

# Mining and Metals: Trends, Challenges and the Way Forward

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# Introduction

## What transformative trends will reshape the mining and metals industry in the years to come?

Minerals and metals are indispensable for countless economic activities. The energy transition is set to increase the demand for materials, and numerous industries are expected to require more minerals in the near future. This, combined with a renewed focus on sustainability, makes the mining and metals industry ripe for a transformation whose implications will extend beyond the immediate sector to a myriad of industries and processes essential to everyday life.

Over the year 2023, the World Economic Forum gathered a select group of senior leaders from the mining and metals community to discuss the new challenges the industry is facing, as well as opportunities for the way forward. The group agreed on the need to shape a collective vision and share their thought leadership with multiple audiences. This report captures this vision to help inform discussion on the future of the mining and metals industry.

The report has been written by a select group of senior leaders from the mining and metals community, all with first-hand experience, knowledge and comprehensive understanding of the industry's strategic priorities and opportunities. This process has allowed them to put into words their perspectives on the current state and future of the industry.

The authors have examined industry trends, identified potential disruptions and highlighted their effects on the industry and other socio-economic systems. From energy transition and geopolitics to the need to rethink business models through innovation and partnerships, this report recognizes the interplay between supply chains, environmental impacts and socio-economic considerations. At its core, it echoes the need for collective action for the industry's resilience amid global challenges.

The results are relevant for all mining and metals stakeholders, and especially for those who want to understand the stimulating and complex nature of this industry. This report provides a foundation for insightful and informed discussions. The World Economic Forum provides a unique platform for these conversations within the industry and across other industries, and to enable a responsible transformation.

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# Key trends driving the industry

The most recent version of the Global Risks Report<sup>1</sup> highlights the increasing interdependencies between global risks, shedding light on the intricate challenges that span geopolitical tensions, state interventions in markets, and the foreseeable deployment of economic policies for strategic purposes. The report introduces the concept of a potential “polycrisis” – a convergence of interconnected environmental, geopolitical and socio-economic risks relating to the supply of and demand for natural resources.

Not surprisingly, geopolitics and climate change have stood out as driving forces for the mining and metals industry and its global value chains. The imperative for an energy transition has accelerated the dual demand for increased production and sustainable performance.

In this chapter, the authors discuss the key trends that they expect will shape the industry in the coming years, along with the challenges and opportunities that will arise.

## 1.1 Industry megatrends

Tom Palmer, President and Chief Executive Officer, Newmont<sup>2</sup>

The mining and metals industry started 2023 in a promising landscape of increased demand and investment, with the energy transition spotlighting the leading role the industry must play. It has become evident that resource demand will grossly outstrip supply, and current technology must rapidly evolve. Those who work in the resources industry very clearly understand and recognize the necessity, value and role of mining and metals in the modern way of life. Still, it is critical to understand the extent to which society is unaware of its deeply rooted dependency on the minerals and metals that this industry produces.

During 2023, the industry experienced global megatrends: ever-increasing societal and investor demands, exponential acceleration of technological change, and geopolitical turbulence. The intensity and velocity of these megatrends are so disruptive that if companies are not agile enough to adapt, align and lead, they will risk losing control of their businesses. Each of these megatrends could impact our workforces by creating confusion, uncertainty and anxiety. Taken together, their convergence into a potential meta-crisis could break the critical social bonds between individuals, communities and nations.

### Social transformations

Society and investors are demanding increased accountability, value sharing and values-based decision-making. The post-pandemic consequences of government fiscal interventions,

which were aimed at preventing complete economic collapse, have ballooned national deficits and debt, and have left the working- and middle-class anxious about dislocated macroeconomic conditions (such as heightened inflation and increased interest rates). The industry has been called on to contribute more through taxes, royalties, economic development and social investments while responsibly supplying the materials to support the modern way of life and the new energy economy.

Creating a new energy economy through renewable power and electrification will require massive increases in the production of minerals. For instance, copper demand is expected to nearly double from 25 million tons today to about 50 million tons by 2035 in order to deploy the technologies needed to achieve net-zero targets by 2050.<sup>3</sup> Based on current copper production trends, copper supply will fall short of demand by 10 million tons by 2035,<sup>4</sup> and by 2050, the world will only be producing 20% of the copper needed to meet the net-zero climate goals. Bridging this gap will require significantly more copper mines, recycling facilities and enhanced copper leaching processes.

This means more deposits need to be discovered and mines built at an unlikely pace given the drawn-out time frames to secure approvals. Even with the growing interest and opportunities for recycling, increased circularity and expansion of secondary markets for minerals, production will still need to increase. To even come close to achieving this pace, the industry will need as much goodwill and trust as possible, by demonstrating that it is responsible.

“ Values-based governance, transparency and accountability are all critical to helping stabilize the geopolitical environments in which the industry operates so that it creates a degree of certainty that will satisfy shareholders, while living up to the commitments to other stakeholders.

This will require leveraging the capability, creativity and goodwill of industry workforces and community partners to anchor decisions and actions in people-centric approaches. It is about establishing and maintaining long-lasting relationships built on trust and respect – relationships that have at their foundation the creation of safe, healthy and equitable workplaces.

## Acceleration of technology

While technology has helped make businesses safer, cleaner, more efficient and productive, the velocity of technological change today is affecting social and economic dynamics in ways not seen since the industrial revolution. For instance, automation is helping mitigate safety risks, reduce emissions and improve efficiencies. Specifically, autonomous vehicles, automated drilling, remote operations and asset monitoring are critical to how mining is done today and, even more so, in the future.

Artificial intelligence (AI), including large language models such as Chat GPT, is advancing and self-learning so rapidly that even their creators are still determining how models do what they do. AI's accelerating advancement is creating unknown unknowns.

The industry must prepare businesses and workforces to responsibly navigate these technological opportunities and threats by anchoring itself to core values so that it makes moral and people-centric decisions in fast-moving and complex situations, either driven or exacerbated by technology.

