alberta Energy Regulator (AER) and conduct stakeholder and rights holder engagement prior to development.[31] From here, the extraction life cycle is developed with integrated planning, including tailings management (for oil sands mining), along with a completed assessment of the potential environmental impacts.[32] Once the project scheme is approved (if approval is required), construction can commence. Depending on the deposit, mining or in situ extraction may be employed.[33]

Variable life cycles

In addition to the permitting required, mines[34] and oil extraction sites feature unique life cycles, with different requirements at each stage. In this sector, different technologies tend to be employed at different stages. For instance, during initial exploration, advanced mapping tools may be used to source deposits, while during active operation, environmental monitoring technologies may be used. Additionally, different sites have varying life cycles, meaning that the amount of available resources changes across sites. For instance, the largest oil sands production area in Canada is the Athabasca Oil Sands area, approximately 93,000 square kilometres, with the other two located in the Peace River Oil Sands area (over 29,000 square kilometres), and the Cold Lake Oil Sands area (almost 18,000 square kilometres).[35]

Unique geographic operations

Connected to the variable life cycle of operations is the unique nature of each site (e.g., its geographic features and the extraction method used). Simply put, the nature of the deposit also determines the method used—whether it is surface or underground mining,[36] or whether it is digging up shallow oil sands or in situ extraction using steam (e.g., Steam-Assisted Gravity Drainage).[37]

Given that sites run concurrently and start at different points in time, a variety of technologies could be used at any given site depending on the geographic constraints and method used to extract. Some could be in widespread adoption while others are in the piloting stage, and technologies vary by company.

28 Ontario Mining Association, "Mining 101."
29 Ontario Mining Association, "Mining 101."
30 Ontario, Ministry of Energy and Mines, "Ontario's Ring of Fire."
31 Alberta Energy Regulator, "Project Life Cycle"
32 Oil Sands Alliance, "How it works: Oil sands surface mining 101."
33 Alberta Energy and Minerals, "Oil Sands 101."
34 BC Mine Information, "The Mining Lifecycle."
35 Alberta Energy Regulator, "Oil Sands: Bitumen Deposits in Alberta."
36 Burkhardt, Rosenbluth, and Boan, "Mining in Ontario: A deeper look."
37 Oil Sands Magazine, "In Situ Bitumen Extraction."

In their own words

Permitting

"Permitting has always been slow because it's a long, multi-jurisdictional process."
Mining industry professional

"Delays happen because mine development is hard. Regulatory and environmental requirements, plus ESG obligations, make investors hesitant to fund new mines."
Mining industry professional

Variable life cycles

"Most of our decisions depend on mine life, usually 5–10 years or less. If we consider innovation, we ask if it will pay off within that time frame. Often it doesn't, so we delay. The problem is that 'five years' keeps getting extended every year, so the short-term mindset never ends."
Mining industry professional

"Projects can take 10 years just to develop, and by then technology has changed. That makes planning complicated."
Support industry professional

Unique geographic operations

"When I started working in the industry, technology was standardized across sites so employees could move easily and use the same tools everywhere. That was great for efficiency. Today, it's more decentralized, each site does its own thing instead of following a central standard."
Mining industry professional

"We tend to do a pilot in one place first. We may extend to two or three if the use cases are different. We learn by doing these and then bring the use cases to more of our operations."
Oil & gas industry professional

All three of these unique external sectoral factors combined create a cautious innovation culture that can hinder the use of emerging technologies. While both federal and provincial governments are working to address some of the issues regarding permitting (e.g., Ontario's *Protect Ontario by Unleashing our Economy Act*[38]), we seek to understand how innovative transformation could take place in this sector through workforce readiness for the adoption of emerging technologies.

38 Ontario, *Protect Ontario by Unleashing our Economy Act.*

From reaction to readiness

Workforce readiness

We suggest that firms continue to prepare their workforces, as that is central to successfully adopting technology.

