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Tracking the trends 2026

Working together to create lasting value through mining and metals

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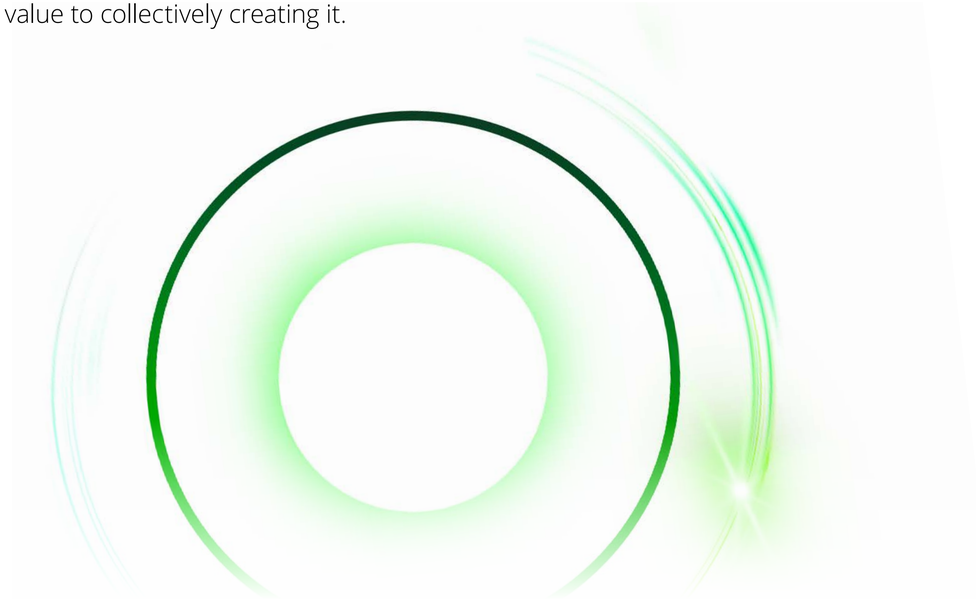
Introduction

Around the world, mining and metals companies are redefining how they create and share value. Nations are seeking to balance industrial and defense strategies with energy security and many communities are calling on mining companies to contribute meaningfully to local well-being and planetary health. The question is no longer whether the industry can supply the materials that power global progress, but how it can do so in a way that uplifts people, economies and ecosystems alike.

The 18th annual edition of *Tracking the trends* explores how mining and metals organizations and their broader ecosystem of collaborators can work together to meet this challenge. The industry's future will likely be shaped less by competition and more by cooperation as industry, governments, technology firms, customers, and communities come together to solve shared problems and generate mutual benefits. In this context, true transformation will likely depend upon winning together: creating the trust, agility and shared vision needed to turn complexity into collective progress.

Companies that align commercial ambition with societal and environmental value creation can tend to perform better, innovate faster and endure longer. In mining and metals, that means collaborating to reduce emissions in operations, regenerate nature, strengthen regional infrastructure and develop future workforces.

The trends featured in this report offer practical pathways to act, from data and AI-enabled exploration and smart operations to future-fit operating models and resilient value chains. Together, they demonstrate how the industry can evolve from simply extracting value to collectively creating it.



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Trend 1

Critical minerals in national security: The strategic role of mining and metals

Authors

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Once seen primarily as enablers of the energy transition, critical minerals are now at the center of national security discussions worldwide. This elevation from industrial feedstocks to strategic assets is reshaping the landscape for mining and metals companies.

For the mining sector, the implications are significant. Companies are increasingly expected to play a dual role: powering the clean energy transition while also reinforcing national defense strategies and maintaining pace with ever-increasing consumer demand. The convergence of these priorities creates new opportunities to drive purpose, as well as risks, and responsibilities that could redefine the industry's role in the world.

The transition from energy to security

Over the past decade, mining and metals companies have come under mounting pressure to meet heightened minerals demand generated by reducing emissions and electrification. Now, national security imperatives layer urgency and complexity onto those expectations.

A recent and impactful example of this playing out is in trade negotiations between the US and China. In October 2025, China tightened its export controls on rare earth elements (REEs) and other critical materials in a bid to "safeguard national security." Foreign companies now require approval from the Chinese government to export products containing REEs and explain their intended uses. Similar restrictions were also imposed on the export of lithium batteries and some forms of graphite.[1] However, the more recent suspension of these export control measures by China following trade talks with the US reinforces the entanglement of market uncertainty with politics.[2]

For governments and companies across the globe, moves like this have emphasized how fragile and heavily concentrated their supply ecosystems have become. Other events reinforced this realization. The Russia-Ukraine war exposed Europe's dependence on imported resources,[3] while instability in the Middle East added to global uncertainty.[4] The result is that market signals are increasingly entangled with political considerations.

Trade fragmentation is also accelerating, as global growth was projected to slow to 2.3% in 2025 due to rising barriers and policy uncertainty. The World Economic Forum estimates the cost of global financial system fragmentation at between US$0.6 trillion and US$5.7 trillion.[5]

Why minerals matter for defense

The defense sector's reliance on critical minerals is clear. An F-35 fighter jet contains more than 408kg (900lbs) of REEs and an Arleigh Burke-class DDG-51 destroyer needs approximately 2,358kg (5,198.5lbs).[6] Minerals such as gallium and germanium, though consumed in smaller quantities, are indispensable for semiconductors, radar systems and satellite technologies.[7] Antimony, meanwhile, is important to produce munitions and flame-retardant materials.[8]

For mining companies, this demand dynamic is distinctive. Unlike bulk commodities such as copper or iron ore, the volumes of critical metals required for defense are relatively small. But the stakes are disproportionately high. That creates space for companies to extract value by focusing on the recovery of byproducts from mine waste or tailings, or by developing specialized midstream processing capabilities.

Richard Longstaff, managing director, Public Sector lead, Deloitte Consulting LLP, said:

"There will likely be a short window in which governments are willing to subsidize the development of secondary products via measures such as loans, offtake agreements and grants. The quantities of materials could be relatively small, but the investments are significant and front-loaded. These are supplementary revenue opportunities for mining companies that will probably be a one- or near one-time event."

Although revenues from these products may be a fraction of those from primary production, they could help to keep operations salient or reduce operational volatility.

Interventions like these create opportunities, but they can also reshape risk. Mining companies accustomed to competing in open markets now navigate an environment where national security implications need to be considered alongside commercial operations and financial gains. At the same time, entering defense supply chains could bring heightened reputational expectations.

Reshaping the international supply landscape

Of the 50 elements deemed "critical" to the American economy and national security, the US is 100% dependent on foreign suppliers for 12, and over 50% reliant on non-domestic sources for another 31.[9] As such, the government has implemented measures to counteract this sensitivity. For instance, in August 2025, the US Department of Energy (DOE) Advanced Research Projects Agency–Energy (ARPA-E) announced US$60 million in funding for two new technology programs to secure and expand America's critical minerals supply chain, strengthen domestic magnet manufacturing and reduce reliance on foreign-controlled supply chains.[10]

Canada and Australia, both resource-rich and with well-developed mining ecosystems, are positioning themselves as trusted collaborators to the US and Europe. For miners operating in these jurisdictions, this creates favorable conditions for investment in critical minerals projects, often backed by international alliances.

In 2025, the Australian federal government extended a US$88.5 million (A$135 million) support package to keep Nyrstar's smelters operating in South Australia and Tasmania — facilities essential for processing antimony, zinc and lead.[11] It also considered introducing a floor price mechanism for REEs to counter global price manipulation. This policy, modelled on similar approaches in the US, would provide a safety net for producers, such as Lynas and Arafura and could help reduce the risk of sudden market collapse.[12]

Europe and the UK are also embedding critical minerals into broader defense and industrial strategies. The UK's revised Critical Minerals Strategy emphasizes recycling and diversification, creating new opportunities for companies specializing in secondary recovery and circular economy approaches.[13]

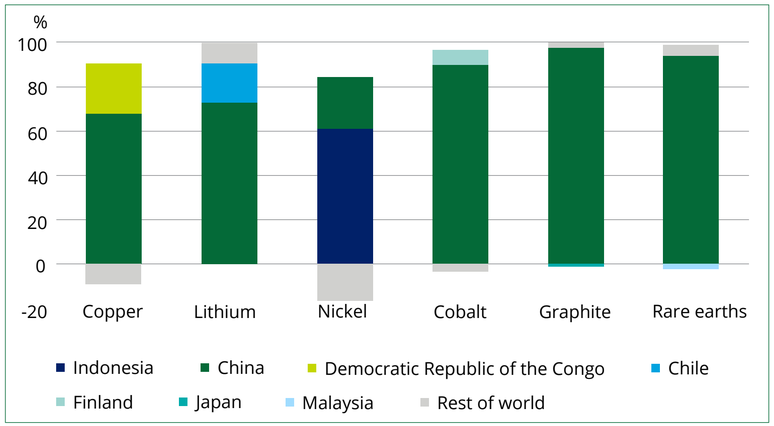
Stacey Toder Feldman, partner, Mining & Metals leader, Deloitte UK, said:

"Strategies such as these could create new opportunities for companies specializing in secondary recovery and circular economy approaches."

Understanding the supply-demand equation

Despite global diversification efforts, the geographic concentration of refining increased across nearly all critical minerals between 2020-2024. The average market share of the top three refining nations of key energy minerals rose from 82% in 2020 to 86% in 2024, as some 90% of supply growth came from the top single supplier alone: Indonesia for nickel and China for cobalt, graphite and REEs (see figure 1).[14]

Figure 1: Change in refined copper, cobalt, nickel, graphite, lithium and REE production by country, 2020-2024.



Source: International Energy Agency[15]

Most critical minerals have limited or no open market pricing; supply is primarily via bilateral contracts and offtake agreements. This lack of transparency is a challenge, as market pricing is often used to underwrite the calculation of price support.

A level of control over both supply and demand is often required to open a market. For example, the reason that oil markets are so transparent, is that the US produces 22% of global supply and consumes about 20%.[16]

In critical minerals, much of the reason that China dominates refining is because it also consumes most of that output.

Navigating trade tariffs

Trade policy is now a frontline challenge for critical minerals. While tariffs are often proposed to protect domestic industries, their effectiveness is mixed and can create unintended consequences.

Recent analysis from the Center for Strategic and International Studies argued that tariffs on commodities such as copper are unlikely to resolve underlying vulnerabilities and may even create new distortions.[17] For miners, this underlines the need to plan for policy shifts that may redefine access to markets, not just costs of production.

Richard Longstaff, managing director, Public Sector lead, Deloitte Consulting LLP, said:

"A new mine or a processing facility is a long-term investment. As such, companies must not only think about where trade and tariff measures make it attractive for them to operate, but also what the stability of those environments is likely to be over a multi-decade time horizon."

Today, effective strategies incorporate these factors, in addition to time-tested variables, such as resource availability, capital and operating expenditure, and fiscal and permitting regimes.

New opportunities and risks

The elevation of critical minerals into the realm of national security changes the role of mining companies in fundamental ways.

They're no longer seen just as suppliers of raw materials; they're becoming strategic collaborators to governments and defense industries.

This likely presents new possibilities. For example, a leading Indian miner and lead-zinc producer is reshaping its growth strategy to reflect national and global security priorities. It announced plans to diversify its portfolio beyond zinc and silver to include up to four new metals by 2030, such as neodymium, tungsten and potash.[18] Shifts like these could also increase access to cheaper capital, guaranteed offtakes and international incentives in the short term.

At the same time, heightened political exposure introduces new forms of risk. Alignment with national security strategies may deliver benefits, but it can also draw companies into geopolitical competition. Exploration pipelines are increasingly under pressure as governments seek to shorten timelines from discovery to production, and companies may need to work more closely with governments to accelerate permitting and development.

South32's CEO recently warned that Australia's complex environmental approval processes hinder the development of critical minerals projects, despite their strategic importance. He contrasted this with the US, where projects such as Hermosa in Arizona benefit from dedicated oversight and streamlined permitting under national security frameworks.[19] The comparison underscores the likely need for regulatory reform if resource-rich countries are to realize their potential as trusted suppliers of critical minerals to global markets.

Harnessing international alliances

As critical minerals rise on the national security agenda, governments are moving quickly to build international cooperative frameworks that support shared resilience.

In October 2025, the US and Australia announced a common policy framework for mining and processing critical minerals and REEs. They plan to accomplish this through use of economic policy tools and coordinated investment to help accelerate development of diversified, liquid, fair markets. Both countries intend to capitalize on their respective existing domestic mining and processing operations and bring new capacity online through 2026.[20]

The G7 Critical Minerals Action Plan, launched in 2025, also commits member states to collaborate on investment, technology sharing and transparent value chains.[21] Similarly, the Critical Minerals Production Alliance seeks to mitigate reliance on single-suppliers, particularly China.[22]

For mining companies, these alliances open new doors. Projects aligned with such initiatives may help with access to financing, accelerated permitting and long-term offtake agreements. They also help companies navigate geopolitical volatility by embedding operations in trusted supply ecosystems.

Stacey Toder Feldman, partner, Mining & Metals leader, Deloitte UK, said:

"It's important that state and private sector work hand-in-hand on this across borders and sectors. Free markets alone will not create resilient supply chains."

Thriving in a security-driven future

The shift toward security-driven demand for critical minerals is unlikely to reverse. For mining and metals companies, the path forward involves navigating a more complex and politically charged environment. Success will likely come to those that embrace new roles as strategic collaborators, balance short-term agility with long-term investment, and align their business models with both security imperatives and sustainability commitments.

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From ideas to action

- **Deepen engagement with governments:** Companies can play an active role in shaping policy by engaging directly with regulators and trade groups. By contributing data, insights, and practical experience, miners may help governments design interventions that are realistic and commercially viable.
- **Explore secondary recovery opportunities:** Quick wins, such as extracting germanium from zinc tailings or REEs from historic mine waste, not only strengthen supply chains but also demonstrate agility and alignment with national security priorities. These initiatives can deliver near-term volumes while exploration pipelines mature.
- **Diversify portfolios with a security lens:** Miners may consider balancing high-volume energy transition minerals, such as copper and lithium, with smaller but strategically important minerals like antimony and gallium. This can help position portfolios to benefit from both commercial demand and government incentives.
- **Prepare for geopolitical volatility:** Companies that scenario-plan for tariffs, sanctions, or supply chain disruptions will likely be more resilient. Flexibility in contracting, financing and market access strategies could become a source of competitive advantage.
- **Build relationships across ecosystems:** Collaborating with downstream manufacturers, technology firms and allied governments can help miners strengthen their role in critical supply chains while realizing deep purpose. These relationships may also open access to new markets and funding opportunities.

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Trend 2

Future-proofing portfolios: Positioning organizations for long-term value growth

Authors

Edwin Datson, partner, Strategy, Risk & Transactions, Deloitte UK

Nicki Ivory, partner, Mining & Metals leader, Deloitte Australia

In the current environment, mining and metals organizations are being asked to perform a delicate balancing act. On one hand, they should manage current cashflow and shareholder distributions to deliver near-term production and profitability. On the other, they should position themselves for long-term growth as demand for critical materials surges, customers seek low-carbon feedstock and investors scrutinize exposure to emerging risks.

Edwin Datson, partner, Strategy, Risk & Transactions, Deloitte UK, said:

"The combined effects of the energy transition, shifting geopolitics and technological evolution are disrupting mining and metals portfolio choices. Decisions surrounding which minerals, which sites, and which customers to pursue and in what form are more complex than in the past. Therefore, customer intelligence, creating optionality and portfolio agility could be more valuable than ever before."

The value growth challenge

As the mining and metals landscape has grown more complex, companies often face a new set of priorities, demanding a shift from traditional portfolio management approaches to more strategic, agile and sustainable practices. They may also require a broader range of capabilities and technologies to deliver purpose as well as profit.

Operational efficiency remains important, and ways to achieve this have been explored through smart operations in trend 5. But going forward, enhanced skills in areas such as mergers and acquisitions (M&A) execution and governance, customer segmentation, carbon tracking and trading sophistication could play important roles in driving value growth.