## Geopolitical turbulence

Geopolitical developments have material impacts on the supply and demand of individual commodities. The leadership in the resources sector extends well beyond the boundaries of operations and into local communities, civil society organizations, legislatures, and ministerial and presidential offices.

The industry must navigate resource nationalism and turbulent geopolitical trends to satisfy society's rapidly growing demand for minerals. It must quickly adapt and invest time, energy, resources and skills on systematic, high-quality engagement with governments and other stakeholders. Values-based governance, transparency and accountability are all critical to helping stabilize the geopolitical environments in which the industry operates so that it creates a degree of certainty that will satisfy shareholders, while living up to the commitments to other stakeholders.

Looking forward, these megatrends will animate one another in ways that cannot be predicted. However, under any scenario, responsible production of minerals and metals remains the only way the industry can generate sustainable value for its workforce, communities, host countries and shareholders while supplying the essential resources necessary for the new energy future.

Successfully navigating this period of disruptive change will require leveraging the capability, creativity and goodwill of our workforces and community partners to anchor our decisions and actions in people-centric approaches.



## 1.2 Will the energy transition create dangerous dependencies on critical minerals?

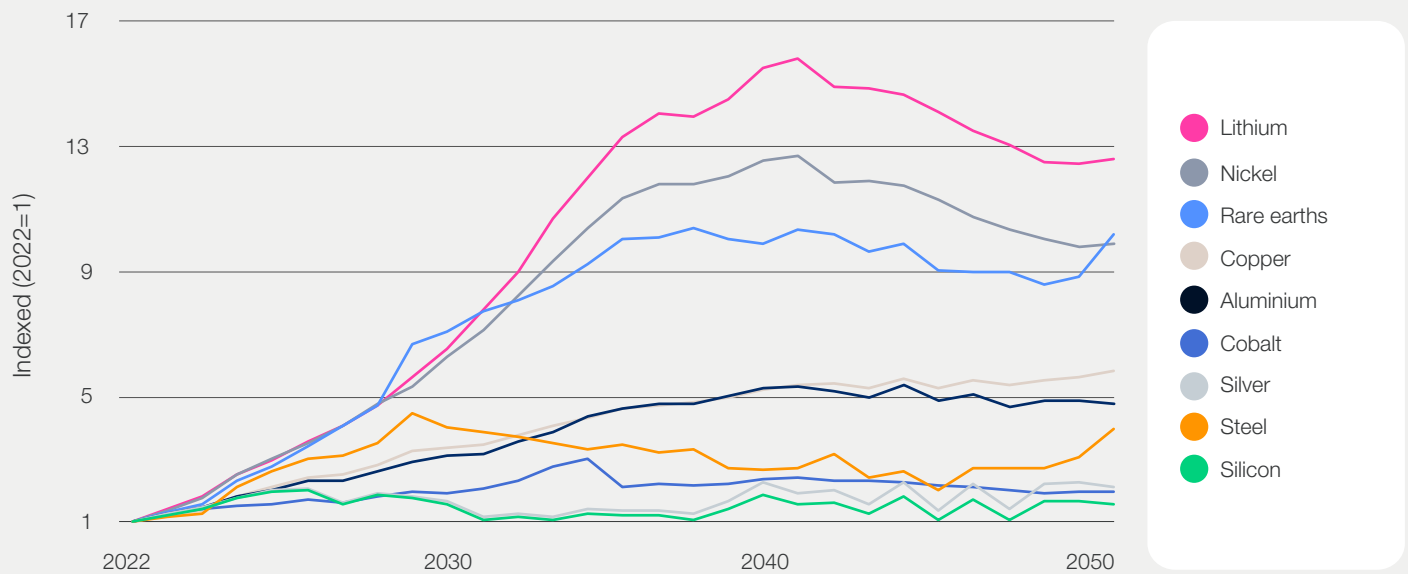
David G. Victor, Professor, University of California, San Diego (UCSD)<sup>5</sup>

The world is beginning to see a rapid rise in demand for mining and metals along with industrial processes that can convert mined materials into useful products such as batteries for electric cars, cells for solar panels and magnets for wind turbines. This demand is driven by the energy transition – more of a revolution in how the world produces and uses energy rather than an orderly, gentle transition. This transition, essential to making deep reductions in emissions that cause climate change, is certain to rely on large amounts of critical minerals.

Figure 1 shows projections for future demand. Other studies paint slightly different pictures, which is a reminder that with changes in markets, suppliers and technologies, governments must keep re-evaluating priorities and strategies. What is clear is that demand for some materials is expected to soar, with at least three materials (lithium, nickel and rare earths) on every list of concern. Also on many lists are copper and aluminium, among others.

FIGURE 1 Demand for metals essential for the energy transition under the net-zero scenario

Growth in demand for metals used for clean energy transition under BloombergNEF's Net Zero Scenario



Source: BloombergNEF, 2022.

These shifts in demand for critical minerals are creating at least three pressures on the industry. First, there is growing scrutiny about whether supply can keep up with demand – and there will be scrutiny on the industry where those supply gaps appear, as well as opportunities for producers who can ramp up output. Many studies suggest that gaps between demand and supply will appear soon, though there is a lot of uncertainty.<sup>6</sup> To avoid supply shortages, the industry and governments must collaborate, particularly on improving the ability to site new mines.<sup>7</sup>

Opportunities exist on both demand and supply sides. Supply-side uncertainties include the potential for innovation to lower the cost of identifying and extracting materials, for example, lithium. On the demand side is the potential for innovation – for example, in battery materials, anodes and cathodes – that could enable a shift away from lithium, cobalt and other materials. These market responses are already beginning. For example, companies have shifted to ferrous cathodes, reducing the need for costly nickel. Improved recycling and reuse has implications for both demand and supply.<sup>8</sup>

“ The industry will find itself in the spotlight because of its centrality to the energy transition but will also be scrutinized heavily because of its environmental impacts.