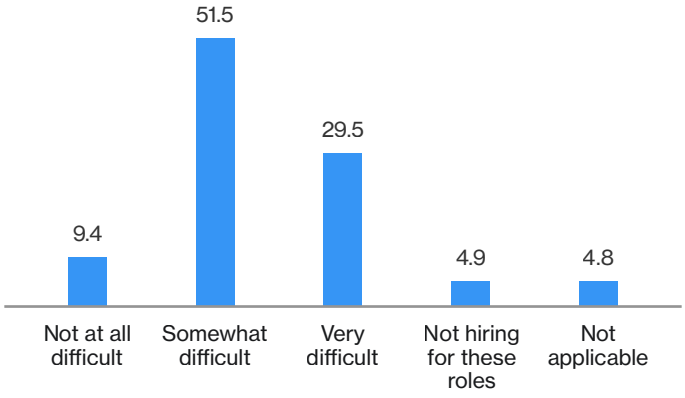
Since technology adoption can help address talent shortages, it is essential that workers possess the skills needed to operate or oversee these systems. Reports highlight the need for tech-forward talent to help drive adoption[39] and similarly to protect vulnerable digital assets from cybersecurity attacks.[40] Our survey findings indicate that 29.5 per cent of firms currently say it is very difficult to find skilled workers for roles related to advanced technologies, while 51.5 per cent of firms claim it is somewhat difficult. (See Chart 13.)

Chart 13

Difficulty in finding skilled workers

Q: Over the last year, how difficult has it been for your organization to find workers with the skills required for roles related to advanced technology adoption?

(per cent, N = 204)



Sources: Signal49 Research.

39 Parys, Danny, “Lack of tech talent holds mining innovation back.”

40 Krugel, Lauren, “Oil and gas industry players embracing AI and other tech.”

Regardless of the difficulty in finding skilled workers, 65 per cent of firms say they are prepared to manage workforce transitions, and 59 per cent say that training has been effective. (See Chart 14.) In-house training efforts also present another opportunity to include advanced technology to help secure and acclimate a tech-ready workforce.[41] Survey respondents also reported that training is equally prioritized for field workers and managers.

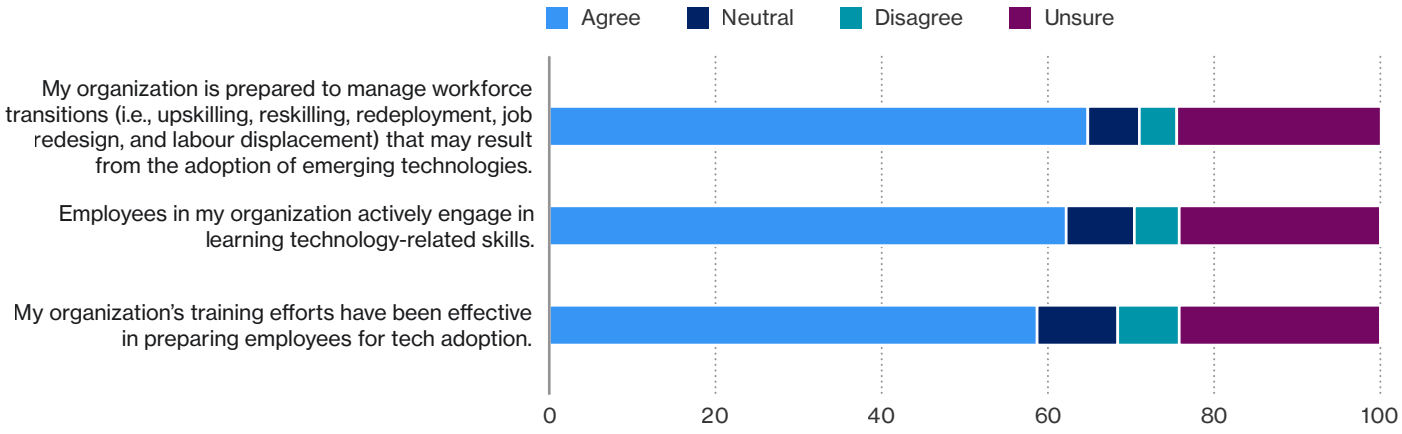
Potential supports for workforce readiness and upskilling include more time (47 per cent), increased budgets, and skilled trainers (43 per cent) (see Chart 15), while their opposites, time constraints (53 per cent) and limited budgets (42 per cent) were the most frequently cited barriers.