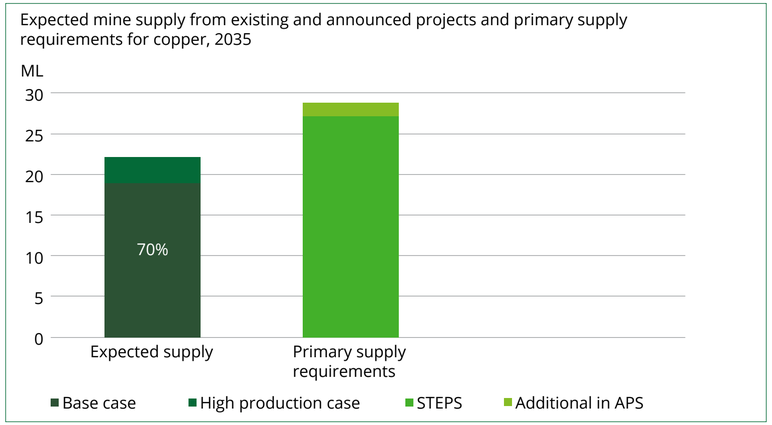
There's a clear imperative in developing this capacity. Given global volatility, companies that persist with a narrow or static definition of portfolio management could risk being left behind. While those that embrace complexity and develop the ability to adapt may be better positioned to lead.

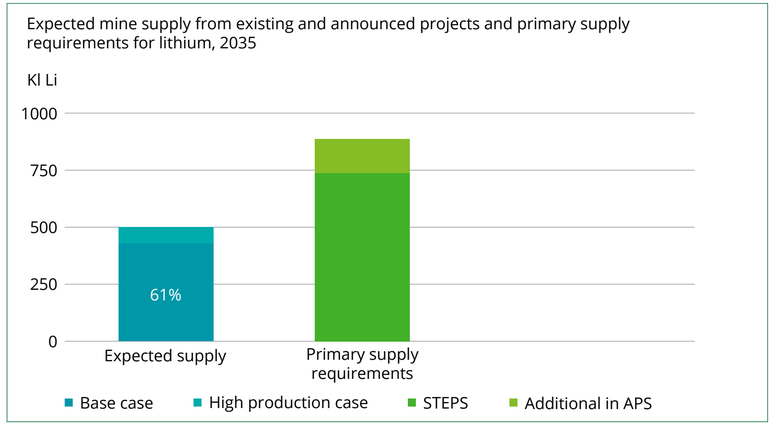
Rebalancing for commodities and markets

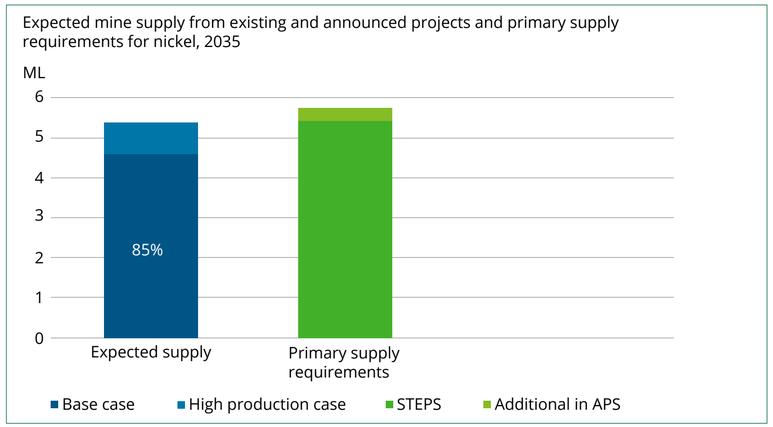
A central question in defining portfolio strategy is which commodities to back. Despite contrasting trends in different economies, the underlying structural drivers of the world's coal use remain broadly unchanged and demand is expected to plateau through 2026.[1]

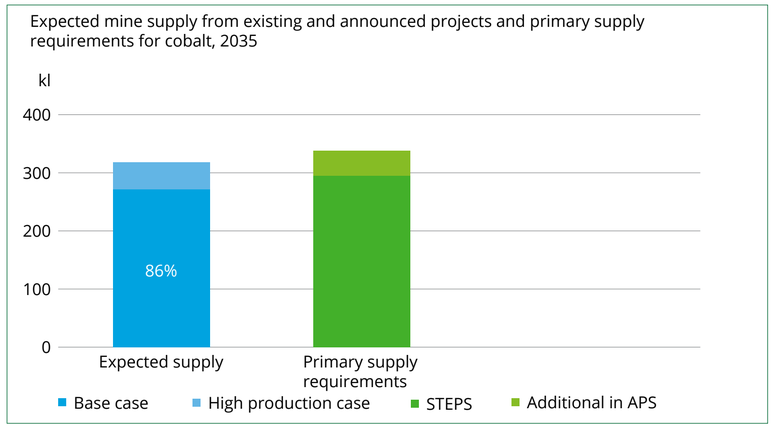
Iron ore remains important, but prices are expected to decline over the long term, largely due to a projected surplus in the global seaborne trade balance.[2] In contrast, demand for critical metals, including copper, lithium, nickel and cobalt, continues to rise (see figure 1) as governments and industries pursue reducing emissions and national security interests.[3]

Figure 1: Projected demand for key energy metals to 2035.









Source: International Energy Agency

Against this backdrop, mining and metals producers are taking different bets. For example, following its 2025 acquisition of Arcadium Lithium, Rio Tinto now boasts one of the world's largest lithium resource bases. The company aims to grow the capacity of its tier 1 assets to more than 200,000 metric tons per year (t/y) of lithium carbonate equivalent by 2028.[4]

Vale is using its high-grade iron ore advantage to support downstream low-carbon steel solutions. The company signed an agreement in 2024 with European hydrogen company, Green Energy Park. Through this, the companies will work on feasibility studies for a green hydrogen production facility. This will supply a future "Mega Hub" in Brazil – an industrial complex aimed at manufacturing low-carbon steel products.[5]

Copper, meanwhile, remains the sector's "safe bet", and companies seem increasingly willing to undertake highly complex deals to unlock access at more attractive implied values. One example is Anglo American's 2025 merger of equals with Canadian headquartered Teck Resources to create "a top five global copper producer." [6]

Beyond single commodities, many miners are beginning to look at portfolios through the lens of customer ecosystems. Electric vehicle (EV) manufacturers, for instance, require integrated access to lithium, cobalt, nickel and copper. Serving these bundled needs could create stickier customer relationships and encourage long-term offtakes and other stakes to guarantee downstream companies security of supply.

Secondary markets are also emerging as an important part of the picture. With global mined copper supply forecast to fall short of demand by 30% by 2035,[7] recycling and circular economy strategies could fast become a tool to build portfolio resilience.

For example, Glencore signed a multi-year deal in December 2024 with Canadian rare earth and metals recycler, Cyclic Materials. Under this, Cyclic Materials will supply at least 10,000 metric tons (mt) of recycled copper to Glencore for processing and refining at its Horne Smelter and Copper Refinery in Québec for copper cathode production.[8]

M&A as a lever for future-proofing

The mining and metals sector has seen constant and significant M&A activity in the past two decades, influenced by market dynamics, sustainable growth challenges and global economic trends.[9] Deal value has grown 47% since 2000 as companies have sought to secure future-facing commodities, access key capabilities, lower their costs, and share risk.[10]

Striking the right deal and integrating effectively can help companies to unlock portfolio synergies, enhance production and improve EBITDA without the difficulty of setting up new assets. Research shows mining deals that announce and track revenue synergies outperform peers and tend to overachieve revenue targets by an average of 39%. Solid and well-tracked costs, as well as strong governance processes, are also key to success. In contrast, poor integration or paying too much for an asset could impact company valuations, perceptions and profit.[11]

M&A is also evolving beyond resource access. Companies are increasingly acquiring downstream capacity, technologies to enable more efficient production, recycling infrastructure and customer-facing platforms.[12]

This reflects a broader redefinition of what a mining portfolio comprises; tomorrow's portfolio could be about capabilities as much as commodities.

Unlocking additional value through secondary materials

As primary metal reserves become increasingly scarce and project permitting times lengthen, recycling and secondary materials may offer a way to increase production without the capital intensity of new mines. However, companies that take this approach will likely need to manage more complex value chains (potentially both up and downstream activities) to extract maximum value.

Recycled copper can be up to 13 times cheaper to produce than mined copper while using up to 85% less energy.[13] Aluminum recycling requires only 5% of the energy used for primary production, with nearly 75% of all aluminum ever produced still in use.[14] Lithium recycling, though nascent, is drawing significant interest as automakers seek to secure sustainable supplies; lithium-ion battery recycling patents grew at an average annual rate of 56% from 2017 to 2022, and venture capital investment in battery and waste recycling surged between 2022 and 2023.[15]

Customers are driving this shift. Technology firms like Apple have signed contracts for recycled aluminum,[16] while automakers, such as Ford, BMW, and Jaguar Land Rover are seeking recycled materials to help meet carbon reduction targets and critical raw material demands.[17] Energy companies are also looking to recycled copper to support renewable power networks that use approximately six to 12 times more copper than non-renewable systems.[18]

Rio Tinto's joint venture with Giampaolo Group, Matalco, already produces over 500,000mt/y of recycled aluminum.[19] Stena Metall is also building a lithium battery recycling hub capable of processing 10,000mt/y in Sweden.[20]

Entering secondary markets can require new logistics capabilities, traceability systems, and industry collaborations. It's important that organizations develop a structured process to evaluate "where to play" in the secondary materials value system, supported by clear business cases and a firm understanding of the potential return on investment. The pay-off could be greater optionality and resilience and the chance to meet growing demand in a capital-light way.

Exploring downstream and customer-centric models

Nicki Ivory, partner, Mining & Metals leader, Deloitte Australia, said:

"A future-proof portfolio could require mining companies to shift their mindset from supplying commodities to providing solutions. This may necessitate moving further downstream into refining, processing and semi-finished products."

Many downstream consumers of minerals and metals have their own sustainability and traceability goals to meet and are willing to pay premiums for differentiated products. Moving downstream could allow miners to capture this value, while also realizing deep purpose. For example, 98% of Vale's CO_2 emissions come from its value chain. Following 20 years of research, the company began marketing a new product in 2021, iron-ore briquettes. These can reduce greenhouse gas emissions in steel production by up to 10% by eliminating the carbon-intensive sintering stage.[21]

Vale has since signed more than 50 agreements with clients to offer energy transition solutions, encompassing 35% of the company's scope 3 emissions. They include three agreements aimed at setting up Mega Hubs in Saudi Arabia, the United Arab Emirates and Oman to produce briquettes. These are intended to supply local and seaborne markets, leading to lower CO_2 emissions,[22] and help the company to realize its purpose of "improving life and transforming the future." [23]

Models like this often require closer customer engagement, and instead of simply selling into anonymous markets, some miners are beginning to co-develop roadmaps with original equipment manufacturers (OEMs) and industrial collaborators. The result is a more customer-centric portfolio that aligns production with end-market needs and captures greater share of value.

Winning the next decade

The mining sector is under pressure but also potentially poised for renewal. As investors seek sustainable returns, customers consider low-carbon solutions, and more governments push for security of supply, the definition of a successful mining portfolio is ripe for being rewritten.

Leveraging strategic commodity bets, evaluating secondary markets, collaborating with customers in new ways and understanding the power of bold M&A activity could help position companies to win. To these businesses, future-proofing may be less about protecting the past and more about creating a platform for purpose-driven growth in an unpredictable world.

From ideas to action

- **Evaluate downstream potential:** Companies could consider moving into refining, processing, and differentiated products to command premiums and build customer intimacy. Developing semi-finished products, like low-carbon aluminum or iron-ore briquettes, could embed miners more deeply into value chains. Working directly with OEMs on product specifications may help secure long-term offtake contracts and reduce exposure to spot market volatility.
- **Collect value chain intelligence:** Regardless of whether companies opt to own or collaborate for downstream activities and assets, it will be important to obtain intelligence about end customers as well as parties throughout the value chain, including in processing and extraction. The ability to synthesize that intelligence quickly into smart marketing and operational decisions could also be key to future success.
- **Upskill the workforce:** Future-proofing portfolios may require new skills, talent, and organizational capabilities such as M&A execution and governance, demand sensing and customer segmentation. Consider implementing talent strategies that blend mining skills with digital, commercial and sustainability skills. Upskilling initiatives could include collaborations with universities and technology firms, cross-industry exchanges and in-house academies to nurture new competencies.

  Mining companies that successfully reposition their employer brand as central to the clean energy transition could also be better positioned to attract scarce digital and sustainability talent.
- **Consider the full material life cycle:** Investing in secondary materials and building circular economy capabilities may reduce reliance on primary mining and unlock new value streams. Companies could develop in-house recycling hubs, work with downstream customers on closed-loop supply models or explore traceability platforms that give recycled products a premium market position. This approach not only provides resilience but can also strengthen sustainability credentials.

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Trend 3

Deep purpose: A new imperative for mining and metals

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For more than a century, the mining and metals industry has operated with a clear mandate: to extract, process, and deliver the raw materials that help underpin global economic progress. That mandate remains unchanged. What has changed — and continues to accelerate — is the set of expectations placed upon mining companies by employees, communities, regulators, investors and society at large.

In this new era of heightened scrutiny, shifting societal values, and rapid technological transformation, the pursuit of deep purpose is emerging as a defining factor of competitiveness. This is not a branding exercise, nor is it an extension of sustainability, or corporate social responsibility (CSR). Instead, deep purpose represents the shared desire for an ideal future that aligns those who influence an organization's success, unlocking its full potential.[1]

The mining sector, more than most, stands at the heart of this shift.

Ian Sanders, Global Mining & Metals leader, Deloitte Global, observed:

"Mining organizations know they cannot simply rely on operational excellence. The next horizon of competitiveness requires rethinking how we create meaning and mobilize stakeholders around that purpose."

Why purpose matters now

Mining companies today face a confluence of pressures. The energy transition is reshaping demand for commodities, from copper to lithium.[2] Communities are looking for stronger collaboration.

Regulators and investors are raising expectations on transparency, sustainability and long-term value creation. At the same time, talent shortages may impact the sector's ability to deliver on growth ambitions.[3]

Deep purpose provides a unifying response to these challenges and more. Unlike mission statements that describe what a company does, or sustainability strategies that help mitigate risk, purpose articulates an enduring reason for being; one that speaks to a company's broader societal impact.

Mining companies increasingly recognize that a clear, authentic sense of purpose is no longer a "nice to have". It's important in building resilience, stakeholder trust and fuelling business growth. Purpose can help to guide decision-making through volatile environments, support social license to operate, and attract both talent and investors who are looking for organizations with values beyond shareholder returns.

Mike Robitaille, partner, Strategy, Risk & Transactions, Deloitte Canada, explained:

"Every CEO today should regard their job as akin to a leader of a nation; you're running for office, building coalitions of employees, consumers, communities, and regulators. If you can earn their trust and belief, they will help your company succeed."

From purpose to deep purpose

It's tempting to assume that having a mission statement or a sustainability report fulfills the requirement of purpose.

Mike Robitaille, partner, Strategy, Risk & Transactions, Deloitte Canada, noted:

"For many, the first era of purpose was an attempt to suggest that companies cared about more than money. However, statements like 'we create the materials the world needs' are platitudes. Deep purpose is different. It reorients a company as an agent of a human ideal, something people genuinely want to rally behind."

Deep purpose builds on decades of management thinking but takes the concept further.[4] It fuses economic logic with social logic, creating outperformance by capturing both the "mind" (driving operational excellence, efficiency and shareholder returns) and the "heart" (with devotion, belief and enthusiasm).[5]

Research suggests that while IQ and fact-based logic account for 20% of high performance within organizations, the remaining 80% lies in untapped human motivation, group identity and moral psychology.[6]

Deep purpose in action: The Saskatchewan First Nations Natural Resource Centre of Excellence

In Saskatchewan, the mining and critical minerals sector, including emerging processors such as the Saskatchewan Research Council (SRC) Rare Earth Processing Facility, is increasingly turning to the Saskatchewan First Nations Natural Resource Centre of Excellence (the Centre) as a trusted collaborator for building meaningful, long-term relationships with First Nations. With a mandate from the leadership of the 74 First Nations in Saskatchewan, the Centre plays a central role in supporting collaboration between communities and industry to help ensure that the benefits of resource and energy development flow directly into community building, workforce inclusion, and First Nations business participation across the value chain.