Second, concerns about the sustainability of the supply chain are growing. The energy transition is part of a larger societal transformation involving the lowering of emissions as well as achieving an ever-shifting list of social attributes such as equity, protection of human rights and environmental stewardship. Mining and metals will face similar pressures, implying full value-chain scrutiny. Accordingly, the industry should expect to become much more transparent and adept at accounting for behaviour at each step in the value chain.

For example, it remains challenging – perhaps increasingly challenging – to site new mines and expand new production facilities in much of the world. The industry will find itself in the spotlight because of its centrality to the energy transition but will also be scrutinized heavily because of its environmental impacts. Moreover, the properties of the supply chain, such as life-cycle emissions and other impacts, will be linked to the products in which these materials are used. The more intense the efforts to reduce total emissions from the industrial system, the more intense this kind of life cycle scrutiny is likely to become.

Third, geopolitics. The “energy transition” implies a shift from dependence on conventional fossil fuels to dependence on cleaner energy infrastructure, which requires critical materials. That dependence is leading to geopolitical concerns, particularly concerns anchored on imports of raw and processed materials from China, Russia, the Democratic Republic of Congo and a few other countries. Every material is different. For some, such as rare earths, a single project can diversify global supplies substantially, as happened recently when a California-based rare earth mine expanded.<sup>9</sup> In other cases, the concern is processing and upgrading, notably for lithium, where China plays the dominant role, and those

facilities may be easier to diversify because they require building facilities in other countries rather than sourcing new ores and reserves.

These concerns arise at a time when power in the international system is getting diffused, and international institutions are under threat and perhaps becoming less capable of managing collective global problems effectively. These geopolitical concerns, in tandem with local economic interests, have led some countries to onshore or “friend-shore” their supplies. These initiatives could produce many new suppliers and more diversity in global supplies, leading to more security. All else being equal, commodity markets with highly diverse supplies tend to be more reliable, resilient and thus secure. As Churchill said about the oil market a century ago: “security comes from diversity and diversity alone”. But these initiatives could have perverse effects if friend-shoring or nationalization of supply chains is pursued in a way that creates fragmentation.

As this surge in demand spreads across the industry, the future could unfold in many ways. Higher prices and credible increases in expected demand will spur innovation in supply and demand. For policy-makers, it could be especially important to let markets work where they can work effectively and identify a narrow list of materials and areas where more active policy interventions, such as stockpiles and import controls, might be necessary. This will need to be done under conditions of deep uncertainty since so much of industrial supply and demand, and the characteristics that society will expect from both, is shifting. The metals and mining industry should keep abreast of how this evolves and how events far outside the industry will affect its future.

## 1.3 Mining and metals in the geopolitical spotlight

Sofiane Khatib, Strategic Adviser, Trafigura Group

Covid-19, the war in Ukraine and major-power rivalry have fast-tracked policies to advance the energy transition and harness supply diversification, causing a shift in priorities. Competitiveness is key, but other factors are becoming critical for stakeholders, such as supply security in a fragmented world, the way in which materials are extracted and transformed, and the carbon footprint of the processes.

These dynamics have, for the first time, put the metals and mining industry in the geopolitical spotlight. In April 2023, the Group of Seven (G7) countries adopted a “Plan for Critical Minerals Security” and pledged \$13 billion in support.<sup>10</sup> In July 2023, leaders of the Group of 20 (G20) countries emphasized the need for diversified, sustainable and responsible supply chains for the energy transition,

including for critical minerals. This is particularly the case for the mining and processing of metals required for clean energy technologies, whether for generation, transmission or storage, such as copper, aluminium, zinc, cobalt, lithium and nickel.

### Supply-demand gap

The shift to a greener energy mix will result in a significant increase in commodity demand. Copper demand could rise by 40% in 2035, while supply from existing assets or committed projects will only increase by 20%, meaning new mining projects will need to begin construction in the coming years. Lithium demand is expected to increase five-fold by 2035, primarily due to the electrification of light