Two-thirds or more of firms say that hiring new skilled talent, investing in upskilling, and upgrading technical infrastructure are key strategies for adoption. (See Chart 16.)

Chart 15
Supports for upskilling
Q: Which of the following supports would allow your organization to better implement technology-related upskilling and reskilling training programs for employees? Please select all that apply.
(per cent, N = 204)

Sources: Signal49 Research.

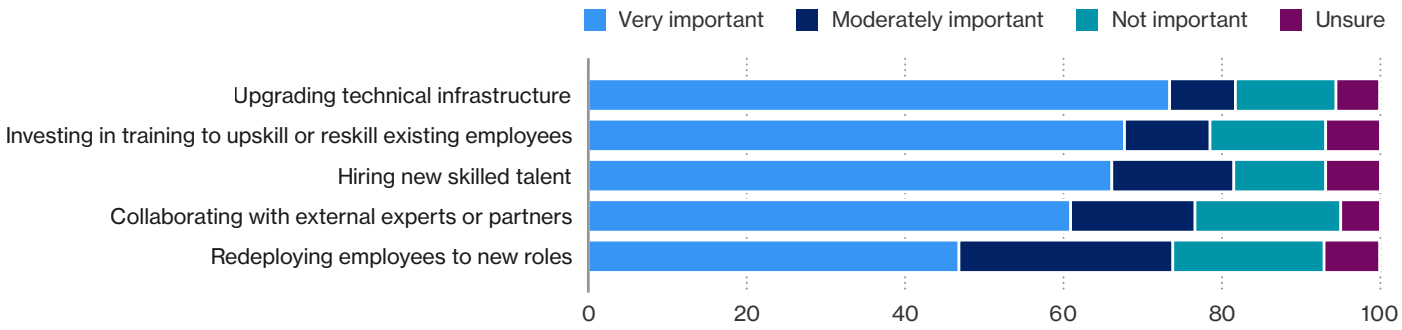
Chart 14
Technology adoption and workforce transitions
Q: To what extent do you agree or disagree with the following statements?
(per cent, N = 204)



Sources: Signal49 Research.

41 Duvall, Don, "Pay attention: The world of mining is changing."

Chart 16
Strategies for adoption
Q: How important have the following strategies been in helping your organization adopt advanced technologies?
(per cent, N = 204)



Sources: Signal49 Research.

Retaining talent

Finally, the last step in securing the pipeline is to retain it, which has been a challenge for firms in the sector that encourage self-driven development. This is going to be even more difficult as upskilling workers to enable them to combine expertise in fields like engineering and machine learning (or artificial intelligence)[42] may make them more attractive to larger organizations or industries where mining and oil & gas may not have the capacity to compete (e.g., data centre infrastructure).

"We see a lot of turnover. For example, someone left today who was very talented. If your employee is strong in process work and then gains AI/ML experience, they become highly marketable and hard to keep. Retaining top talent is tough, especially those who combine engineering skills with a willingness to learn AI. These people end up with exceptional skill sets, strong networks, and entrepreneurial drive. We don't have great systems to keep them, and it's hard to compete."
Oil & gas industry professional

Maintaining a core workforce is central to this sector because attracting talent, especially younger workers, has been challenging. Ultimately, securing the talent pipeline for a lifetime of workers from post-secondary to retirement, and upskilling them to use the technology of today and using automation where possible will provide the pivot for this strategic sector to thrive as demand increases.