As Sheldon Wuttunee, the Centre's CEO and president, notes, "Our work is about building reciprocal partnerships that advance both community well-being and industry success. When First Nations are fully included, as owners, workforce participants, and business leaders, everyone benefits."

These relationships are strengthened through transparency, capacity building, and ongoing dialogue that help rebuild trust, enhance social license, and model a new standard for purpose-driven resource development.

Why mining and metals companies may need deep purpose

The processes and functions within most mining companies (and heavy industry in general) are still governed by operator-style management principles that were defined in the 1980s and 90s. These approaches are based on the premise that corporations wield a certain level of power over their stakeholders.

While this was once sufficient to help drive success, the past decade has borne witness to a change in prevailing social dynamics and a reclamation, or reversal, of power by groups, including consumers, employees, customers and communities. This shift has seen companies pulled in many different directions.

Deep purpose offers three distinct roles for mining companies today:

1. **As economic engines for non-urban populations.**
   Operating in remote areas, mines often define the economic and social trajectory of many regions. By investing in local jobs, skills, businesses, and infrastructure, mining companies can embed themselves as collaborators in prosperity.

2. **Bedrock of the technological revolution.**
   From semiconductors to AI data centers, many advanced technologies are impossible to create without minerals.[7] In producing these materials, mining companies have an opportunity to define themselves not as extractors, but as enablers of human progress, shaping the next critical minerals supercycle.

3. **Stewards of the energy transition.**
   Mining is a key determinant in the speed and scale of the global energy transition. Responsible resource development and innovation may advance global progress while addressing environmental and social challenges.

This trifecta – economic, technological, environmental – makes deep purpose not just relevant but an important factor for mining. Without it, companies could risk losing their social license, their talent pipelines and ultimately their future competitiveness.

Building a business case

While mining and metals companies are working to augment their operations and capabilities with AI and data insights, fundamentally they are still organizations of human beings that exist to serve the needs of human beings, i.e. society. They will probably remain this way for the foreseeable future, and so reorienting business purpose, mission and values to place people and their ideals at the core makes sense.

For an industry that's built on physical products and assets, there's a risk that purpose could be dismissed as a "soft" or intangible concept. But the evidence tells a different story. Companies with deeply devoted followings are often more resilient, innovative and valuable over the long term.[8]

Volatility has become the new norm for mining and metals companies over the past decade, and so resilience is an especially desirable quality.

Companies that stand for something beyond extraction could be better positioned to weather commodity cycles, mobilize communities and attract investors seeking growth with meaning compared to those that do not.

For investors, power through purpose is equally compelling. Financial multiples are often driven less by current earnings than by belief in a company's future. Mining leaders could articulate that ambition more clearly.

Make purpose actionable and relevant

If questioned, most leaders would agree that winning hearts and minds is important to the success of their businesses; 89% of CEOs say their company has a stated purpose and 76% agree that the importance of purpose has increased over the past five years. However, research has shown that CEOs find their stated purpose neither actionable nor relevant. Deep purpose brings success patterns and discipline to this important subject for next era-leaders.[9]

Embedding deep purpose often requires time and discipline. It cannot be outsourced to corporate affairs or marketing. It should sit at the core of leadership, culture, strategy, and operations. In ensuring this, there are four key "trunks" to consider:

1. **Strategy:** Purpose should guide corporate choices and direction.
2. **Culture:** It should motivate and inspire employees.
3. **Brand and reputation:** It should be evident in each stakeholder interaction.
4. **Responsibility:** It should shape corporate responsibility, ensuring alignment between words and actions.

For example, Apple's purpose is "to create technology that empowers people and enriches their lives."[10] Fulfilling this depends heavily upon innovation, and so the company's organizational design and leadership philosophy are optimized for this. Apple has a relatively flat, functional organizational structure where subject matter specialists report directly to the CEO rather than a middle manager. Decision-making is also led by subject matter specialists. These moves are based on the premise that world-class talent wants to work directly for and with world-class talent.[11]

Early mover examples

Across the industry, examples of this shift are emerging. For example, ArcelorMittal has framed its business around the purpose of delivering "Smarter steels for people and planet."[12] Steel is one of the only materials to be completely reusable and recyclable. It will likely play an important role in building the circular economy of the future so ArcelorMittal's 126,000-person strong global workforce is focused on research and development.[13]

"Steel will continue to evolve, becoming smarter, and increasingly sustainable," ArcelorMittal's mission statement notes. "We have some of the best and brightest people in the business — engineers who work for us because they get to tackle the most complex of problems."[14]

Anglo American's purpose of "re-imagining mining to improve people's lives"[15] is evident in the way it designed and executed the Quellaveco copper project in Peru. Together with local communities, the company co-developed water management programs to help secure social license and build long-term trust. Quellaveco now provides clean drinking water to local towns through a modern treatment plant, powered entirely by renewable solar energy.[16]

These are some early signals of how deep purpose can move from narrative to practice.

Understanding the opportunities and risks

The risks of neglecting deep purpose could be significant. Without it, mining companies face the very real danger of talent attrition. OECD (Organisation for Economic Co-operation and Development) research shows that 86% of mining executives report growing difficulty in recruiting and retaining skilled workers.[17]

Many employees today, particularly younger ones, seek more than remuneration through work. Many aim for higher meaning and the chance to pursue work that connects with their own personal reasons for being as well as their cherished values and beliefs. Companies that pursue deep purpose could help deliver this meaning for employees, potentially changing the nature of their relationship with work and the organization.[18]

Equally, many communities and regulators are better organized and more vocal than ever, and ready to challenge extractive models that may not demonstrate long-term benefit for all. A failure to act risks eroding trust and constraining access to resources, which could undermine the future competitiveness of the industry.

Yet the opportunities available are just as important. Mining companies that embrace deep purpose have the chance to advance their trust with stakeholders by addressing past mistakes and prioritizing long-term impact over short-term extraction. There's the chance to create shared value through investments in local infrastructure, workforce development and collaborations that likely endure well beyond the life of a mine.

Just as importantly, mining companies could position themselves at the forefront of the global energy transition, defining their role not merely as suppliers of raw materials but as indispensable enablers of technological progress and sustainable development.

In doing so, companies could recast themselves as agents of human ideals – economic prosperity, environmental stewardship, and innovation – in a way that resonates with stakeholders and helps secure their place in society's future.

The next way to win

Mining is a long-term endeavor. Projects often span decades, and relationships bridge generations. In this context, deep purpose is not a distraction from operational excellence, it's the next frontier of it.

Companies that can orient themselves around deep purpose can be well equipped to navigate volatility, attract stakeholders and unlock organizational potential. They could stand, not just as extractors of resources, but as enablers of human progress, technological transformation and environmental stewardship.

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From ideas to action

- **Engage broadly with stakeholders:** Purpose cannot be defined in isolation. To do this, mining leaders could create forums for dialogue with employees, hosting communities, investors, regulators and industry collaborators. By understanding what matters across this ecosystem, companies and stakeholders can co-create a purpose that is authentic and durable.
- **Audit and articulate clearly:** Conduct a candid assessment of current company values, behaviors, and perceptions, then define a concise, inspiring purpose statement that distinguishes the company's role in society. This should move beyond extraction to emphasize values such as stewardship, innovation, or shared prosperity.
- **Embed in strategy and culture:** Purpose should translate into measurable objectives, key performance indicators (KPIs), and incentives. It's important that leaders model behaviors consistent with the company's stated purpose and reinforce it through recognition, storytelling and day-to-day decision-making.
- **Align investments and innovation:** From community infrastructure to circular mining initiatives, capital allocation should reflect the company's deeper ideals. Companies that align investment choices with purpose could differentiate themselves in capital markets and with stakeholders.
- **Revisit and renew:** Purpose is enduring but not static. Regularly revisiting the purpose statement helps ensure it evolves alongside external expectations and organizational ambitions, keeping it relevant for the next decade and beyond.

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Trend 4

Evolving operating models: Structuring organizations to deliver value over volume

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To thrive in an increasingly complex and unpredictable future, mining and metals companies should go beyond re-thinking business strategies and look more deeply at breaking the conventions of industry operating model designs. This early and ongoing interlinkage is important to delivering shareholder returns and creating long-term competitive advantage.

While business models often define how value is created and captured, the design of the operating model will likely determine how exactly the organization can effectively execute and deliver on that intent. This means defining the configuration of governance, people, processes, technology, and culture to optimally deliver value and help enable resilience, agility and long-term profitability. Yet, many mining and metals organizations continue to run or incrementally build on legacy operating models designed for an earlier era of mining.

Why rethink operating models?

Mining projects are becoming ever-more complex, operations are increasingly in challenging jurisdictions, and meanwhile, shareholder expectations around operational efficiency are continually being stretched. Due to growth in demand for commodities such as copper, recent years have seen an influx of new entrants into this market, including well-funded startups backed by global investors and smaller miners acquiring and advancing copper assets.[1] Many of these players also have highly efficient, fit-for-purpose operating models.

Against this backdrop, how can a modern miner outcompete and exceed shareholder expectations? In this context, cost discipline, operating efficiency and effective deployment of innovation are key.

At the same time, digital tools, automation, and artificial intelligence (AI) are offering new opportunities to optimize productivity, improve safety and reduce environmental impacts. However, without an agile operating model that integrates information technology (IT) and operational technology (OT), these benefits risk being fragmented or under-realized. This is often compounded by an innovation function that's either siloed or faces challenges in commercializing new technology into the business, particularly into production operations.

The global competition for skilled talent is also intensifying, particularly as younger generations seek purpose-driven, flexible work environments; according to Deloitte Global's 2025 Gen Z and Millennial Survey, 9 in 10 Gen Zs (89%) and millennials (92%) consider a sense of purpose to be important to their job satisfaction and well-being.[2] Rigid, hierarchical structures that once defined mining businesses are increasingly at odds with employee expectations.

Future-fit operating models enable sustainability principles to be embedded into everyday decision-making, rather than treated as compliance or add-ons. They may also enable companies to better explain the link between sustainability and financial resilience.

Merlyn Gregory, partner, Strategy, Risk & Transactions, Deloitte UK, emphasized:

"Strong operating models drive cost reductions through efficiency in decision-making and defining clear incentives and accountabilities; but crucially, it's also about setting the organization up for its next phase of growth. Allowing organizations to seamlessly harness and integrate new technologies and maximize return on investment. With ore grades in decline; efficient, modern operating models are table-stakes in order to protect margin."

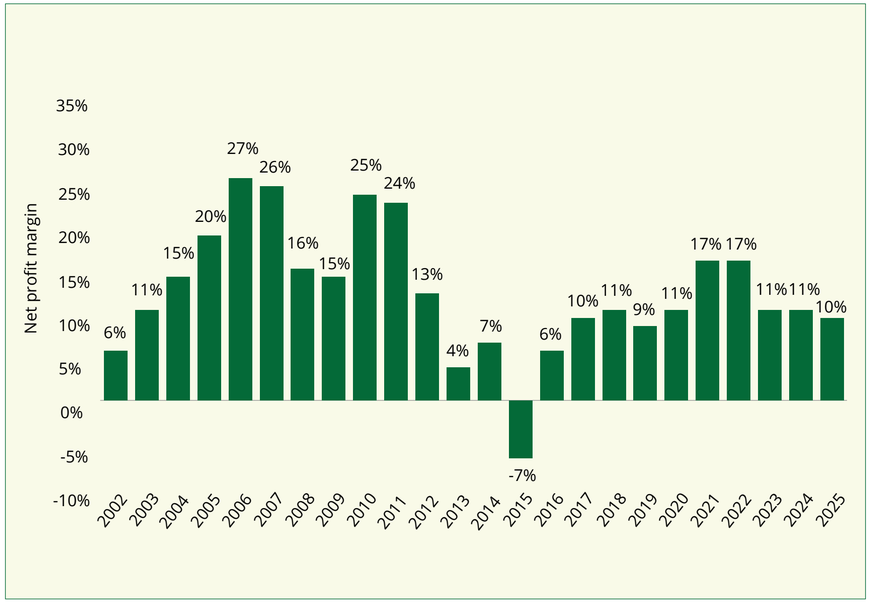
Traditional models under pressure

For decades, the operating models of mining and metals companies were designed around scale. Production volumes were the key measure of success, and structures reflected that. This approach delivered growth throughout cycles, particularly in bulk commodities where scale is important.

However, today's environment is different. Declining ore grades, capital constraints, and rising expectations around sustainability and safety may expose weaknesses in models built primarily for volume.[3] For example, these may necessitate more nuanced production processes and systems, or the navigation of more complex supply chain configurations and supporting infrastructure.

Capital markets are also signalling the need for a reset. Industry revenue growth has stalled in recent years while earnings have been squeezed by volatile prices and rising costs. Since 2011, the net profit margin of the mining industry's 40 leading companies has fallen from 24% to 10% (see figure 1).[4]

Figure 1: Net profit margin of leading mining companies worldwide from 2002–2024 with projection for 2025.



Source: Statista

This challenge is compounded by the blurring of business and operating models. When the two are not properly aligned, companies may unintentionally destroy value. For instance, if organizations only incentivize tonnage, they risk encouraging employees to think more about volume and less about profitability and purpose.

Some mining companies, such as Evolution Mining, are actively prioritizing "margin over ounces."[5] Evolution does this by driving a high-performing culture with values and reputation as non-negotiables; being willing to take appropriate geological, operational and financial risks; building a portfolio of assets in Tier 1 jurisdictions generating superior returns; and having financial discipline centered around margin and appropriate capital returns.[6] However, approaches like this remain an exception rather than the industry norm.

Rethinking customer involvement

In parallel, new demand patterns linked to the energy transition are changing value pools, with copper and high-grade iron ore playing an outsized role as system enablers. Growing interest in secondary materials is also creating new options for growth.

Struan Buchanan, partner, Strategy, Risk & Transactions, Deloitte Australia, said:

"For mining and metals companies, the big challenge is understanding customer dynamics better, as many miners reconfigure their portfolios toward commodities more closely tied to consumer behavior dynamics. That shift to customer-centric thinking could change where businesses play and operating models will need to shift with it."

Traditional customers of miners with critical minerals and future facing commodities (e.g. battery or auto manufacturers) are seeking greater control and line-of-sight of the complete value chain. This is creating more cross-value chain collaboration and giving them greater involvement in production, for instance, through buying up or down the value chain. Uranium miner Cameco's 2023 acquisition of Westinghouse Electric Company in collaboration with Brookfield Asset Management, which gave it a 49% interest in one of the world's largest nuclear services businesses, is one example.[7]

To fully leverage increased collaboration could require mining businesses to adjust their operating models and ways of working. If company systems, ways of working, and governance processes fail to shift in response, then these ventures may not be fully effective.

From rigidity to flexibility

Enabling this shift likely requires rethinking operating models at their core and anchoring design choices to where value is created now. Bulk commodity producers have historically built end-to-end operating systems, controlling assets, such as infrastructure, to move vast volumes of material efficiently. Meanwhile, base metals producers have tended to rely on complex processing chains and deep supplier collaboration. Each configuration brings its own set of challenges when it comes to cost, flexibility, and agility.

Merlyn Gregory, partner, Strategy, Risk & Transactions, Deloitte UK, explained:

"When cost inflation combines with ore grade decline, pre-existing reward structures that focus on production volumes create underperformance and stifle problem-solving. The risk is rigidity: structures built for stability and scale slow down decisions in an era that demands, and rewards, speed and learning."

By contrast, programs that reduce overheads, such as trimming just one percentage point of selling, general and administrative expenses (SG&A) as a share of revenue, could have a disproportionately positive impact on margins.