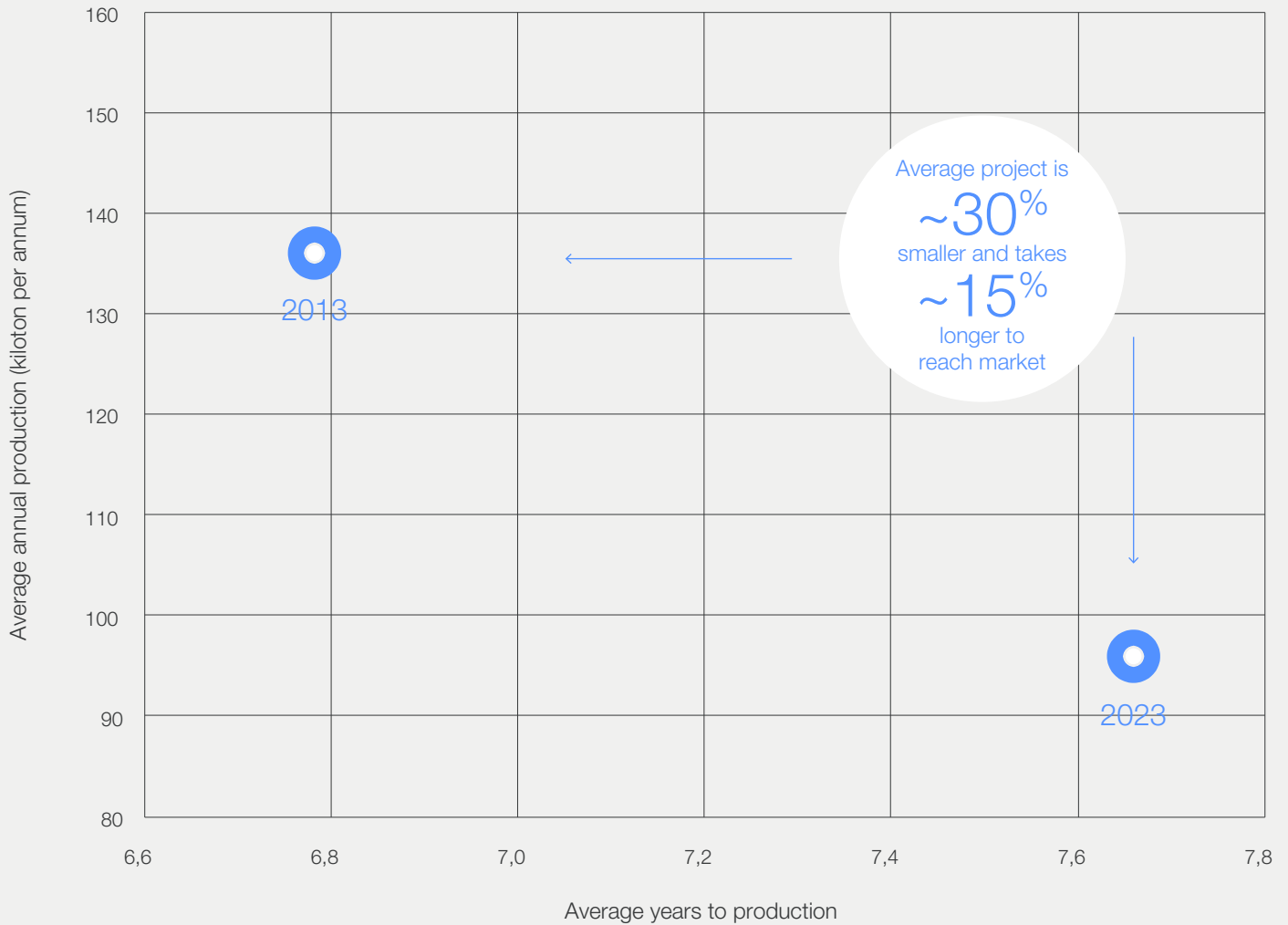
vehicles. Current operations will meet only 7% of this demand, and among the projects to cover the remaining supply, around 20% will depend on untested technologies.<sup>11</sup> Recycling, ongoing efforts to reduce the metal intensity of energy transition infrastructure and adoption of new technologies

to increase the efficiency of mining operations will help. Still, it won't be enough to close the gap. Furthermore, an average mining project is now 30% smaller, takes 15% longer to reach the market than a decade ago and increasingly requires operating in socio-economically challenging jurisdictions.<sup>12</sup>

FIGURE 2 Copper projects now take longer to reach the market

### Copper project pipeline comparison

Stated in kiloton per annum (Y Axis) and years (X axis)

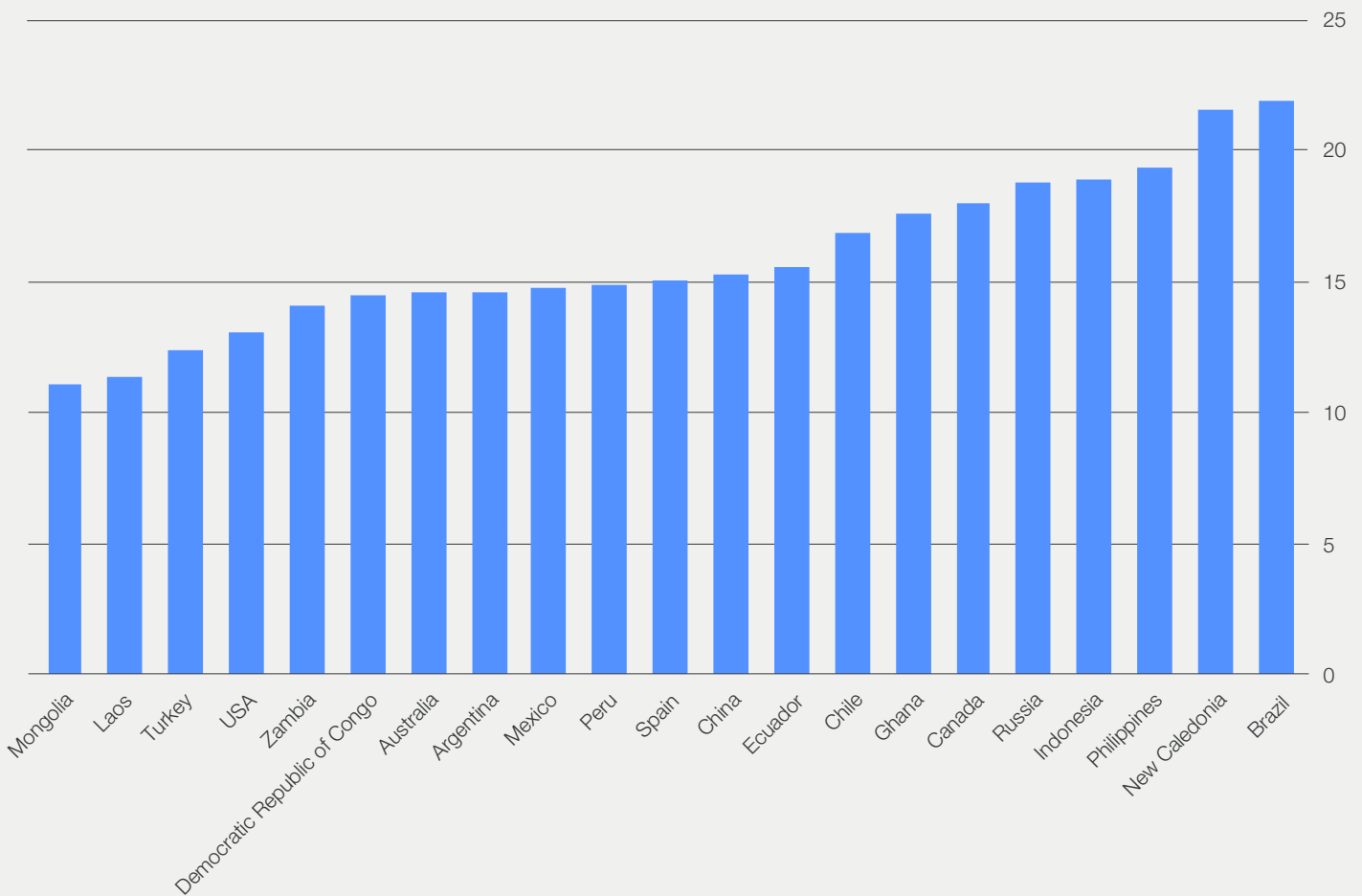


Source: CRU, Trafigura Research.