42 Yameogo and Makoyeva, "A mining makeover: inspiring the next generation."

Actionable insights

Federal policy-makers who are interested in enhancing the opportunities for the mining and oil & gas industries can consider the following:[43]

- Extend accelerated capital cost allowances to energy and mining solutions beyond liquefied natural gas equipment meeting high emissions standards.[44] This can include providing financial incentives for technology adoption, especially in partnership with Canadian-based technology manufacturers, throughout the sector, focusing on pursuing innovative solutions in automation.
- Implement parallel permitting processes nationwide (e.g., One Project, One Review[45]), paying close attention to the One Project One Process framework as an emerging practice to monitor and reference[46] both upcoming and existing mining and oil & gas development projects.
- Introduce industry-specific co-operative education tax credits or grants (similar to the Ontario co-operative education tax credit[47]) to help companies invest in upskilling and reskilling their workforce, especially for adoption of automating and emerging technologies.
- Continue to support recruitment and outreach programs like the “Mining Needs You”[48] and “Careers in Energy”[49] campaigns and invest further to help expand scope into elementary and secondary schools to address the labour shortage.
- Prioritize partnerships with Indigenous-led organizations like Saskatchewan Indian Institute of Technologies (SIIT) for workforce recruitment and development[50] to provide increased opportunities for local talent and skill development. Provide financial incentives for organizations to recruit graduates from these programs and offer work-learn opportunities to strengthen the talent pipeline.
- Provide targeted increases in international student caps[51] in both mining and energy programs and restore post-graduate work permit eligibility to help sustain program viability and provide another stream of skilled talent for the workforce.

43 Department of Finance Canada, *Budget 2025*, “Building a stronger Canadian economy.”
44 Department of Finance Canada, “Building a stronger Canadian economy.”
45 Department of Finance Canada, “Building a stronger Canadian economy.”
46 Ontario, Ministry of Energy and Mines, “Mining: One Project, One Process framework.”
47 Canada Revenue Agency, “Ontario co-operative education tax credit.”
48 Mining Industry Human Resources Council, “Mining Needs You.”
49 Government of Canada Sectoral Workforce Solutions Program, “Careers in Energy.”
50 Saskatchewan Indian Institute of Technologies, “Home page.”
51 Immigration, Refugees and Citizenship Canada, “2026 provincial and territorial allocations under the international student cap.”

Businesses in the mining and oil & gas sector looking to capitalize on these findings can consider the following:

- Engage with consortiums like the Clean Resource Innovation Network (CRIN) or the Centre for Excellence in Mining Innovation (CEMI) to stay updated on novel use cases of emerging technologies and their productivity returns.
- For mining industry leaders: Partner with the Northern Centre for Advanced Technology (NORCAT) or industry-specific colleges (e.g., Cambrian College) for skilled labour supply to support the adoption of emerging technology.
- For oil & gas industry leaders: Partner with the Canadian Petroleum Training Institute (CPTI) or colleges that have a strong industry focus (e.g., Southern Alberta Institute of Technology, Northern Alberta Institute of Technology) for skilled labour supply to support the adoption of emerging technology.

University institutions seeking to adjust their programs to match the labour demand for mining and oil & gas can consider the following:

- Create closer partnerships with polytechnic institutions and/or industry for better alignment with changes in technology deployment and skills requirements.
- Bring in industry ambassadors to speak to students in relevant disciplines to raise awareness of career viability (e.g., an ambassador from the Mining Needs You[52] campaign).

52 Mining Industry Human Resources Council, “Mining Needs You.”

Appendix A

About the research

Two of Canada's key primary industries, mining and oil & gas, are projected to undergo rapid technological transformation. Robotics, digitization, artificial intelligence, and other emerging technologies will reshape how work is performed and will drive innovation in these industries, demanding new skills and augmenting existing ones. Identifying these skills gaps, workforce needs, and cross-cutting competencies will be critical in ensuring Canada's primary industries remain competitive in a rapidly evolving landscape.