One of the most important steps could be to distinguish between differentiating capabilities and key functions within organizations, then position them closer to where value is generated. Organizations that stratify their capabilities could focus investments on the areas that matter most to their competitiveness, while seeking efficiencies or collaboration in supporting functions.

For example, with rising capital constraints, miners are increasingly asking whether they should continue to own and operate infrastructure, such as energy, logistics, and water assets, or whether those functions could be managed more effectively through collaborations.

In South America, where water scarcity is a top challenge for mine operators, collaborative infrastructure projects are a growing trend. In July 2024, mining company, Hot Chili, announced it had signed a joint venture with Chilean iron-ore producer, Compania Minera del Pacifico, to supply seawater and desalinated water to mining projects in Chile's Huasco Valley.[8]

Antofagasta signed a US$600 million deal in 2024 to transfer Minera Centinela's existing water transportation assets and rights to an international consortium of partners. The planned expansion of the water transportation system for the Centinela Second Concentrator Project will now be undertaken by the acquiring consortium, resulting in a reduction in the overall capital cost of the project by approximately US$380 million.[9]

Configuring operating models in this way may not only reduce cost pressures on organizations but could also help ensure that purpose and sustainability are embedded into core processes, making the link between financial performance, environmental outcomes and community impact even more transparent.

Opportunities to create and scale value

Technology integration offers further opportunities. By better aligning IT and OT, mining companies could apply predictive analytics, Generative AI (GenAI) and Agentic AI solutions more effectively at the enterprise level, delivering value multiples (see sidebar on p.34, "Supporting AI usage at the enterprise level"). This could transform productivity through uptime and efficiency improvements, as well as support new ways of working, such as remote operations, remote collaboration and integrated planning across the value chain, as discussed in trend 5

Some miners are already doing this. MMG, for example, reshaped its IT operating model to better support agility and resilience. Moving away from a purely outsourced structure, the company noted that the adoption of a blended managed-services approach and the migration to one of the cloud providers enabled it to have more flexible capacity and manage cost control.[10]

This shift helped reduce costs, improve risk management, and enhance the user experience across its international footprint. By rethinking how IT was delivered, MMG created a technology backbone that was more flexible and sustainable, allowing its IT function to focus more highly on governance and strategy.[11]

While targeted changes like these can deliver value, the greater opportunity may lie in reimagining operating models at the organizational level. For instance, some majors are applying devolved structures to push decision-making closer to the front line, improving responsiveness to local conditions. Smaller miners, on the other hand, are moving in the opposite direction, centralizing governance to strengthen oversight and capture scale benefits.

Mining is not alone in this transformation. One example comes from Bayer. The life sciences organization has reimagined its management approach by introducing a dynamic shared ownership model. This flattened hierarchies and empowered employees to make up to 95% of business decisions without escalation through multiple layers of management.[12]

In practice, the company reduced management positions by approximately 50% and consolidated operations into 5,000 to 6,000 self-directed teams, each working in 90-day sprint cycles. The result was faster decision cycles, greater speed to market and stronger employee engagement.[13]

Struan Buchanan, partner, Strategy, Risk & Transactions, Deloitte Australia, said:

"Embedding a culture within an operating model that prizes empowerment, problem-solving, and efficiency is just as important as structural or technological change. The challenge is shifting mindsets away from volume for volume's sake toward purpose-driven value creation."

Supporting AI usage at the enterprise level

In early adopters, the application of emerging technologies such as GenAI and Agentic AI is helping to flatten and simplify organizational models. Organizational structures exist, in part, to process information and support its proliferation throughout the organization. GenAI and Agentic AI can provide new ways for the workforce to analyze and leverage complex data that was previously difficult to understand, (as discussed in trend 7) and, in the case of GenAI, the ability to synthesize it as a decision-maker. This could reduce the layers within organizational structures, and simplify workflows and traditional interfaces between functions.

Refocusing for value over volume

The transition to new operating models is not without risk. Restructuring organizations at scale can be disruptive and resource intensive. Long-standing traditions of hierarchy and volume-based incentives may also be difficult to overcome, creating cultural inertia.

However, the cost of inaction may be higher. In time, companies that fail to evolve their business and operating models in parallel could see their competitiveness, profits and stakeholder trust decline. Meanwhile, companies that act fast to reconfigure their organizations for greater alignment with deep purpose, agility and accountability could better position themselves for long-term success.

The choice is clear: Continue with structures that reflect the past or embrace transformation to help build a more profitable, and sustainable future.

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From ideas to action

- **Reassess strategic alignment:** Regularly review whether the current operating model and incentive structure aligns with both corporate strategy and capital market expectations. Where gaps exist, leaders could take deliberate and meaningful action to ensure both remain aligned.
- **Stratify capabilities:** Consider distinguishing between differentiating capabilities and ticket-to-play functions. This could enable companies to prioritize investment in differentiators, while considering efficiencies or collaborations for non-core activities.
- **Reconfigure governance:** Analyze the practical trade-offs of shifting accountability to assets or back to the center to help scale efficiencies, taking input from those on the ground. Piloting new structures before rolling them out more broadly could help them to gain traction among key roles.
- **Embed culture and incentives:** Companies could redesign their performance incentives to reinforce the prioritization of value-creation, safety and efficiency over sheer volume. Providing leadership development programs may encourage autonomy and accountability.
- **Integrate technology more deeply:** Treating technologies like GenAI and Agentic AI as enablers of new operating models, rather than add-ons, could help realize greater value. Effectively integrating these technologies into key areas of the business may drive value creation and enable teams to be more autonomous in creativity and problem-solving. Governance frameworks that connect digital adoption with measurable sustainability and profitability outcomes can help maintain trust.

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Trend 5

Extracting advantages from data:

Using smart operations to overcome complexity

Authors

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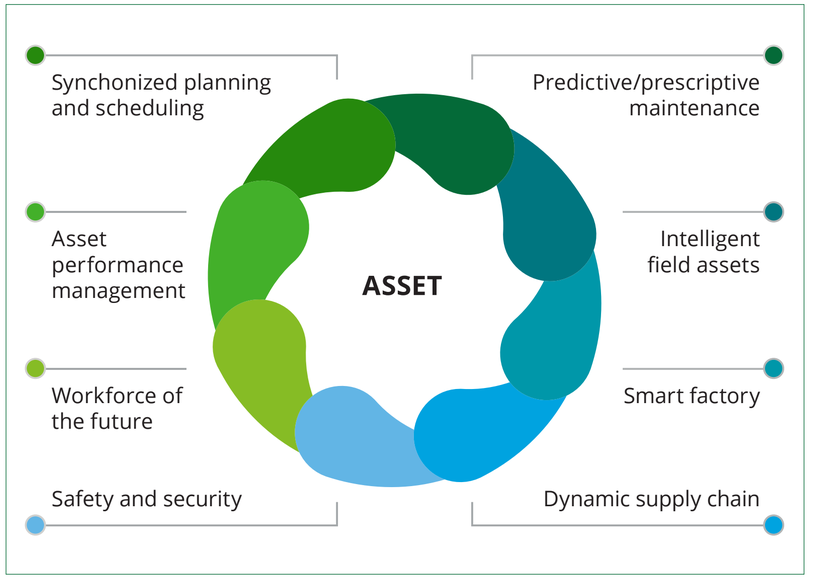
Artificial intelligence (AI) is already enabling improvements and efficiencies across the mine life cycle, as discussed in trend 6. But to optimize the performance of highly complex operations and value chains could require the creation of smart operations: fully connected ecosystems where assets, systems, and people work together in real time to make mining safer, faster and more reliable (see figure 1).

Steve Dyson, partner, Strategy, Risk & Transactions, Deloitte Australia, said:

"Smart operations go beyond single-point solutions. They require multiple systems, platforms and sensors that can 'talk' to one another to extract maximum value from companies' data. With advances in Generative AI (GenAI) and Agentic AI, we're reaching a point where operating systems can begin to make better-informed decisions, driving safety, productivity and profitability."

The question for mining leaders is not whether their organizations should move in this direction, but how quickly and boldly they're willing to begin. Speed is of the essence, and trusted systems integrators could prove important in capturing value.

Figure 1: Key elements of smart mining and metals operations.



Source: Deloitte & Touche LLP[1]

Data volumes are increasing

Today, mining companies gather vast amounts of operational data: from haul trucks and drilling equipment to processing plants and power systems, sensors are generating time-series data at exponential rates. However, productivity improvements are only possible if that data is managed and leveraged to achieve the organization's goals.[2]

This growth of digital information is mirrored in industry investment trends. The global mining automation market, covering solutions from autonomous haulage to integrated control systems, was valued at US$5.7 billion in 2024 and is projected to reach nearly US$8.7 billion by 2030.[3] These figures reflect not only the volume of data being generated but also the need for mining companies to harness it for better performance.

Yet many mining companies struggle to realize this value. Data often remains siloed in equipment-specific platforms or isolated dashboards, preventing leaders from gaining a holistic picture of operational performance. Even when efficiency gains are achieved, they often fail to translate into financial outcomes.

In practice, this might look like an improvement program that delivered 5% additional fleet availability — at first glance, a success story. However, if that value failed to reach the company's bottom line because asset management and finance systems weren't connected, then the program's impact wasn't fully realized.

Unlocking additional benefits through smart operations could require effective integration layers, such as private 4G and 5G networks, data lakes, edge-based analytics and cloud-native platforms, which can ingest large, diverse data sets and make them available for AI-driven insights. These tools help eliminate redundant reporting, reduce human labor associated with dashboard maintenance and support decision-making in real time.

No one vendor holds the key to integration

Unlike back-office functions, where enterprise resource planning (ERP) systems provide end-to-end coverage, operational technology (OT) implementations in mining are often fragmented. Dozens, sometimes hundreds, of systems govern different aspects of production, maintenance, and logistics.

This reality creates complexity for mine sites that often navigate a proliferation of vendors, technology interfaces and overlapping capabilities. A persistent lack of unifying data standards complicates the matter further, limiting system interoperability and the usefulness of shared data.

Rajib Maitra, partner, Mining & Metals leader, Deloitte South Asia, explained:

"Every operation is built and run differently. That's why miners often need integrators — organizations with both broad knowledge and deep technical capability — to help pull everything together and optimize systems performance."

Trusted systems integrators can design the front-end architecture, stitch together vendor solutions, and help ensure the project outcomes are aligned to each client's business objectives. Without this role, miners could spend heavily on technology without seeing recurring benefits.

Enabling cost control and competitiveness

The benefits of smart operations can extend well beyond operational efficiency. By automating hazardous tasks and enabling remote operations, companies can improve safety as well as productivity across the value chain.

Lowering cost per ton is another important outcome. The average grade of copper mines has declined by 40% since 1991. BHP estimates that between one-third and one-half of global copper supply will face grade decline and aging challenges over the next decade, driving increased unit costs and the requirement for capital reinvestment.[4] Smarter decision-making, whether in maintenance scheduling, energy use or process optimization, can help reduce unit costs and sustain margins in a challenging market.

For example, the Dahaize Coal Mine in Shaanxi Province, operated by China Coal Group, is one of China's first smart mining operations and is pioneering an integrated 5G 700 MHz and 2.6 GHz data network. This architecture enables seamless underground and surface connectivity, forming the backbone for intelligent applications, including autonomous mining equipment, remote-controlled shearers, video-based analytics and a team of inspection robots.[5]

The introduction of 5G-enabled systems has reduced the number of personnel required underground at the mine, mitigating exposure to hazardous conditions. Tasks once requiring multiple operators are now managed remotely by a single control specialist supported by a safety inspector. In parallel, 15 inspection robots equipped with advanced sensors provide real-time monitoring of environmental conditions, delivering early warnings of anomalies and strengthening incident prevention.[6]

According to China Coal Group, integrated digital systems have cut coal production costs at Dahaize by approximately US$1.68 per ton (RMB 12 per ton) and reduced annual labor costs by around US$2.8 million. Improvements in predictive maintenance and real-time operational oversight have further increased equipment availability and efficiency.[7]

Building effective data governance

While technology is advancing rapidly, and software, hardware and related services are key considerations in creating smart operations, data governance remains fundamental. Not all data is ready to use in its raw form and gathering, preparing and cleaning data can make up a substantial portion of operational costs.[8] Poor-quality or inconsistent data can also undermine the value of AI models.

Adam Grahn, partner, Technology & Transformation, Deloitte Canada, said:

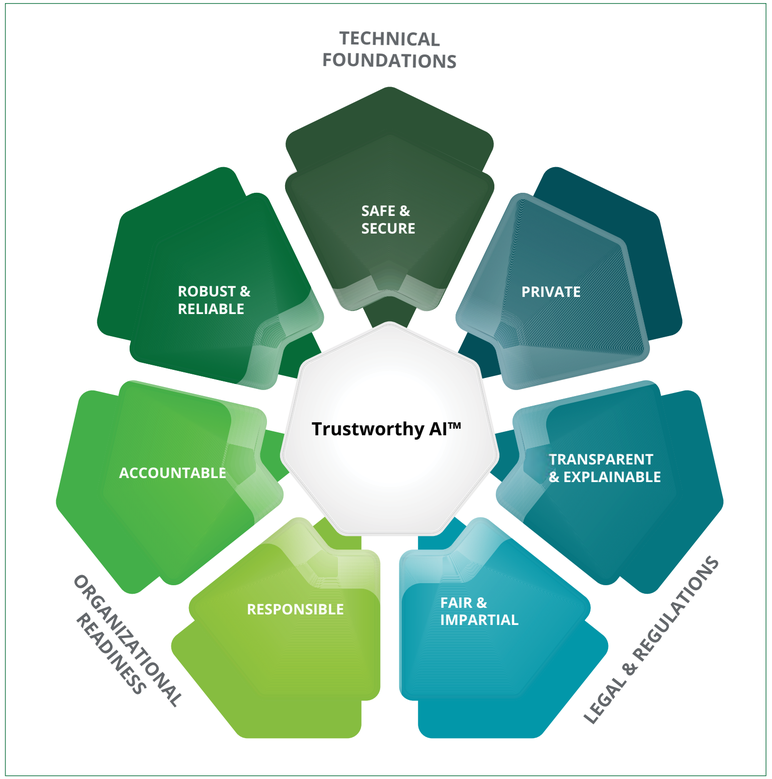
"Strong governance frameworks are needed to ensure data accuracy, consistency and security. Companies must also navigate questions of intellectual property (IP), particularly when AI-generated outputs create new forms of knowledge. Who owns that IP? How could it be shared or protected? These debates are not unique to mining, but their implications may be significant given the sector's reliance on proprietary operational data."

With the advent of novel technologies, like GenAI and Agentic AI, comes inherent risks. To help navigate these, Deloitte UK's Trustworthy AI™ framework (see figure 2) defines principles and foundational capabilities that businesses can use as guidance when assessing current or future AI implementations.[9]

This includes methods to establish AI governance and regulatory compliance, cybersecurity parameters, and other practices that help address the risks and intricacies of AI in this rapidly changing industry landscape.

Because GenAI presents nuanced risks like context-dependent outputs, technical vulnerabilities, and "hallucinations" (a term describing what happens when GenAI outputs a confident response to a request that doesn't appear to be justified by its training data), more vigilant and stringent monitoring may also be necessary.[10]

Figure 2: Deloitte UK's Trustworthy AI framework.