Average lead time for new mines: Discovery to production  
Stated in years



Source: CRU, Trafigura Research.

### Supply chains' resilience

As with other globalized industries, economies of scale, supply chain integration and optimization of trade flows have driven the emergence of industrial metal processing hubs. Ownership of the mining assets and metal processing plants relevant for the energy transition is mainly concentrated in China, whose share of metal refining is 35% for nickel and 50-70% for lithium and cobalt.<sup>13</sup> Chinese companies have also invested substantially in copper and cobalt mining assets in the copper belt in Africa and in nickel assets in Indonesia. As major-power rivalry intensifies, these choke points increase the risk of weaponization of trade interdependencies through export bans, sanctions, tariff wars and other shocks.

### Onshoring, “friend-shoring” and mining diplomacy

To increase their security of supply, the United States (US) and Europe have set different strategies. The US, through the Inflation Reduction Act, aims to attract metal processing on its territory or in countries with which it has free-trade agreements. On the other hand, Europe’s priority is carbon dioxide (CO<sub>2</sub>) content and the environmental, social and governance (ESG) compliance of electric vehicles (EVs); it has focused on reducing end-to-end carbon emissions from the European EV manufacturing value chain.

“ More efficient and resilient supply chains will be vital in avoiding bottlenecks that will slow down, or, even worse, derail the energy transition.

Consumer countries are also intensifying “mining diplomacy” aimed at securing the supply of raw materials. This will likely result in competitive financing, help to secure market access and provide support to downstream processing facilities when possible. China has been active in this space for two decades, as was, to a lesser extent, Japan. Nascent efforts in the US and Europe include the US Minerals Security Partnership and the EU Critical Raw Materials Act. Europeans have been proposing the idea of a “buyers’ club” for critical minerals comprising the G7 countries, which would set common ESG standards for suppliers.

## Resource nationalism

The expanding strategic role of transition metals is driving host countries to demand greater ownership of these resources. In Latin America, for instance, various governments have enacted new regulations to ensure the control of lithium assets, while Indonesia has banned the export of raw nickel to encourage the development of a domestic processing industry.

The prices of key commodities do not yet reflect the looming shortage, but as the supply gap materializes and prices increase, the industry will be confronted with significant challenges linked to resource nationalism. Past trends affecting the oil and gas industry show that high prices raise the bargaining power of producing countries, contributing to a resurgence of nationalistic policies. To address these concerns, the metals and mining industry will need to strengthen its social licence to operate, foster trust and nurture balanced relationships with host countries.<sup>14</sup>

More efficient and resilient supply chains will be vital for avoiding bottlenecks that can slow down, or worse, derail the energy transition. This means better access to current resources, diversification of supply sources, access to strategic reserves and deepening of the financial markets that underpin the extraction and transportation of transition metals. In addition, the industry leadership will have to develop the skill sets to navigate geopolitical fault-lines and to operate in a volatile field with increased exposure to potential disruptions. They will have to devote significant time and energy to fostering cooperation with key stakeholders along the value chain and to manage the spillovers of geopolitical confrontations and resource nationalism.

## 1.4 The changing role of governments

Karina Gistelink, VP Strategy and Marketing Intelligence, BHP Group

“ Governments are understandably concerned about ensuring a consistent, sustainable supply of these critical minerals at reasonable prices.

The relationship between governments and mining has been transformed in response to three critical interrelated trends that underline mining’s pivotal role in the energy transition: i. decarbonization and the imperative for securing resources for the energy transition; ii. mining in post-pandemic economic recovery; and iii. the shift towards geopolitically driven supply chains. These trends highlight the increased importance of collaboration between governments and the mining sector as well as among governments.

First, the global commitment to decarbonization has intensified governments’ focus on securing resources required for the energy transition. To achieve the Paris Agreement goals, double the amount of copper and nickel will be needed, and more than 10 times more lithium.<sup>15</sup> This has already created intense competition for these commodities, reflected in significant price volatility reaching or exceeding historical maximums. For example, London Metals Exchange (LME) nickel prices have ranged from ~\$20,000/ton to \$31,000/ton in the first half of 2023, copper prices broke through the \$4.6/pound mark in 2022, while lithium prices jumped from \$25,000/ton to \$80,000/ton in the first half of 2023.<sup>16</sup> In this context, governments are understandably concerned about ensuring a consistent, sustainable supply of these critical minerals at reasonable prices.

In response, countries have rolled out new policies, including substantial updates to critical mineral lists, strategic plans and international cooperation mechanisms. While many of these policies are designed to improve supply reliability, including the US and EU Critical Mineral Acts, most of the policy support has been directed towards midstream processing and downstream manufacturing. For supply to keep up with demand, governments also need to consider how to support upstream mining projects appropriately. This is complicated by disaggregated levels of project sanctioning, the complexity of governance in some resource-rich nations, and the concurrent need to build an efficient, secure and sustainable supply chain. These challenges are reflected, for instance, in the difficulty of implementing the EU’s plan to accelerate permitting (two years for strategic mining projects) and access to finance. Canada is a good example of a country supporting the full value chain, though with a local focus. Its policies are designed to create a path for Canada to become a global supplier of choice for critical minerals, with a \$4 billion budget allocated to this objective.<sup>17</sup>

Second, resource-rich countries are increasingly looking for resource companies to bolster domestic revenue, partially in response to post-pandemic depleted coffers and in the context of rising commodity prices for energy transition metals.