Mining and oil & gas collectively comprise just over 5 per cent of Canada's GDP, drive global trade, and help sustain rural communities. As these industries evolve through the adoption and advancement of automation technologies, it is crucial to assess how well industries and workers are prepared to adapt. Our research will provide essential insights to help industries, post-secondary institutions, and policy-makers strengthen workforce resilience, close skills gaps, and position Canada's mining and oil & gas sectors for long-term success in the face of uncertainty.

This paper is part of an exploration of these sectors, focusing on the following central questions:

1. To what extent are businesses in mining and oil & gas in Canada adopting and innovating with emerging technologies, and what barriers, if any, are affecting their ability to fully integrate these technologies?
2. What skills do employers in mining and oil & gas need to support technology adoption and innovation, and what are the gaps between current workforce skills and emerging skill needs?
3. What are the cross-cutting factors (economic, demographic, institutional) causing skill shortages in mining and oil & gas?

Methodology

We used a mixed-methods approach to converge the impact of emerging technologies on this unique Canadian sector. Interviews, surveys, and the automation-exposure analysis were conducted in parallel; however, the interview guideline and survey questionnaire were developed simultaneously and were informed by trade periodicals and reports on the sector.

Interviews

Interview recruitment

Potential interviewees were identified through members of the Research Advisory Board (see Acknowledgements for details on Research Advisory Board members) and our networks. Invitations were sent via email and through social media channels (i.e., LinkedIn). The team followed up directly, providing details about the research project, outlining the interview goals, and inviting participation. Interested individuals then scheduled a virtual interview with a member of the research team.

Between August and October 2025, the research team scheduled and completed interviews with 33 industry-related professionals:

- 3 interviewees from Canadian post-secondary or upskilling institutions
- 4 interviewees from support industries
- 10 interviewees from oil & gas industries
- 16 interviewees from mining industries

The individuals interviewed for this study were senior leaders, such as CEOs, CTOs, VPs, and Directors, with an emphasis on innovation and technology roles in the industry.

Semi-structured interview questions

We developed a versatile set of interview questions to accommodate interviewees in these industries.

The semi-structured interview guide was developed based on the research questions, our background research, existing team expertise, and initial conversations with our Research Advisory Board members. The guide was reviewed and approved by our internal Research Office.

Our questions were structured around a core set of topics including the following:

1. The culture of innovation
2. Technology adoption and implementation
3. Drivers and barriers for technology adoption
4. Skill requirements and upskilling initiatives
5. The talent pipeline
6. Short-term outlook on innovation and technology adoption (three to five years)

Sample interview questions for all interviewees

What is your role in adopting new technologies or shaping workforce development within your organization?

How would you describe the current availability of talent in your industry?

How do you see technology and innovation evolving in your organization (or the industry) over the next three to five years?

Qualitative analysis

The research team conducted virtual interviews with 33 stakeholders over Microsoft Teams between August and October 2025. Interviews lasted approximately 35 minutes to one hour. Interviews were recorded and transcribed, yielding approximately 876 pages (239,784 words) of text.

We opted to use a deductive approach to transcript analysis, informed by a review of relevant reports and trade periodical articles while remaining sensitive to novel themes. This approach was more suitable than line-by-line inductive coding, since most of the main thematic issues explored in this paper are well documented in the literature. However, new themes emerged during the course of data collection (e.g., challenges retaining talent) that added to the understanding of problems in this sector. Given the different types of stakeholders interviewed (e.g., post-secondary, industry), we also leveraged each interviewee's expertise to delve deeper into relevant issues (e.g., post-secondary institution professionals were prompted more to discuss issues of enrolment). Interviewee quotations have been edited for clarity.