Source: Deloitte UK

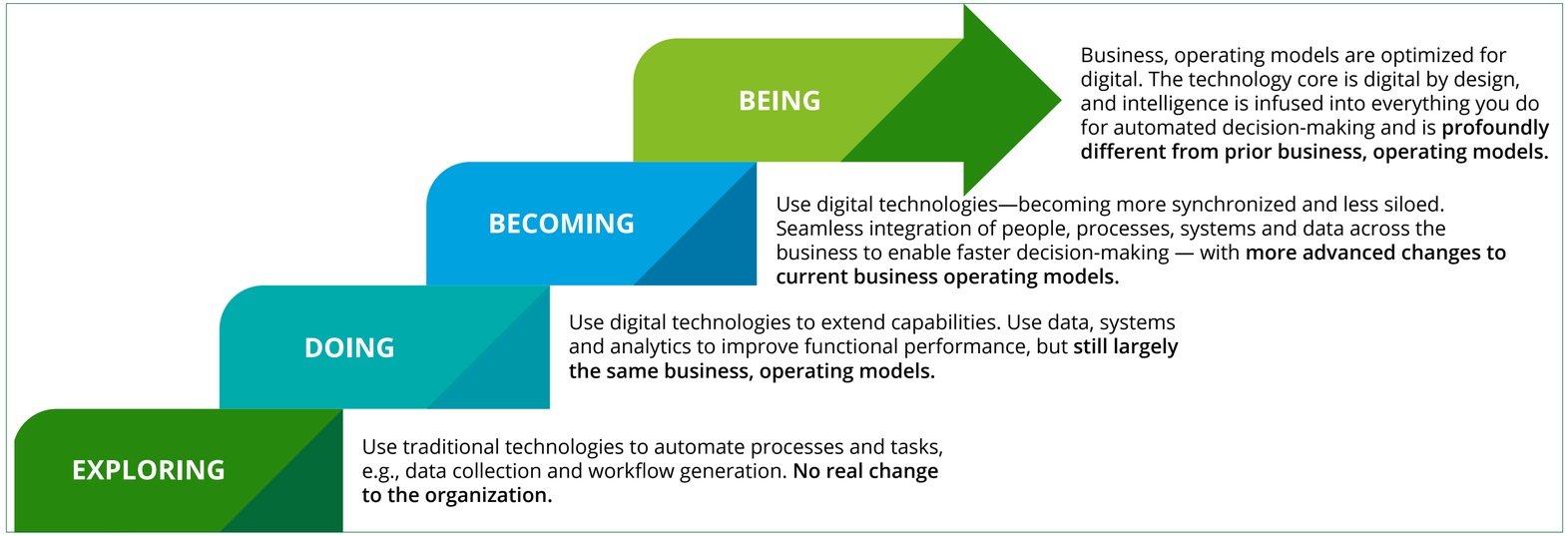
Addressing technology preparedness and digital culture

The level of technology preparedness among mining organizations can vary widely. While some leading companies have made strides in adopting and integrating advanced technologies, others are still in the early stages of their digital transformation journey. Many organizations fail to integrate new technologies across departments and functions due to a lack of technological infrastructure and readiness in existing systems, processes and practices.

A strategic, phased approach may be necessary to increase digital adoption and overcome challenges on the path to smart operations. This approach should be broad and supported by leadership to help ensure effective technology scaling and integration. Initial steps include securing strong commitment from top leadership, with a clearly defined vision for digital transformation aligned with organizational goals. Executives could actively champion this vision, demonstrating commitment through involvement and resource allocation. A robust management strategy may also address resistance, communicate benefits and foster a culture of innovation.

Without these elements, there is a risk of companies getting caught in an endless loop of the "exploring" and "doing" stages of technological maturity, rather than "becoming" and "being" (see figure 3).[11] However, with the right technology ecosystem in place, organizations can make the necessary changes to their business, operating and customer models to help ensure they reach true "digital" status.

Figure 3: Roadmap towards higher levels of digital maturity scale.



Source: Deloitte India

Blueprints for smart operations

Mining and metals organizations are no strangers to the concept of smart operations. However, other heavy industries, like energy and chemicals, are on similar journeys and could offer valuable insights for companies seeking to accelerate their deployment.

For instance, Shell's collaboration with C3 AI has transformed the way it manages assets and uses data. Recognizing the scale of risk and opportunity across its global operations, the company collaborated with C3 AI to build predictive maintenance models. Today, Shell monitors more than 10,000 pieces of critical equipment worldwide, deploying millions of different models capable of detecting anomalies before failures occur. This has enabled it to avoid unplanned downtime and generate economic benefits.[12]

The industry is also collaborating at scale. In 2021, Shell, Baker Hughes, Microsoft, and C3 AI launched the Open AI Energy Initiative (OAI), a global ecosystem designed to accelerate the adoption of AI in energy. The initiative aims to create shared industry standards and reusable AI solutions that can be deployed across operators, fostering efficiency and reducing duplication.[13]

These examples demonstrate the importance of starting early, building scale and embracing ecosystems to help accelerate collective progress. They also show how AI can deliver tangible returns while advancing broader industry sustainability goals.

Leveraging connections to overcome complexity

By connecting disparate AI deployments and systems, scaling digital maturity across value chains, and enabling adaptive, resilient decision-making, smart operations offer a pathway to next-level productivity despite growing operational complexity. Trusted integrators can help bring the pieces together in a timely manner to capture maximum benefits.

From ideas to action

- **Develop a focused yet flexible roadmap:** Become clear on potential sources of competitive advantage and create a roadmap that leverages data and technology to target these points. Willingness and the ability to shift course based on new technologies and developments could prove key to reaching the upper levels of technological maturity. Without a clear roadmap, companies risk delivering isolated projects that may not scale to enterprise-level impacts.
- **Map data flow against organizational priorities:** Companies could map base operational, engineering and business data flow throughout their value chains to higher-order targets and business objectives, like cost per ton, throughput and safety performance. This may help provide clarity around what data and systems are needed to drive meaningful shifts in performance and decision-making.
- **Invest in integration platforms:** Consider investing in data platforms capable of ingesting and harmonizing diverse operational data sets. These form the “nervous system” of smart operations, allowing insights to be shared across departments and assets rather than stay trapped in silos. They can also make it easier to plug in new AI models and applications as technologies mature.
- **Prioritize data governance:** Allocate resources to ensure data quality, security, and consistency across systems. Effective governance frameworks may help address ownership, accuracy, and access so that operational data can be trusted and used confidently by AI tools. Getting this right also reduces compliance risks around environmental and social performance.
- **Build cross-functional teams:** Often, productivity improvements stay locked in operational key performance indicators (KPIs) without showing up in financial statements. Cross-functional teams may help break these barriers, aligning initiatives with budgeting, planning, and performance management processes.
- **Consider cultural readiness:** Fostering a culture that supports innovation, continuous learning and cross-functional collaboration could ensure that the workforce is equipped with the necessary skills to leverage emerging technologies effectively. Leading organizations have addressed this through planning of culture and capability development, initiatives such as capability bootcamps, communities of practice, and digital mindset activation workshops.

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Trend 6

AI for operational excellence: Managing safety risks and enabling productivity

Authors

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Where mining and metals companies once relied on historical data and deep workforce skills to forecast production or anticipate disruptions, that approach may no longer be sufficient. Ore quality continues to decline across commodities as high-quality deposits (and higher-grade parts of deposits) are exploited earlier,[1] and operators are increasingly expected to "do more with less" in the face of rising operating costs.

Shak Parran, partner, Technology & Transformation, Deloitte Canada, said:

"Swathes of experienced professionals are expected to retire over the next decade, taking with them knowledge that's vital in fields like geotechnical engineering and maintenance. This erosion of skills may raise concerns for both safety and productivity."

Artificial intelligence (AI) is often seen as a tool for efficiency, yet its transformative potential could also lie in elevating operational resilience and competitiveness. When strategically deployed, AI may detect threats earlier than humans, preserve institutional knowledge, and help maintain operational efficiencies under stress.

Patricia Muricy, partner, Energy, Resources & Industrials leader, Deloitte Brazil, explained:

"AI has the capacity to help mining and metals companies adapt in real time, making their operations safer, smarter, and more durable. However, employees should be upskilled to harness it effectively."

Risk detection and anomaly monitoring

Safety remains the mining industry's highest priority. ICMM has highlighted that while progress has been made in key mining jurisdictions, fatalities and serious injuries continue to occur, with high-hazard activities such as transportation and maintenance posing ongoing risks.[2]

In this context, and with appropriate governance and guard rails, AI can serve as a sentinel, running continuously in the background of an operation to detect subtle signals of risk that could result in safety incidents. This shifts safety management from being reactive to predictive and even proactive.

Through its collaboration with RAMJACK Technology Solutions, AngloGold Ashanti (AGA) has implemented SmartCap's fatigue monitoring system on a fleet of 35 CAT 777 haul trucks at its Iduapriem gold mine in Ghana. The technology uses electroencephalography (EEG) and AI to measure signs of operator fatigue and predict incidents before they occur. Since the implementation, no driver fatigue-related incidents have been recorded at Iduapriem, and AGA is considering rolling out the system to all its African operations.[3]

This example shows how working with industry collaborators to embed AI into everyday operations can help strengthen operational excellence by protecting people and equipment.

Shak Parran, partner, Technology & Transformation, Deloitte Canada, said:

"Safety is an area where mining and metals companies might be more willing to share data, and that makes it a natural place to scale AI deployments. If competitors were willing to pool their safety information in a shared, precompetitive environment, AI could help identify broader industry risks and raise operating standards."

Once trained on shared data sets, AI could move beyond analytics into functioning as a real-time, query-enabled safety agent. This would mark a shift from traditional safety dashboards to dynamic agents capable of offering immediate, context-specific insights across the sector.

Petrobras, Deloitte Brazil, and NVIDIA embed AI for decision-making

Brazilian oil and gas producer, Petrobras, has worked with Deloitte and NVIDIA to turn decades of operational knowledge into an AI assistant named Petronemo. Petronemo is designed specifically for offshore and onshore maintenance tasks.

Deloitte and Petrobras created a digital "subject matter specialist" capable of delivering real-time recommendations to maintenance crews. Leveraging NVIDIA NeMo Framework, Deloitte and Petrobras trained a domain-adapted large language model (LLM) on 30 years' worth of operational data, including maintenance logs, incident reports, and technical manuals. This agentic solution has not only streamlined complex decision-making but also reduced response time during important maintenance interventions.[4]

Petrobras conducts around 30,000 asset inspections per year and about 20% result in inconsistencies that require repair recommendations. Petronemo now provides suggested recommendations that are assessed by the company's team of 400 reliability engineers to enhance the efficiency and effectiveness of maintenance activities. The project utilized Meta's open-source LLMs, Llama 1 and 2, as the training foundation for the AI assistant. The more robust data load and training were developed in-house and hosted on Petrobras' computers.[5]

Petronemo's model is processed on four supercomputers running NVIDIA's graphic processing units (GPUs). These include Petrobras' Pegasus, Tatu, and Gaia machines, along with the Santos Dumont supercomputer from the National Laboratory for Scientific Computing. This strategy resulted in a 30% performance gain and a 50% reduction in cost per token. The assistant seamlessly integrates into the company's processes and even speaks the "Petrobras jargon" used by the company's engineers.[6]

By 2029, Petrobras expects to save US$3.7 million (R$20 million) by enhancing maintenance efficiency with the AI assistant.[7]

Making scarce skills available globally

The ability to capture and redistribute skills can enhance operational performance by maintaining continuity of knowledge and making the services of strategically valuable specialists available globally. Petrobras' inspection planning tool illustrates how algorithmic judgment can potentially be used to support tasks that traditionally required decades of human intuition.

Agentic AI takes this capability a step further using a network of AI agents that act autonomously and cooperatively to help fill skills gaps where talent is lacking (i.e., in very remote geographies). Through this system, specific tasks, such as monitoring and scheduling, can be performed independently, with agents triggering actions and coordinating their efforts. In a mine, such a system might look like an ecosystem of AI agents managing maintenance schedules, logistics, inventory, and team alerts[8]—a topic that is discussed further in trend 5.

For instance, short interval control (SIC) is a scheduling technique that's still typically linked to Excel spreadsheets. However, with Agentic AI, if a truck breaks down mid-shift, deviations could be detected and responses coordinated in real time. Loads could then be rescheduled and equipment reassigned immediately.[9]

Infrastructure, sovereignty, and cyber resilience

For AI to deliver real-time safety and productivity improvements, data infrastructure must be robust and adaptable. Mining operations are often located in remote regions where connectivity is limited, but relying on cloud computing alone can introduce latency that could undermine safety.

Vale has addressed this challenge by deploying hybrid infrastructures that combine edge computing with local data centers. GPUs are placed onsite to process data instantly, enabling real-time monitoring of conveyor belts, rail lines, and safety systems. Latency is reduced to milliseconds, ensuring that alerts reach operators quickly enough to prevent costly or dangerous incidents.

Patricia Muricy, partner, Energy, Resources & Industrials leader, Deloitte Brazil, explained:

"Integrating cybersecurity into AI systems from the design stage is becoming standard practice. Approaches such as micro-segmentation, in collaboration with global security providers, are helping companies reduce vulnerabilities and build trust among regulators and communities."

Moving from pilots to strategic deployments

Despite these advances, most AI applications in mining and metals remain small scale. Pilots are scattered across different businesses and functions, delivering localized benefits. However, without a broader strategy and upskilling opportunities for employees, these efforts risk becoming expensive and outdated.

In May 2025, BHP unveiled its first Industry AI Hub in Singapore, positioned as a strategic nerve center to help accelerate AI adoption across the mining and resources sector. Drawing on support from Enterprise Singapore and AI Singapore, the hub brings together BHP's AI specialists to help address enterprise-wide challenges with data-driven tools aimed at boosting safety, productivity, and decision-making effectiveness.[10]

Building on previous AI initiatives, such as AI-enabled plant controls that have saved 3 billion liters of water and 118 GWh of energy at Escondida mine since FY2022.[11] The hub demonstrates how mining companies could take steps towards scaling operational efficiencies globally. In the future, facilities like these could provide the basis for broader industry collaboration on topics such as AI.

To help other companies forge their own path, Deloitte Brazil is establishing a Smart Solution Center. This facility gives companies access to advanced AI infrastructure, prebuilt models, and advisory services to help move beyond pilots. The focus is not just on experimenting, but on aligning AI with enterprise strategies, calculating return on investment (ROI), and creating a roadmap for scale.

Turning AI pilots into strategy

Deloitte Brazil is establishing a Smart Solution Center in Brazil that is practically showcasing and applying the latest technology for AI in operations from NVIDIA and other technology providers.

The initiative aims to give clients access to advanced GPU capacity (often a limiting factor in AI deployments) and cutting-edge AI models, while also drawing on Deloitte's deep industry knowledge and advisory skills. The aim is to accelerate the development of practical solutions in areas such as safety and predictive maintenance.

Another advantage lies in the center's emphasis on data sovereignty and security. By enabling companies to retain control of their data within local jurisdictions, it addresses growing concerns over data governance while also embedding cybersecurity measures into each stage of solution design. This ensures that longevity is built not only into operations, but also into the digital foundations on which those operations depend.

The Smart Solution Center also brings financial discipline to projects. By modeling return on investment and linking AI initiatives to strategic business objectives, the center aims to shift AI from proofs of concept to a measurable driver of competitiveness.

AI as a competitive differentiator

AI is rapidly becoming more than a support tool for mining and metals operations; it's morphing into a foundation for operational excellence, helping companies to realize productivity uplifts while prioritizing safety, closing workforce gaps, safeguarding operations against cyberthreats and more.

Organizations that deploy AI strategically, rather than tactically, could find themselves better positioned to anticipate risks, protect their people, and seize emerging opportunities.

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From ideas to action

- **Prioritize use cases:** Initial investments could target areas where AI both reduces risk and delivers measurable value in productivity, such as ground-support monitoring. These domains often provide the quickest wins and garner strong board-level support.
- **Invest in data quality, ethics and governance:** AI outcomes are often only as reliable as the data they process. Standardizing collection methods across sites, cleansing legacy systems, and introducing metadata protocols may improve model accuracy and trust. Also consider building governance capacity, for example, through training for executives and boards.
- **Develop an enterprise-wide AI strategy:** Coordinated strategies endorsed by senior leadership are important. This means identifying priority domains, defining an operating model for AI deployment, designing appropriate upskilling programs, and aligning adoption with organizational purpose and corporate goals, such as reducing emissions and workforce renewal.
- **Model ROI and track outcomes:** Like many capital projects, AI initiatives should have robust business cases. Benefits could be tracked across safety incidents avoided, downtime reduced, or workforce productivity gained. This builds accountability and helps refine systems deployment.
- **Collaborate across the ecosystem:** Sharing noncompetitive data, particularly in areas like safety, could create industrywide resilience benefits. Pooling resources can help lower costs, improve model accuracy, and accelerate innovation.
- **Embed sovereignty and cybersecurity by design:** Ensuring that AI deployments comply with local data laws and include built-in cyber protections can help strengthen stakeholder confidence and guard against future regulatory or operational shocks.