This translates into measures such as royalty and tax increases and nationalization, which are often positioned as a fair share of profits. Examples include increased coal royalties in Queensland, Australia,<sup>18</sup> nationalization of lithium reserves in Mexico,<sup>19</sup> and proposed state ownership of mining and petroleum companies in Namibia.<sup>20</sup> While these measures can increase government revenues in the short term, the fiscal and regulatory uncertainty can make a region less attractive for investment and undermine the long-term viability of mining projects. For example, both BHP and Glencore decided not to proceed with new investment in Queensland, Australia, while Mexico may struggle to develop its nationalized lithium resources on its own given the potential lack of capital and technology.

Third, recent geopolitical events have caused disruptions to supply chains and triggered a move away from globalization towards the establishment of local, geopolitically driven supply chains, which creates inefficiencies. For example, Indonesia's attempts to ban bauxite exports and facilitate the buildout of the local aluminium sector did not account for the relative abundance of bauxite and the significant investment required to substitute existing facilities, reducing the attractiveness of the bauxite industry in the country.<sup>21</sup> Successful policies will facilitate cooperation based on efficiency and sustainability rather than enforcing it under restrictive conditions. Building these supply chains also requires a degree of cooperation within the value chain that has not been typical in industrial commodities.

To strengthen the global economy and facilitate the energy transition, governments could follow these three recommendations:

1. Recognizing mining's essential role in decarbonization and sustainable development, governments can focus on developing capabilities for the mining sector, and collaborating with mining companies to implement sustainable practices that enable project development, minimize environmental impact, respect local communities and ensure the long-term viability of the industry.
2. Governments' understanding of the need for cooperation and avoiding protectionist or interventionist policies will ensure that measures aimed at securing critical minerals' supply do not undermine efforts to achieve the outcome that the world needs.
3. Governments' efforts to set and maintain transparent requirements are critical. These include efforts to streamline and standardize permitting and approval regulations, as well as harmonizing international and local regulations, where relevant, without jeopardizing the important ESG-related standards. Cross-government coordination is also critical for aligning on ESG requirements and global targets.

These measures would make mining companies trusted partners of governments and local communities, facilitating the energy transition and creating greater outcomes for everyone involved.

## 1.5 What to watch in 2024

Menno Sanderse, Head, Strategy and Investor Relations, Rio Tinto

“ We expect 2024 to be a year when governments and businesses face increasing pressure to make choices while faced with budget pressures, loss of buying power, geopolitical uncertainties and divergent regional priorities.

The interplay of climate change and geopolitics, increasing end-customer and societal scrutiny, and the changing role of governments could meaningfully reshape metals and mining value chains. While these trends are likely to result in a long-term evolution, we expect 2024 to be a year when governments and businesses face increasing pressure to make choices while faced with budget pressures, loss of buying power, geopolitical uncertainties and divergent regional priorities. While demand for the energy transition will positively impact the sector, market participants will need to navigate a world of economic uncertainty, capital intensity, operating cost escalations and conflicting societal sentiment.

### China: The energy transition will accelerate shift in domestic end-use demand

We expect that end-use demand in China will continue to move away from construction and towards the manufacture of more sophisticated end-products. China's share of global manufacturing output has increased six-fold since 2000 to over 40%, and over the last two years it has become a major net exporter of passenger vehicles. With its strong technology capabilities, cost advantages and presence throughout multiple value chains (including those for a range of high-growth applications such as EVs, solar panels and

wind turbine components), we believe this trend will strengthen in 2024. This will support growth in domestic demand for several commodities, including copper and lithium. By contrast, steel demand is expected to be similar to 2023, with the locus of consumption continuing to shift towards other jurisdictions, including India and Indonesia.

### **Industrial policies: Reindustrialization will spur new value-chain partnerships**

In several regions, including North America, Europe and Japan, governments are showing clear support for regional reindustrialization to support growth, technology leadership and geopolitical de-risking. While new subsidies, incentives, trade policies and other enabling policies (from technology R&D programmes to workforce upskilling) are creating favourable conditions for new manufacturing and clean energy projects, they could exacerbate raw material supply risks. Given the inherently decoupled distribution of resource endowment and the long lead times for new mining and processing assets, we believe that in 2024 a key priority will be the establishment of new bilateral and multilateral trade partnerships. Consequently, we expect a politically charged year for the metals and mining sector as presidential and general elections in a number of resource-rich countries are met with strong international competition for trade partnerships.

### **Energy transition: “Firmed” clean energy will create new processing hubs**

As the energy transition accelerates, long-standing materials supply chains will be reconfigured to locate energy-intensive processes in areas with plentiful green energy. Industries that can use intermittent power or green hydrogen will be advantaged in areas rich in solar and wind resources. Industries that require firm power will prize access to hydroelectricity or continue to rely on nuclear or fossil-fuel based electricity to offset variability in wind and solar energy.

In 2024, we expect further announcements, emergence of new players and early-stage progress on developing green industrial hubs across renewable energy-advantaged regions. Countries and regions seeking secure domestic supply will need to decide if they are willing to accept these new regions in their material supply chains, or if they will seek to offset the energy cost differential via new industrial policies.

### **Recycling: Scrap will become vitaly important in ensuring supply security and cutting CO2**

The combined focus on climate action, supply security and the reindustrialization of areas that generate scrap is creating favourable conditions to accelerate recycling. Given the technological challenges and the long time it will take to decarbonize large-scale, continuous production processes such as those for aluminium and steel, we believe that 2024 will see end-customers increasingly focus on securing recycled materials as they look for immediate solutions to reduce their CO<sub>2</sub> footprints. This trend will be further supported by recent industrial policies that have set recycling content targets for new products. An example is the EU Critical Raw Materials Act's 15% target for recycled content by 2030.