Survey data

To supplement the in-depth interviews, we surveyed 204 decision-making industry leaders in this sector in positions of human resources, strategic planning, information technology, artificial intelligence, R&D, innovation, operations, production, sustainability, and technology and strategic planning across Canada.

The survey included a mix of Likert-scale and multiple-choice questions. The survey also captured demographic information including firm size, firm revenue, location, and industry. Survey responses were anonymous.

We used Leger, a Canadian market research firm, to distribute the survey online from September 2025 to October 2025. The sample obtained was a non-probability, convenience sample based on their panel of respondents and is not generalizable to the broader population. The survey was pre-tested among 15 respondents before fielding to ensure its external validity and to identify any wording problems. Since the survey was administered online, it cannot be considered a random probability sample. Therefore, a margin of error cannot be applied to the data set.

The survey data was analyzed in SPSS. Multiple-response Likert-scale questions were numerically coded to facilitate the development of contingency tables and frequency analysis. We do not apply inferential statistical techniques since we do not seek to generalize but present these findings as cross-sectional explorations into the topics in question.

We applied weights for industry representativeness at the three-digit NAICS level (i.e., 211, 212, 213), resulting in a minimum weight of 0.305, a maximum weight of 2.8135, and an effective sample size of 99. We explored using province, size, and NAICS classification. While this option achieves the correct proportions for all three variables, it results in an unreasonably high maximum weight (26.8) and a very low effective sample size (16.9). As a result, the overall data set would become unreliable for analysis.

Automation exposure

Occupational-level automation-exposure scores

Please see our companion publication, *The Productivity Potential of Automation Technologies*, for the detailed methodology. Natural-language processing was used to compare text in occupation descriptions in the OaSIS database with text in U.S. Patent Office data from Q1 2005 to Q1 2025. The share of tasks within an occupation that could be performed by automation technologies was estimated, based on the degree of match between the two sources.

Tasks were defined using two OaSIS datasets: main duties (occupation-specific tasks) and work activities (importance-ranked tasks). Main duties received the highest weight in constructing the task-level exposure score to reflect their critical role. Each task is matched to patent titles using cosine similarity (range: -1 to 1). Scores above 0.4 are considered exposed—a threshold selected after testing to minimize false positives and negatives. Nearly 390 million task-patent comparisons are classified into five mutually exclusive technology clusters. When patents span multiple clusters, they are assigned to the closest match.

Exposure at the task level is aggregated to occupations using two components: intensity, which reflects the relative number of patent matches normalized against the highest observed value; and extensiveness, which measures the importance-weighted share of tasks exposed to at least one patent. The final exposure score is the product of these components, normalized between 0 and 1, and interpreted as the percentage of tasks at risk of being automated. Values closer to one indicate a larger number of tasks being more intensively exposed to innovation.

Industry-level automation-exposure scores

To estimate automation exposure at the industry level, we combined occupational exposure scores with employment data using the industry–occupation matrix from the 2021 Census (Statistics Canada). This matrix reports employment by 5-digit NOC occupations within 3-digit NAICS industries. For each industry, we calculated employment-weighted exposure scores by multiplying the occupational automation score by its share of total industry employment and summing across all occupations. This approach ensures that industry exposure reflects both the degree of occupational vulnerability and the relative employment size of those occupations within the industry. The resulting measure provides a robust indicator of how automation technologies may impact sectors such as mining and oil & gas.

The following is the formula for calculating industry-level automation-exposure scores:

$$E_i = \frac{\sum_{0 \in Oi} Employment_{io} \; x \; E_o}{\sum_{o' \in Oi} Employment_{io'}}$$

Where:

E_i = industry-level automation-exposure score for industry i

O_i = set of occupations within industry i

E_0 = automation-exposure score for occupation o

$Employement_{io}$ = number of workers in occupation o within industry i

$\Sigma_{o'} \epsilon oi \; Employement_{io}$ = total employment in industry i

Appendix B

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