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Trend 7

The next evolution of human resources: Using AI to reimagine the role of HR

Authors

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As artificial intelligence (AI) continues to help streamline activities across organizations, human resources (HR) professionals are also being challenged to rethink the skills and capabilities they require to lead the way. The business of HR is evolving. Today, the interplay between technology and people has created an opportunity for HR functions to realize their potential as leaders and architects of the human-machine workforce.

Generative AI (GenAI) has opened the door to new possibilities. Yet Agentic AI could be even more transformative. To realize the value of these technologies for the organization, this will likely require a fundamental rethinking of roles, workflows and organizational design.

Joanne Doyle, partner, Technology & Transformation, Deloitte Canada, observed:

"The mining and metals industry is past the point of tinkering with AI. Soon, GenAI and Agentic AI will likely infuse many parts of the employee life cycle. These technologies can't be an afterthought; they should be baked into organizational structures and processes."

The future of HR in mining is not about replacing humans with machines. It's about creating a workforce that's human-led and technology-powered. By elevating the role of HR in leading the human-machine workforce, operational outcomes desired by mining and metals organizations could become a reality.

Jessica Sonnekus, associate director, Technology and Transformation, Deloitte South Africa, added:

"Even in Africa, where the challenges of appropriate energy, infrastructure, security and data connectivity are significant, mining organizations are proactively re-looking at AI for their core operations, safety practices and enabling functions."

Understanding AI's growing role in HR

A recent survey of chief human resources officers (CHROs) revealed that more than half of these organizations had already deployed AI tools. Use cases spanned resume screening, job description drafting, policy and procedure formulating, learning personalization, chatbots and inclusion audits.[1]

For many companies, these applications were small-scale. Yet it's clear that their appetite is growing as the value potential goes beyond what previous technological breakthroughs promised.

For instance, digital assistants can now help with reskilling at scale, and can handle routine employee queries, freeing HR professionals to focus on strategic tasks. Learning platforms powered by AI can recommend training tailored to individual aspirations and performance. AI-enabled bots can also help ensure that employees have access to information in the field; using platforms like messenger apps, bots can provide information to operators while in the pit by simply answering their questions.

As such, the Deloitte Consulting LLP State of Generative AI in the Enterprise 2024 Q4 report, found that 78% of business leaders expect to increase their AI spending in the next fiscal year.[2]

Joanne Doyle, partner, Technology & Transformation, Deloitte Canada, said:

"Each example underscores how AI can shift HR's role from transactional to transformational without losing sight of important objectives like safety."

While HR leaders are optimistic about the value AI can bring, most organizations are still building the capability to deploy it strategically and responsibly. HR functions may need to evolve their own skills and capabilities to help the rest of the organization do the same.

Creating a next-gen digital employee experience

One of the most immediate ways AI is reshaping HR in mining and metals is through the employee experience. Mining workforces are often distributed across remote sites, making access to HR support difficult. GenAI-enabled chatbots and digital assistants are beginning to bridge this gap. For example, rather than waiting for responses from distant HR teams, workers can now use different platforms to receive instant answers to questions about policies, payroll or procedures.[3]

A Deloitte Africa member firm has developed and deployed a Standard Operating Procedure Helpdesk Intelligent Assistant (SOPHIA) bot that provides employees with real-time access to standard operating procedures. In a mining context, a tool like this could give frontline workers clarity on compliance or safety requirements, directly influencing safety outcomes and operational efficiency.[4]

These innovations also signal a broader sentiment and cultural shift. For younger employees who expect digital-first interactions, the availability of AI-powered HR support could help drive positive employee perceptions and position mining as a modern, technologically advanced industry.

This matters because, today, mining companies are competing with tech companies for digital talent. In this context, a seamless, digitally enabled employee experience could further position the sector as a forward-looking and purpose-led employer of choice.

From roles to skills: A new paradigm for talent management

Today, traditional recruitment models focused on filling predefined roles may prove too rigid in an environment where technology continually reshapes tasks, skills and capabilities. In contrast, AI can enable mining and metals organizations to break work down into component tasks and map them to available skills. It can then maintain real-time profiles of employee capabilities, identify gaps and recommend targeted training.

This shift is particularly relevant in mining, where large cohorts of experienced workers are nearing retirement. Nearly 50% of mining engineers are expected to reach retirement age within the next decade.[5] Capturing their knowledge and transferring it to the next generation is important to safety and productivity. AI can support this process, while also helping companies redeploy existing workers into new or augmented roles created by automation and electrification.

Globally, more than 39% of workers' core skills are expected to change by 2030.[6] Without understanding the skill and capability requirements, as well as prioritizing systematic upskilling and reskilling across the organization, including HR, companies could risk falling behind in productivity and their ability to attract and retain talent.

Challenges on the path to adoption

Despite momentum, the journey is not without obstacles. Cultural resistance remains a barrier. Employees may fear that AI will replace them rather than enable them. Organizational commitment to human-first solutions, transparency and clear communication from the start—and the co-creation of solutions between employer and employee—could help build trust in technology and drive deep purpose.

Leadership alignment may be another hurdle. Within many executive teams, enthusiasm for AI can vary widely, leading to inconsistent investment and stalled pilots.[7] Change fatigue in leaders who have undergone various technology transformations could also slow the process, with the hope of the next leader spear-heading the change.

Measurement is equally difficult. This creates a risk of "pilot paralysis," in which small experiments rarely scale into enterprise-wide transformation. The deeper challenge, however, is organizational readiness. With Agentic AI, layering AI onto outdated workflows could risk amplifying inefficiencies rather than eliminating them.[8] For mining CHROs, this means resisting the temptation of incremental adoption and instead rethinking how work itself is structured.

The rise of the human–Agentic workforce

Unlike traditional automation or even GenAI, Agentic AI introduces autonomous systems that can orchestrate multi-step processes across workflows. Humans remain "on the loop" rather than "in the loop," shifting their role from execution of mining and metals tasks and processes to orchestration.[9] The result could be a human–Agentic workforce in which people and digital agents collaborate to achieve outcomes that neither could deliver alone.

For mining CHROs, achieving this may demand a bold rethinking of tasks and work, both in and outside of HR and governance thereof. In a blended human-Agentic workforce, future work could be defined by outcomes and capabilities rather than static job descriptions, and roles should be designed to allow both humans and digital agents to thrive. Growth might be measured, not by headcount expansion, but by scaled productivity and efficiency enabled through human–agent collaboration.[10]

Three lenses for CHROs

The role of the CHRO is pivotal in achieving this transformation, both in- and outside of the HR function.

To navigate the complexities of AI adoption, mining CHROs could adopt a three-lens framework that considers the business owner, workforce leader and people steward in turn (see figure 1).[11]

Figure 1: Three different lenses for CHROs to apply when implementing GenAI.

Source: Deloitte Development LLC

As business owners, CHROs should ensure AI adoption aligns with organizational priorities. This means using AI-powered tools to quantify where AI can create capacity and where disruption may occur, allowing organizations to redeploy resources proactively.[12]

As workforce leaders, CHROs are tasked with building trust and driving adoption. Investing in AI to capture the knowledge of retiring workers could ensure continuity while equipping new employees with important insights. This is as much about culture as it is about technology.

And as people stewards, CHROs should champion ethical AI usage. Résumé screening algorithms may reduce bias, but only if safeguards are in place.[13] Monitoring employee well-being through AI can help drive proactive interventions, but it also raises questions of privacy and transparency. CHROs have a responsibility to ensure that AI adoption supports fairness, inclusion and trust.

Opportunities for tomorrow's workforce

If today's challenge is AI adoption, tomorrow's challenge is integration. AI will not remain a set of discrete tools but will likely become a pervasive part of how organizations function. For mining and metals HR leaders, this could mean reimagining core processes such as:

Workforce planning: AI can help model future workforce needs based on business strategy, demographics, and external labor market dynamics. This data-driven approach allows companies to make smarter build-buy-borrow-bot decisions.

Talent management: AI can assist in alleviating capacity constraints of behavioral specialists and help enable them to provide meaningful coaching and talent guidance to supervisors, managers and leaders.

Succession planning: AI can highlight emerging leaders, track career progression, and ensure pipelines remain resilient.

Leadership development: Mining executives of tomorrow will likely need curiosity about technology, cultural competency to manage diverse teams and compassion to balance productivity with people's well-being.

Jessica Sonnekus, associate director, Technology and Transformation, Deloitte South Africa, added:

"The leader of the future is going to be a different leader, one who understands the relationship between AI and human, and who can manage succession in a dynamic environment."

As AI plays a larger role in mining and metals work, it's also likely that humans will spend less time on process execution and service delivery, and more time on delivering insights and solutions. In realizing this shift, there is an opportunity for HR to position itself to deliver greater value.

Leading at the tipping point

GenAI has already begun reshaping HR processes and functions in mining and metals, but the next horizon—Agentic AI—will likely require a rethink of how work is structured, how roles are defined, and how humans and digital agents collaborate.

For CHROs, this is not just a technology challenge but a leadership imperative. By balancing their responsibilities as business owners, workforce leaders, and people stewards, they can harness AI's potential while keeping humans at the center. Those who succeed will help mining companies meet today's workforce challenges and build resilient, purposeful and future-ready organizations.

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From ideas to action

- **Evaluate AI maturity:** Assess where the company's HR function sits on the AI adoption curve—from exploration to experimentation, scaling and innovation—and establish clear timelines for future progress.
- **Understand AI skills and capabilities:** Starting with the HR team, take the time to assess and understand the level of AI maturity in each team and operational function.
- **Secure leadership alignment:** Frame AI adoption as a driver of organizational productivity and resilience rather than a stand-alone HR initiative, using data and case studies to gain executive buy-in.
- **Invest in workforce readiness:** Develop continuous upskilling and reskilling programs tailored to emerging skills and capabilities. Consider creating academies for next-generation HR leaders and teams.
- **Embed governance and ethics:** Establish transparent standards for data privacy, fairness, and accountability while involving employees in designing AI-enabled processes. Creating an AI trust framework could help to protect your organization and its people.
- **Build AI ecosystems:** Collaborate with technology providers, universities, and industry peers to accelerate adoption, share learnings and expand talent pipelines.

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Trend 8

Redefining mineral exploration: Using AI to unlock the next wave of major discoveries

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The next generation of mineral discoveries may not only determine individual company growth, but could also influence national security, the pace of the energy transition, and the ability of governments to deliver on sustainability commitments. This raises the stakes for how exploration is conducted and opens the door to a profound shift.

Van Ramsay, partner, Mining & Metals leader, Deloitte Canada, explained:

"The mining industry's visible connection and enabling role in global megatrends means that for the first time in a long time, politicians are starting to view the industry positively. This creates a window of opportunity to redefine exploration and the value it delivers."

While the narrative surrounding mining and metals has shifted, the way in which companies explore for minerals has changed little in decades, even as the pressure for new discoveries has intensified. The tried-and-true method of drilling to define resources remains based on subjective evaluations of targets and by a dwindling pool of geologists. However, global discovery rates have been declining—recent years have seen annual additions of only about 70–90 new significant deposits—while discovery costs have more than doubled compared with pre-2005 levels. At the same time, development timelines have lengthened, with the average delay from initial discovery to production now around 15 years.[1]

Against this backdrop, data and artificial intelligence (AI) are emerging as transformative forces. Adopting AI-powered technologies that can blend diverse datasets and enable data-driven decision-making could cut years off the exploration process. The technologies do this by helping to identify and prioritize targets with greater precision, reducing the need for drilling, and better screening projects to help create more valuable and credible portfolios.

Why data matters more than ever

Mineral exploration has always been data intensive. Drill cores, geochemical assays, geophysical surveys, and field observations produce enormous volumes of information. Yet much of this data (both current and historic) remains underutilized. It's fragmented (across businesses, companies, and governments) and, sits forgotten in digital format on computers and drives, and trapped in legacy formats (paper). Today, some of the industry's most valuable insights could potentially lie hidden in boxes of paper logs, unpublished maps, or hard drives stored in warehouses.

This matters because the quality of AI outputs depend heavily upon data. Algorithms trained on incomplete, inconsistent, or poor-quality datasets could yield unreliable results.

Public-sector initiatives already demonstrate the value of open and organized precompetitive data – a topic explored in *Tracking the trends 2025*.[2] For instance, in Australia, Geoscience Australia and Deloitte Access Economics estimate that precompetitive geoscience data underpins economic activity worth more than 1,000 times its initial production cost.[3]

Canada has launched the Critical Minerals Geoscience and Data Initiative, a US$56.7 million (C$79.2 million) program that supports access to high-quality datasets and funds advanced analytics in aid of Canada's critical minerals strategy.[4] Meanwhile, the US Geological Survey's Earth MRI program is modernizing the mapping of the nation's surface and subsurface to help inform decisions and meet the country's evolving needs.[5]

For mining companies, these programs illustrate how success in exploration could increasingly hinge on their ability to treat data as a strategic asset. Those that prioritize digitization, structure their information consistently, and integrate diverse sources into unified repositories may be best positioned to leverage AI for faster, smarter discoveries.

Becoming data explorers before mineral explorers

To thrive in this new environment, mining organizations may need to rethink the fundamentals of exploration. Historically, a large focus has been on ground acquisition and physical prospecting, but the starting point for future discoveries could be data.

Practical steps are emerging. Natural language processing (NLP)—a branch of AI that enables computers to comprehend, generate, and manipulate human language[6]—is already being applied to thousands of archival reports in Canada, Australia, and the US, turning unstructured text into structured insights about mineral systems and their potential prospectivity.[7]

In British Columbia, machine learning pipelines have processed more than 100,000 historical documents to identify previously overlooked carbonatite targets.[8] These projects highlight how digital tools can reveal value in records that companies have held for decades but rarely revisited.

Standardization is equally important. Without consistent data formats and metadata, AI systems cannot reliably integrate data from different sources. Initiatives such as the international GeoSciML schema offer potential solutions, creating a common language for geoscience data exchange.[9]

For mining leaders, data standardization is not simply a technical challenge. It's about ensuring that valuable insights are not lost in translation and that investments in AI can scale effectively across global portfolios. It can also aid in due diligence for mergers and acquisitions (a topic covered in trend 2 in detail) and in post-deal integration.

Learning from industry parallels

Mining's lag in adopting systematic, data-driven processes in functions such as exploration is not unusual. Other industries have faced similar inflection points, and their experiences could hold valuable lessons.

For instance, in 2018, Shell and AWS were among the founding members of the Open Group OSDU® Forum. The vision of OSDU is to avoid replication in developing the common services required by the energy sector. Today the forum comprises more than 200 energy companies and software vendors that collaborate to develop common interface standards. This solution helps to remove barriers within workflows caused by proprietary data formats, and domain data silos.[10]

To support its efforts, the forum has created the OSDU Data Platform, a cloud-native, open-source technology that provides energy companies with a toolbox to address the undifferentiated capabilities needed to manage large, disconnected data sets. Using the platform, companies can analyze data more efficiently, search information rapidly and take advantage of new digital innovations. For example, Shell has moved its wells data and applications to the AWS cloud to improve efficiency and shorten cycle times.[11]

Standardization projects like these can reduce duplication and make advanced analytics possible at scale – something that the mining industry could leverage to lift the valuation of not only individual projects but, in time, the sector as a whole.

Life sciences provide another useful parallel. Pharmaceutical companies routinely apply AI to screen vast compound libraries, narrowing down the candidates most likely to succeed in clinical trials. This can accelerate timelines while reducing cost – a direct analogue to the mining industry's need to filter hundreds of geophysical anomalies down to a handful of drill-ready prospects.