### **ESG: Balancing societal choices in the face of inflationary risks**

Societal and investor expectations of the metals and mining sector will continue to increase in 2024, with enhanced requirements for corporate transparency and accountability across a range of ESG issues including local communities, water management, nature/biodiversity and workforce diversity. With increasing inflationary pressure and divergent regional and local ESG priorities, we expect 2024 to be a year when governments, global businesses and multinational organizations broach tough societal choices. Leaders will need to weigh sentiment on local versus overseas projects, trade tariffs versus increased prices, and (given the absence of a global carbon tax system) the continued pursuit of ambitious climate goals versus further regional inflationary risks.

# Accelerating transformation through innovation

The industry is facing increased expectations in a complex global landscape that, as mentioned in the previous chapter, are propelling it into a new realm. As conventional approaches fall short, innovation emerges as the cornerstone for success, positioned at the core of the industry's response to the triad of sustainability, productivity and resilience.

This chapter provides a compendium of perspectives, each shedding light on the multifaceted role of innovation in steering the industry through this transformative journey. Each article delves into critical angles where innovation

becomes the catalyst for change: from creative solutions to power the industry in the competition for access to cleaner energy; to leveraging mining capabilities to impact broader global objectives like food security; and to delving into the integration of cutting-edge technology in traditionally carbon-intensive sub-segments such as steel production. Together, these insights coalesce into a narrative that not only underscores the imperative of innovation but also explores the diverse pathways through which it will be instrumental in reshaping the future transformation of the mining and metals sector.

## 2.1 Powering metals: Energy supply in the global mining industry

Christian Kossinov, Director, CEO Office, Eurasian Resources Group (ERG)

Sustainability permeates our lives. From policy-makers to consumers, sustainability has cemented itself at the forefront of society's collective consciousness. A recent survey from McKinsey showed that over 60% of respondents would actually pay more for a product with sustainable packaging.<sup>22</sup>

This zeitgeist has naturally impacted the mining industry and the green energy transition has effectively redefined the industry's *raison d'être*. This sustainability revolution is causing us to reflect on how energy-intensive mining really is, as it accounts for 10% of world energy consumption.<sup>24</sup> The mining industry needs to focus resolutely on the necessary changes so that the underlying goal of the energy transition is not sabotaged by the very means deployed to achieve it.

The sheer demand for critical minerals means the focus of the mining industry is already disproportionately shifting towards Africa, which holds 30% of the world's mineral reserves.<sup>25</sup> As mining in West Africa is growing exponentially, energy supply is struggling to keep up.<sup>26</sup> This trend occurs across most key mining sites critical to the energy transition. The majority of the minerals required for the green energy transition are found in developing countries and in isolated areas where access to power and utilities is limited.

In addition, the lack of sustainability policies and provisions in countries with critical mining sites also contributes to the scarcity of green energy to power the extraction of minerals. Solar, wind, renewable, thermal and hydropower have the potential to become significant players in the mineral extraction process. But so far, the current level of investment does not allow clean energy to be a reliable source of power for the mining industry.<sup>27</sup>

To power an industry as energy-intensive as mining and metals, a significant level of investment and an updated, radical policy approach will be needed, both in mining-rich countries and globally. The mining industry has also been at the cutting edge of innovation and the efficiency of mineral extraction has improved dramatically thanks to the introduction of state-of-the-art electric mining tools. Additionally, the sector has also been undergoing a digital transformation. AI holds vast opportunities for the future of the mining industry, particularly to help optimize energy use by analysing data to identify energy-saving opportunities.

At the same time, this technological shift has generated a demand for new skills within the industry. The analogue mining sector is evolving and as generations pass, a knowledge gap is taking shape. The "brain drain" is quite acute in Africa, notably in South Africa, where the phenomenon

is partially responsible for the implosion of the national electricity utility. The DRC is struggling with a similar issue, prompting an exodus of network contributors. Zambia, however, realized the risk in time and has improved the reliability of power supply to its mines.

In order to bridge this skills gap, the current workforce must be upskilled. At the same time, the mining industry must improve its offering to the younger generations to attract talent, which is a must to match the speed of the digital transformation. This involves a robust programme of internships, vacation work schemes, collaborations with universities, mentorships and, where applicable, apprenticeships. We must train a new generation of mining professionals to take our industry into the new, more sustainably powered age. Moreover, overcoming the energy supply obstacle would result in an unprecedented opportunity for mineral-rich emerging markets to grow and develop, while also gaining self-sufficiency on the energy front.

Companies are becoming aware of the impact of their energy requirements and the bar for corporate responsibility is getting raised exponentially. Managing that impact is complex. It starts with the necessary investment in improving the reliability of sustainable power sources on an industrial scale, and ends with recruitment and a cross-industry upskilling operation.

The mining industry can determine how rapid and successful the global energy transition will be. Companies, policy-makers and wider stakeholders alike must embrace a holistic approach to the issue of industrial energy supply, and work together to address it effectively. The industry has also taken great leaps in innovation and modernization with the view to optimizing and minimizing the energy required for its operations. As a sector, the priority should be supporting technological advancement through investment and research to further reduce energy requirements. This will be a continuous process, but the industry is on the right track to make a real and lasting change.



**Energy transition created “the biggest purchase order in the history of the mining industry”.**

Benedikt Sobotka, Chief Executive Officer, Eurasian Resources Group (ERG)<sup>23</sup>



## 2.2 Sustainable phosphorus mining for scaling food production

Iliass El Fali, Managing Director, Corporate Strategy, Sustainability, Innovation, OCP Group

“The mining industry will play a key role not only in providing the raw materials needed to mitigate and adapt to climate change, but in ensuring the transformation of agriculture which will help scale up food production.”