Consumer-facing industries also illustrate what is possible. By deploying predictive analytics and digital twins, manufacturers and retailers continuously refine models of customer behavior, logistics networks, and product design. The same principles can be applied in mineral exploration, where models of orebodies are continuously updated as new drilling data is captured.

How mining companies choose to use their data also matters. In the same way that the advent of geophysics in the 1930s sparked many of the most successful mineral discoveries of the last century, AI could give rise to the next generation of exploration leaders and mineral discoveries.[12]

Today tech startups, like Terra AI, are using AI-powered multi-physics modeling techniques to redefine orebody modeling and early-stage targeting. The company believes it's possible to cut the cost of exploration by 40% and improve the size and grade of a resource by 5% to15% using its technology.[13] Meanwhile others, like GeologicAI, are using proprietary hardware to generate new and unique datasets.

These, combined with advanced analytics, could transform time and cost-intensive workflows in tasks such as core scanning and logging. BHP and Rio Tinto became two of GeologicAI's latest investors and collaborators in July 2025.[14]

New business models are also emerging. Instead of service contracts, AI firms may increasingly take equity or royalty stakes in discoveries. For example, in November 2024, US Critical Materials Corp completed an AI-powered mineral targeting program on its Sheep Creek property in Montana (US) with mineral asset company, VerAI Discoveries. VerAI's technology was trained on the geophysical data and discoveries previously announced on the 800-acre property. It was then used on the 5,900 acres of claims that had not been explored to produce multiple drill-ready sites, indicating further evidence of possible economic mineralization.[15]

Exploring the future together

Mineral exploration is already difficult. The sheer scale and complexity of the challenge (fewer than one in 1,000 exploration projects may become a mine)[16] means that, in the future, it could be more difficult for companies to find and advance projects on their own. Current exploration processes are fragmented, "easy" deposits are largely found, skills are becoming scarce, and the costs are high. But by recognizing their individual strengths and limitations (and being open to new collaborations and technologies), as well as the advantages that pooled datasets and technological access could enable, companies could accelerate their collective success.

For instance, major miners hold some of the largest land positions and financial resources but often move slowly in their exploration efforts and face constraints based on the risk appetite of traditional investors as well as other factors. Juniors may bring agility and entrepreneurial drive, but many lack consistency in funding. Technology firms contribute AI and data science skills but may require access to domain knowledge and proprietary records. Meanwhile, governments and academia could add research capability and precompetitive data that can derisk projects for many.

Charles Hooper, director, Strategy, Risk & Transactions, Deloitte Canada, said:

"Startups, universities, tech companies, and explorers need to find new ways to work together and new tools. If they can do this, they will lower and diversify their risk and move faster and cheaper. The challenge will be balancing cooperation with competition."

Today, structures and architectures, like edge computing, may allow for collaborative projects and consortia to take advantage of sensitive data while also protecting companies' intellectual property. Clear arrangements surrounding data ownership, data privacy/anonymity, and intellectual property can also give miners and explorers the confidence to participate in collaborative innovation projects centered on shared challenges.[17]

Ma'aden embraces space-enabled exploration in the Arabian Shield

In May 2025, Saudi Arabian miner, Ma'aden, signed a four-year contract with tech startup, Fleet Space Technologies, and Saudi technology and systems integration company, Tahreez, to deploy space-enabled mineral exploration across up to 12,012.6 km² of the Arabian Shield. Together the companies aim to build a broad 3D understanding of the mineral systems that comprise the Kingdom's 2.5 trillion mineral assets.[18]

Using Fleet Space's ExoSphere platform – a vertically integrated system combining low Earth orbit satellites, smart ground sensors, and advanced AI – Ma'aden will gain real-time 3D subsurface imaging at depths of up to seven kilometers. This could enable exploration teams to identify targets within days rather than months, increasing the company's agility while reducing its environmental footprint.

The collaboration supports Saudi Arabia's Vision 2030 ambition to transform mining into the country's third economic pillar. Beyond data, the initiative is expected to create long-term capability by equipping a new generation of Saudi professionals with digital exploration skills.[19]

Implications for mining and metals leaders

By increasing certainty and reducing timelines, data-driven exploration processes could improve project valuations and access to capital. The emergence of new consortia and business ecosystems to harness AI at scale may also see majors act less as self-contained explorers and more as orchestrators of collaborative networks. This could help diversify risk, reduce costs, and open new pathways for value creation through royalties, equity stakes, and shared infrastructure.

There's also a talent dimension. Scarce AI knowledge is unlikely to flow naturally into the mining sector. Leaders may need to rethink their approach, tapping into collaborations, joint ventures, and new models of capability-building to help ensure that exploration priorities receive the same digital attention as operations.

From ideas to action

- **Align AI applications with strategy:** Linking AI initiatives in exploration directly to corporate growth strategies could help ensure resources are targeted towards the projects (both greenfield and brownfield) most likely to generate a competitive advantage and shareholder value.
- **Build internal capability:** Consider developing and scaling data literacy across exploration teams and ensure that AI talent is aligned with exploration priorities, not only operations. Upskilling geologists to work effectively alongside data scientists could enable truly interdisciplinary approaches that drive stronger results.
- **Invest in relationships:** Collaborations with juniors, governments, start-ups and incubators, and technology firms could expand the scope and quality of available data. Well-structured relationships can spread costs, reduce risks, and open access to new methods or datasets that would otherwise be unavailable to a single company.
- **Establish effective AI governance:** Develop clear policies for data management, algorithm transparency and ethical use of AI in exploration. Responsible governance helps to ensure that models are explainable, decisions are auditable, and data integrity is maintained. This could lower risk, and build trust with regulators, investors, and communities while safeguarding long-term value creation.
- **Experiment with AI use cases:** Small-scale experimentation could help to build internal capability and confidence with AI while minimizing risk, allowing leaders to demonstrate tangible value to boards and investors. Begin with pilots in areas such as geological interpretation, target ranking, and project filtering, then scale successes across portfolios.

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Deloitte.

Together makes progress

Trend 9

Unlocking resource wealth: Strategies to catalyze socio-economic transformation

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Demand for critical minerals and metals will likely soar over the next decade as the world population grows and urbanizes, the global energy transition accelerates, and national and regional security scales. This surge in investment could create a once-in-a-generation chance for resource-rich countries to supply the world while capturing more of the value chain and translating natural assets into a durable national advantage.

As governments recalibrate their strategies, mining and metals companies could prove important allies. Their global reach, technical skills and ability to mobilize capital position them as natural collaborators in aligning national ambitions with market realities, ensuring that industry and society both benefit from a rapidly shifting geopolitical landscape.

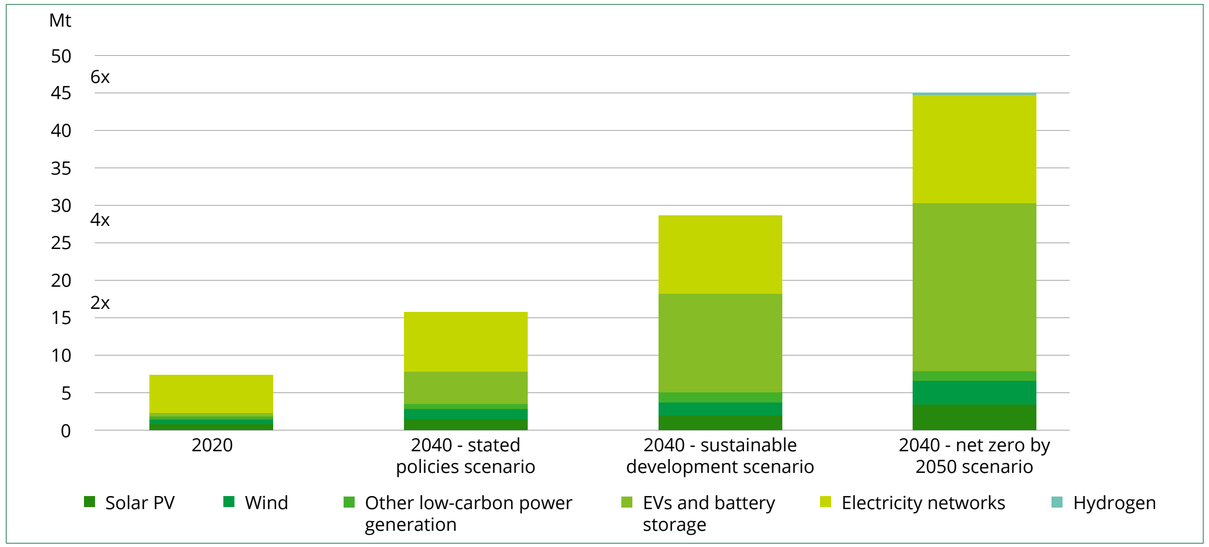
Louis Kruger, partner, Energy, Resources & Industrials leader, Deloitte South Africa, said:

"As global competition for minerals intensifies, governments are shifting their focus from transactional resource development towards more integrated, ecosystem-based models. Mining and metals companies could play a pivotal role in this transformation."

Minerals at the heart of a new geopolitical economy

It is estimated that mineral inputs for clean energy technologies will need to increase sixfold by 2040 if the world is to be net-zero by 2050 (see figure 1).[1] Yet supply of many critical metals is concentrated in a handful of jurisdictions.

Figure 1: Total mineral demand for clean energy technologies by scenario, 2020 compared to 2040.



Source: International Energy Agency

The Democratic Republic of Congo (DRC) produces 70% of the world's cobalt, Indonesia controls nearly half of global nickel supply and dominates processing, while China leads in lithium, graphite and rare earth elements (REE) refining.[2]

In a bid to protect and develop domestic downstream industries, many mineral-rich countries have imposed export restrictions, such as licensing requirements, taxes, quotas and bans on upstream raw materials. For example, by banning the export of unprocessed nickel and investing in domestic smelting and refining capacity, Indonesia has positioned itself as a global hub for battery materials. This has attracted billions of dollars in foreign investment.[3] Similar ambitions are evident in Chile, which is reforming its lithium sector to retain more value domestically, and in Argentina, where public–private partnerships are supporting industrialization.[4]

Meanwhile, the US and Europe are adopting industrial policies to secure critical metal supply chains. The US Inflation Reduction Act includes a 10% credit for domestic critical mineral production[5] (although this will be phased out by the end of 2033).[6] Europe's Critical Raw Materials Act (CRMA) sets 2030 targets for the European Union (EU) to achieve 10% of its annual extraction, 40% of its processing and 25% of its recycling domestically, while also capping imports.[7]

Many globally important critical minerals deposits are located in land-locked and developing countries, including some of the world's poorest economies.[8] For these countries, the challenge as they develop their resources is not just to be competitive, but to mitigate the pitfalls of past booms, when resource wealth did not always translate into lasting prosperity.

Indonesia's projects-to-ecosystems nickel strategy

Indonesia shows how resource-rich economies can shift from project-centric mining to ecosystem-based industrialization. Since banning unprocessed nickel ore exports in 2019, the government has paired restrictions with down streaming incentives, including tax holidays, infrastructure support and streamlined licensing, to attract global collaborators. These measures mobilized US$18.8 billion in downstream investment.[9]

Two flagship complexes exemplify this approach. The Indonesia Morowali Industrial Park in Central Sulawesi and the Weda Bay Industrial Park in North Maluku. Both operate on a shared infrastructure model where industrial utilities and logistics are co-financed, enabling scale economies and faster supplier onboarding. This has had a transformative effect on local economies. North Maluku recorded a 22.9% growth in GDP in 2023, while in Morowali, employment in the nickel sector surged from just 1,800 workers to 71,500.[10]

Ongoing regulatory reforms covering licensing, environmental standards, and local-content rules can reinforce investor confidence and align sustainability to competitiveness objectives.[11] This demonstrates the potential for coordinated policy and industrial clustering to turn mineral endowment into lasting economic capability.

Looking up and down the value chain for opportunities

Realizing greater value from mineral wealth may require deliberate and coordinated movement up and down the value chain and multiple pathways are emerging. For instance, beneficiation can capture more value through downstream processing. Again, Indonesia's nickel strategy demonstrates the potential of this approach. The country saw 5% overall economic growth in 2024 and plans to further strengthen its policies promoting the value addition of transition minerals, including through a possible revision of its mining law.[12]

Cooperation surrounding infrastructure could also reduce duplication and support scale. For instance, in 2023, the DRC and the Republic of Zambia signed an agreement with African Export-Import Bank and the United Nations Economic Commission to establish special economic zones for the production of battery-electric vehicles and related services. The project aims to accelerate the manufacture of pre-export value-added products, enabling both countries to capture more value and create new demand for skilled engineers, providing a boost to local labor markets.[13]

Similar projects could also serve as grounds for greater Indigenous participation and collaboration. In January 2025, the Government of Ontario signed an agreement with Aroland First Nation.

As part of this, the provincial government has committed US$64 million (C$90 million) to upgrading infrastructure in northern Ontario to help enable mining of critical minerals in the Ring of Fire region and connect First Nations communities to major highways.[14]

When undertaken collaboratively with governments and communities, projects like these can create mutual benefits: Nations capture industrial and economic capacity, and companies gain resilient, competitive supply chains.

From projects to industrial ecosystems

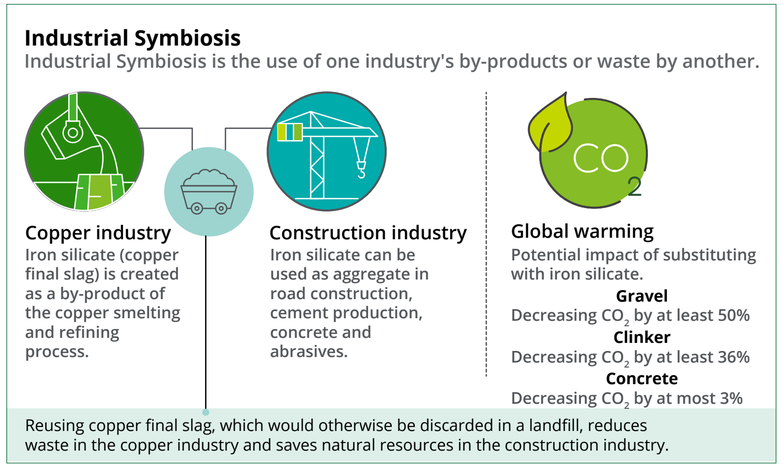
Mining and metals projects are increasingly serving as anchors for wider ecosystems that span infrastructure, energy and downstream industries. These companies are uniquely placed to convene stakeholders, broker relationships and align investment in shared assets.

An ecosystem approach may help to derisk projects and can create opportunities for governments and communities to capture lasting value, for example, through industrial symbiosis, where waste or by-products from one company or industry become feedstocks for another (see figure 2).[15]

For example, in Sweden, LKAB is developing a fossil-free industrial park in Luleå to extract REEs and phosphorus from iron-ore tailings. With US$86 million (SEK800 million) in funding, a demonstration plant is under construction and due to open in 2026. Once fully operational, the facility could meet seven times Sweden's phosphorus demand and significantly boost Europe's self-sufficiency in REEs.[16]

Although business ecosystems tend to coalesce around physical assets, such as mine sites or infrastructure, today, they're also being formed to catalyze less tangible forms of value. For instance, unlocking critical minerals projects at the scale and speed required by future demands could help necessitate skills and technologies that are lacking in some economies.

Figure 2: Example of potential for industrial symbiosis in the copper and construction industries.



Source: ICA

Collaborative ecosystems built on shared investments could help to solve this challenge. In Canada, biotechnology company nPhyla (formerly the Mining Microbiome Analytics Platform) was built on US$11 million in co-investment from collaborators and funding organizations, combining non-dilutive grants, academic infrastructure and early-stage equity support. The company leverages a blended funding model and is raising capital to achieve its goal of using environmental DNA and advanced analytics to develop microbial solutions for mining.[17]

Translating mineral wealth into social prosperity

In the future, the long-term success of miner's business strategies could depend on their ability to deliver benefits to local communities, as well as fiscal contributions to host economies. ICMM member companies contributed US$42 billion in tax and royalty payments to host countries in 2024, including US$28.6 billion in corporate income tax and US$13.4 billion in royalties.[18]

For contributions like these to be sustainable, including through periods of lower profits, mining companies may require innovative mechanisms to manage costs, capital, efficiency, talent, technology and digitization, as well as strategies to help ensure their social license to operate.

The concept of "value beyond compliance" can help to reframe community engagement in critical minerals projects. This leverages the fundamental synergy between economic performance and social progress to create shared value.[19] Success could require authentic community engagement through systematic approaches, genuine listening, and tangible benefits that start during exploration, not production.[20]

An example is Taseko Mine's Yellowhead copper project in British Columbia, primarily in the territory of Simpcw First Nation.[21] When Taseko acquired Yellowhead, a multi-year working group process was initiated to ensure Simpcw priorities and interests were incorporated into the initial project description.

Taseko has committed to assessing the project through the Simpcw Process – an Indigenous-led, consent-based decision-making model. The company opened a community office in Barriere, BC, where residents can drop by with questions or feedback, and tangible community benefits began immediately through programs like Taseko's Beyond Potential Community Investment program, which supports local organizations.[22]

The Designing Sustainable Prosperity framework can also serve as a model for long-term economic activity in areas that host mines. As part of the process, mines act as catalysts for regional sustainable development, resulting in long-term economic and environmental prosperity for the areas affected and could promote the regions as centers of excellence for a particular industry. The method has already been proven in copper producing regions of Chile and Peru.[23]

Peyush Kumar Dixit, partner, Strategy, Risk & Transactions, Deloitte Indonesia, noted:

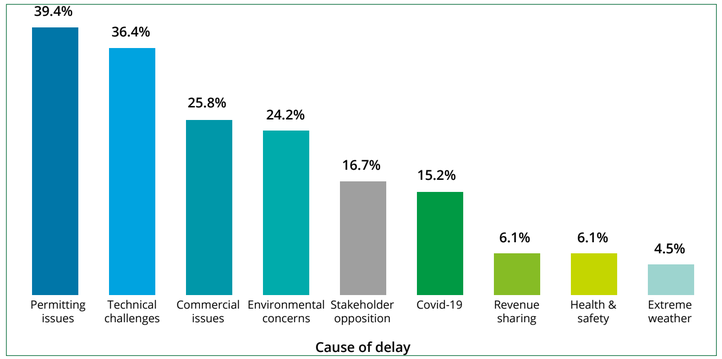
"Mining companies can act as conveners, aligning government, industry, and community stakeholders to ensure benefits flow broadly."

Accelerating development, upholding global standards

Projected future supply shortages of critical metals, like copper and lithium, and the length of time taken to bring new projects online, have sparked concerns around the prioritization of community interests and sustainability in mine development.[24] The biggest causes of delay to critical mineral mine development are permitting challenges, technical challenges, and commercial matters, followed by environmental concerns and stakeholder opposition (see figure 3).

Given these concerns, shared value initiatives and Indigenous or local collaborations represent more than a socio-economic opportunity. These actors could provide a "voice at the table" to ensure that nature and land are not compromised, even when projects are under pressure.

Figure 3: Causes of delays to critical minerals projects (% of delayed projects).



Source: ERM Foundation research (2017-2023 data)[25]

Catalyzing socio-economic transformation

For resource-rich countries, the energy transition offers an unprecedented chance to redefine their socio-economic trajectory. For mining companies, it represents an opportunity to evolve from extractors into conveners, catalysts and enablers of resilience.

Capturing this mutual potential may require coordinated industrialization, the creation of business ecosystems, community empowerment, stable policy and innovative finance. These are not quick or easy wins. However, if managed wisely, mineral wealth could underpin diversified economies, stronger companies, and more resilient societies and deliver a more inclusive global energy transition.

From ideas to action

- **Position operations as ecosystem anchors:** Companies could treat each project as a nucleus for industrial clusters by engaging local suppliers, downstream customers and infrastructure providers early in project planning. Consider using procurement leverage to catalyze local manufacturing and services, as well as a trigger for workforce skilling/reskilling initiatives.
- **Co-invest in enabling foundations:** Where energy, transport, or water infrastructure is underdeveloped, explore shared-use models and public–private partnerships to help bridge investment gaps. This might mean building power plants sized for regional demand or railways that carry community and commercial cargo alongside minerals.
- **Design community value into business models:** Miners are increasingly going beyond corporate social responsibility to embed local procurement, skills transfer, and equity participation into contracts and operations. Setting measurable targets for small-medium enterprise engagement and tracking delivery of social outcomes alongside production metrics could help ensure the impacts are measurable.
- **Build regional alliances:** Collaborating with peers to share infrastructure, align on training programs, and advocate for harmonized standards across borders could speed project development and build resilience to risks such as extreme weather impacts (see trend 10). Multi-company corridors, shared logistics, or joint innovation hubs may lower costs and de-risk investments.
- **Signal long-term stability to investors and stakeholders:** Ensure transparent reporting on fiscal contributions, sustainability outcomes and community impacts. Consistent disclosure helps builds credibility, reduces perceived risk and could potentially lower the cost of capital.

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Deloitte.

Together makes progress

Trend 10

Scaling sustainability adaptation: Leveraging systems advantage for resilient supply chains

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The mining and metals sector is positioned at the frontline of extreme weather impacts. Its products are indispensable to the global energy transition, yet its operations are increasingly exposed to the impacts of a changing world.

Extreme weather events, water scarcity, and ecosystem degradation are no longer distant concerns; they're growing material risks to business continuity, stakeholder confidence and asset value. The Global Tipping Points 2025 conference echoed this message, noting that these risks could arrive faster than anticipated, though positive tipping points, for example, in technology adoption offer grounds for optimism.[1]

For mining and metals companies, the urgency is clear. Building physical extreme weather resilience is fundamental to safeguarding their long-term competitiveness, protecting communities, and enabling the clean energy transition. Yet the scale of the task may be too great for any single organization to manage alone. The sustainability of the mining and metals industry could lie in leveraging ecosystems of stakeholders—including suppliers and services companies, clients and government—to enable collaborative adaptations and advantages, data-sharing and shared responsibility.

Physical risks are disrupting operations today

Mining and metals companies manage some of the world's most geographically exposed and capital-intensive assets. Ports, railways, and power infrastructure are often concentrated in areas that are increasingly vulnerable to cyclones, floods and wildfires. In these instances, even brief operational interruptions could have cascading effects given the central role of metals in sectors such as construction, energy and manufacturing.

Recent events illustrate this vulnerability. In February 2025, Cyclone Zelia forced the closure of Port Hedland in Western Australia, the world's largest bulk export terminal, for three days. The closure disrupted supply chains that contribute more than US$63 billion (A$100 billion) annually to Australia's economy.[2]

In Canada, an unusually warm winter through 2023-24 delayed the opening of the Tibbitt to Contwoyto Winter Road, a 250-mile link serving Rio Tinto, Burgundy Mines and De Beers operations. The two-week delay slowed the delivery of fuel and equipment to Arctic diamond mines.[3] Meanwhile, long-term drought in Chile reduced the country's copper output by 10.4% during 2022, cutting production at major operations, such as Anglo American's Los Bronces and Antofagasta's mines and driving up unit costs.[4]

Geoff Tuff, principal, Global Sustainability Industry leader, Deloitte Global, said:

"Most conversations surrounding economic value and climate change tend to focus on top-line and bottom-line growth as opposed to risk mitigation. Many companies may not yet be thinking deeply about physical risk, but those that have had operations disrupted by major weather events are starting to take notice."

The financial implications of delay could be significant. A 2024 study highlighted that the natural resources base of the mining and metals sector makes it highly dependent upon environmental conditions, leaving companies vulnerable to disruption of supply chains, energy supplies and community relationships.[5]

John O'Brien, managing director, Sustainability lead for Mining & Metals, Deloitte & Touche LLP, stressed:

"Until recently, negative climate tipping points were spoken about as if they were decades away. Now, evidence suggests that some of these shifts could happen within years. Organizations may not be ready for that level of disruption, but by planning now, they could be better positioned to respond when it occurs."

ICMM has also shown that extreme weather can damage long-life facilities, such as tailings dams, reduce mine output, and increase costs through higher insurance premiums and unplanned capital expenditures. In contrast, reducing exposure to climate-related risks (both physical and transitional) can help reduce costs, preserve or enhance revenues, improve stakeholder relationships and help identify new business opportunities.[6]

Extreme weather resilience, therefore, is not just an operational concern but a core driver of organizational competitiveness, deep purpose and license to operate.

From competitive advantage to systems advantage

Traditional approaches to physical extreme weather resilience have tended to focus on site-level interventions, such as reinforcing tailings dams, expanding water storage, or investing in backup power. While necessary, these measures will likely be insufficient in the face of systemic extreme weather risks.

Today the energy transition is reshaping industrial value chains, blurring the lines between sectors and necessitating a move away from linear competition towards systemic collaboration.

Geoff Tuff, principal, Global Sustainability Industry leader, Deloitte Global, explained:

"What we're seeing is the emergence of systems advantage. Mining and metals companies can no longer afford to think only about their own assets. They need to consider how they could work with collaborators across materials, energy, and fuels to grow the value of the whole ecosystem and accelerate the energy transition."

Examples of this systemic approach are beginning to take shape. In southwest England, an integrated supply chain is being built to support electric vehicle (EV) battery production and recycling. By 2035, a gigafactory is set to produce almost half the batteries needed to meet UK EV demands. The region is also home to multiple clean energy projects and the UK's only lithium mines.[7] In April 2025, clean tech company, Altilium, also began construction on the UK's first at-scale EV battery recycling facility with integrated chemical refining capabilities.[8]

Hubs like these are more than industrial clusters; they represent potential for collaborative resilience, where shared intelligence and co-located infrastructure could reduce collective exposure to risks, including those that are extreme weather related.

Sharing data, scenarios, and costs

High-quality, consistent data could be the foundation for collective action, and free, open-access resources already exist to support this. For instance, Probable Futures is a non-profit climate literacy initiative offering digital materials, data tools and customized engagements to individuals and organizations across the globe.[9]

Having a common platform where companies and their collaborators can assess risk together is important. Without a shared view of exposure, it can be difficult to build coordinated plans. However, that data alone is not enough; it should be translated into actionable scenarios.

A 2023 study proposed a framework that overlays extreme weather hazard maps with mining infrastructure, logistics networks and ecosystem dependencies in Chile's Antofagasta region.[10] Applying such geospatial methodologies could help enable copper miners to identify vulnerabilities across their regional value chains, not just at individual sites.

Earth observation, satellite imagery, and artificial intelligence (AI) are enabling the assessment of localized risks, such as wildfire likelihood in specific areas. While these models cannot deliver perfect predictions, they can offer directionally appropriate insights that help enable companies to make informed decisions in advance, rather than reacting after disruption has occurred.

Establishing platforms where miners, processors, transport providers and downstream customers share regional extreme weather risk assessments could allow them to align on common scenarios and signposts. This may shorten decision-making cycles when extreme weather shocks occur and spread adaptation costs more equitably.

Embedding nature, governance, and communities in adaptation strategies

Governance could play a decisive role in whether mining and metals companies succeed in scaling physical extreme weather measures. Specialists have underscored that board-level accountability for climate outcomes is important, as litigation risks and investor expectations are rising.[11]

Policy environments are also evolving. Mineral-rich countries are now embedding climate resilience into permitting and land-use policies and frameworks. These are designed to incentivize the mining and metals industry to invest in climate-sensitive technologies, processes and infrastructure that will not only help achieve their climate goals but also add new green value chains to economies for sustainable long-term growth.[12]

Nature itself should also be treated as an important part of resilience planning. Research shows that 71% of transition-mineral mines are located in ecosystems that are significant for the preservation of biodiversity and the provision of ecosystem services that benefit society on a local and global scale.[13] These ecosystems are not just environmental assets, they act as natural infrastructure, regulating water flows, buffering floods and stabilizing local environments. Their degradation or preservation can therefore directly increase or decrease operational risks for mine operators.

Global examples of ecosystem-based adaptation show the potential of this approach. Instances from Latin America and Africa demonstrate how restoring mangroves or protecting wetlands can shield infrastructure and communities from flooding and storm surges, often more cost-effectively than engineered defenses.[14] In Arctic Sweden, research highlights that mining projects cannot be extreme weather resilient without considering their ecological and social context, including permafrost thaw and biodiversity impacts.[15]

WTW's Mining Risk Review 2024 adds another perspective, recommending that miners should integrate physical resilience into existing planning frameworks. The report outlines five steps: building resilience into existing processes; identifying thresholds that could trigger operational disruptions; stress-testing strategies across future scenarios; quantifying risks financially to guide investment; and maintaining agility by developing multiple adaptation pathways.[16]

Practical frameworks such as this complement the broader ecosystem approach, emphasizing that extreme weather resilience is best achieved when embedded into everyday business decision-making.

Building shared resilience through nature-based solutions

Nature-based solutions can build the resilience and socioeconomic independence of host communities while also making mining companies and their operations more extreme weather resilient and purposeful.

For example, Rio Tinto is investing in diverse landscapes, from mangroves that help reduce storm damage, to wetlands that act as natural sponges during floods and forests that regulate extreme temperatures. These ecosystems not only capture and store carbon, but also provide important services such as soil fertility, pollination and storm protection.[17]

Nature-based solutions are scalable today and can yield rapid benefits, unlike many engineering-based solutions still under development. By embedding these approaches into its operations, Rio Tinto aims to reduce its footprint, accelerate decarbonization, and reinforce resilience across ecosystems and communities.[18]

Forging resilience through systems advantage

The way forward may lie in shifting the collective focus from competitive advantage to systems advantage. By collaborating to share data, aligning on scenarios, co-developing infrastructure, and distributing costs and benefits more equitably, businesses and their stakeholders could gain measurable benefits in extreme weather resilience. Examples from nature-based adaptation projects also demonstrate the value of considering mining operations in the context of natural ecosystems rather than separate.

John O'Brien, managing director, Sustainability lead for Mining & Metals, Deloitte & Touche LLP, concluded:

"Companies are already working together to create integrated value chains in critical minerals. Expanding those relationships to share insights and data around extreme weather risk makes good business sense. The time to build and scale resilience is now, and it will require working together in ways the industry has never done before."

From ideas to action

- **Map dependencies and vulnerabilities comprehensively:** Move beyond asset-level risk assessments to include supply chains, infrastructure, compounding risks and ecosystem services in mapping exercises. Incorporating forests, wetlands, and watersheds into vulnerability mapping could identify natural assets that act as extreme weather buffers, as well as critical gaps in resilience.
- **Develop integrated resilience hubs:** Where new opportunities exist, consider co-locating mining and metals operations alongside recyclers, renewable power producers and community services. Such hubs could share extreme weather related insights to help reduce companies' collective exposure to risks, for instance, through investments in flood defenses, renewable microgrids, and water recycling facilities.
- **Embed extreme weather resilience into governance:** Make extreme weather resilience performance a matter of board oversight, with clear metrics linked to executive incentives and investor reporting. Where capacity is lacking, companies could provide opportunities for board members and executives to learn and upskill.
- **Innovate financing:** Explore blended finance, resilience bonds, or cost-sharing models where suppliers, off takers and end users contribute to adaptation investments. By distributing costs across the ecosystem, capital-intensive resilience measures could become more feasible and sustainable for many parties.
- **Leverage nature as infrastructure:** Consider incorporating ecosystem-based adaptation into operational planning and financial scenario planning. Restoring or protecting natural systems around mining assets can help mitigate risks, such as flooding, heat stress and erosion, while delivering biodiversity and social benefits.

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AI for operational excellence: Managing safety risks and enabling productivity

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Redefining mineral exploration: Using data and AI to unlock the next wave of major discoveries

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Trend 9

Unlocking resource wealth: Strategies to catalyze socio-economic transformation

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Trend 10

Scaling sustainability adaptation: Leveraging systems advantage for resilient supply chains

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