A predicted global population of nearly 10 billion by 2050 means global demand for food and energy is expected to grow exponentially. Yet, the planet's ability to meet this demand is directly threatened by climate change. Accelerating the green transition is therefore imperative not just to combat climate change, but to ensure humanity can feed itself. In fact, food production will need to increase by an estimated 56% to achieve global food security by 2050. The mining industry will play a key role not only in providing the raw materials needed to mitigate and adapt to climate change, but in ensuring the transformation of agriculture to scale up food production.

How does mining contribute to agriculture? Phosphorus,<sup>28</sup> a critical finite resource that promotes the growth of healthy roots, is especially important for young plants and seedlings because it helps with cell division and supports photosynthesis. However, it is not available in all soils and is concentrated in rocks in certain regions of the world. Mining provides the phosphate rock, which is the primary source of phosphorus needed to produce phosphate fertilizers and provide this nutrient to plants. Phosphate fertilizers are central to modern global agriculture, which, along with nitrogen and potassium, constitute the core of plant nutrition essential for achieving healthy soils. Half the food we eat is produced thanks to mineral fertilizers. Agricultural practices must enhance soil and plant nutrition while lowering their environmental footprints. Mining has, therefore, a relevant role to play in the transition to a more sustainable and productive agriculture system.

In addition to supporting food security, the role of agriculture in reducing greenhouse gas (GHG) emissions is critical – and mining can support it. On the one hand, closing the “yield gap”, the difference between what farmers could potentially achieve compared to what they actually get, means that more food can be produced with the same amount of land, and fertilizers play a relevant role here. At the moment, approximately 46% of soils are deficient in phosphorous, with a particularly high deficiency in tropical soils. Addressing this deficiency is, therefore, crucial to increasing yields and ensuring global food security in the years to come.

On the other hand, fertilizers play a key role in reducing emissions by enhancing carbon sequestration and other sustainable practices. For instance, customized fertilizers provide the

mineral nutrients designed to meet the specific needs of each soil and the requirements of the plant sown on it. By using the right customized solutions adapted to each specific soil, it is possible to boost soil health, which improves the soil's natural ability to increase agricultural yields. This also increases carbon sequestration, reducing the overall environmental footprint by minimizing misapplication. Indeed, the most conservative studies estimate the potential of soil carbon sequestration at 10-20% of annual global CO<sub>2</sub> emissions, which could be significantly enhanced through soil health innovation.

Achieving this within the next decade will require the use of a suite of recent innovations in mining and agricultural technologies, not least as mining is estimated to account for 4-7% of global GHG emissions. However, miners globally invest a fraction of their revenue in R&D compared with other industrial sectors such as healthcare, information and communications technology (ICT) and transport. In the mining industry, new technologies to extract, recycle, reduce and rehabilitate key production inputs can more sustainably produce the raw materials required to raise food output.

In addition, the use of digital technologies, data analytics, automation and real-time monitoring helps to enhance the flexibility and efficiency of supply chains, enabling companies to respond more effectively to changing market conditions, produce customized fertilizers adapted to soil requirements and ensure a stable supply of phosphate to meet the increasing global demand. At the same time, sustainable and efficient water practices such as water recycling and monitoring have a positive impact on mining as well as in agriculture.

Last but not the least, reforestation of mining sites also helps sequester carbon from the atmosphere and improve soil health. The mining and metals industry has advanced in its commitment to carbon neutrality on Scope 1 and 2 emissions, but commitment on Scope 3 emissions will be equally essential.<sup>29</sup>

As the green transition advances, miners generally bear a unique responsibility: spending and innovating on new production capacity to meet future demand. But they must do so in ways that preserve resources, and the wider environment, for future generations.

## 2.3 The steel of the future: How technology and innovation will shape it

Debojyoti Roy, Chief Corporate Strategy and Planning Officer, Tata Steel

“As steel consuming sectors change, the nature of steel demand will undergo rapid changes, accelerating technological innovation like never before.”

The unique properties of steel and its appropriate price have rendered it central to the global growth story. Its value-added contribution is nearly 4%<sup>30</sup> of global GDP and 100 million people find their livelihoods in this sector. As steel consuming sectors change, the nature of steel demand will undergo rapid changes, accelerating technological innovation like never before. The following transformations are expected to shape the next few years, leading to the emergence of the steel of the future.

### Transformations driven by process optimization

#### Mining and raw material processing

The potential of technological advances in mining is estimated to be around \$425 billion. Some notable leaps in technology include: a) Exploration studies that use smart sensing to determine mineralogy. For example, BHP uses machine learning to interpret geological data and generate targets. b) Beneficiation and use of lower-grade raw materials for value addition. Rio Tinto and Shougang have developed a sinter that reduces coke consumption by approximately 23%. c) Advancements in AI and remote operations will enable fully automated mining operations, improving safety and sustainability. Rio Tinto's AutoHaul is an excellent example of this.

#### Iron and steel

To meet global energy needs and climate goals, the steel industry must reduce its emissions by 50%.<sup>31</sup> The industry has made progress by adopting sustainable practices such as optimizing raw material usage, increasing energy efficiency, minimizing waste and improving yield. Additionally, it is adopting circularity through the use of scrap, adoption of the direct reduced iron (DRI) and electric arc furnace, and the scaling up of alternative technologies such as carbon capture, utilization and storage (CCUS), the use of biomass and coke oven gas in blast furnaces, and the use of hydrogen as a reductant. The industry is also moving towards predictive maintenance-as-a-service, wherein companies like Caterpillar not only sell equipment but also commit to reliable performance post-sales through sensorization and analytics-based predictive support. Furthermore, the use of AI is enabling automated decision-making in process control, from raw material selection to finished product mix-optimization.

### Transformations driven by changing customer needs

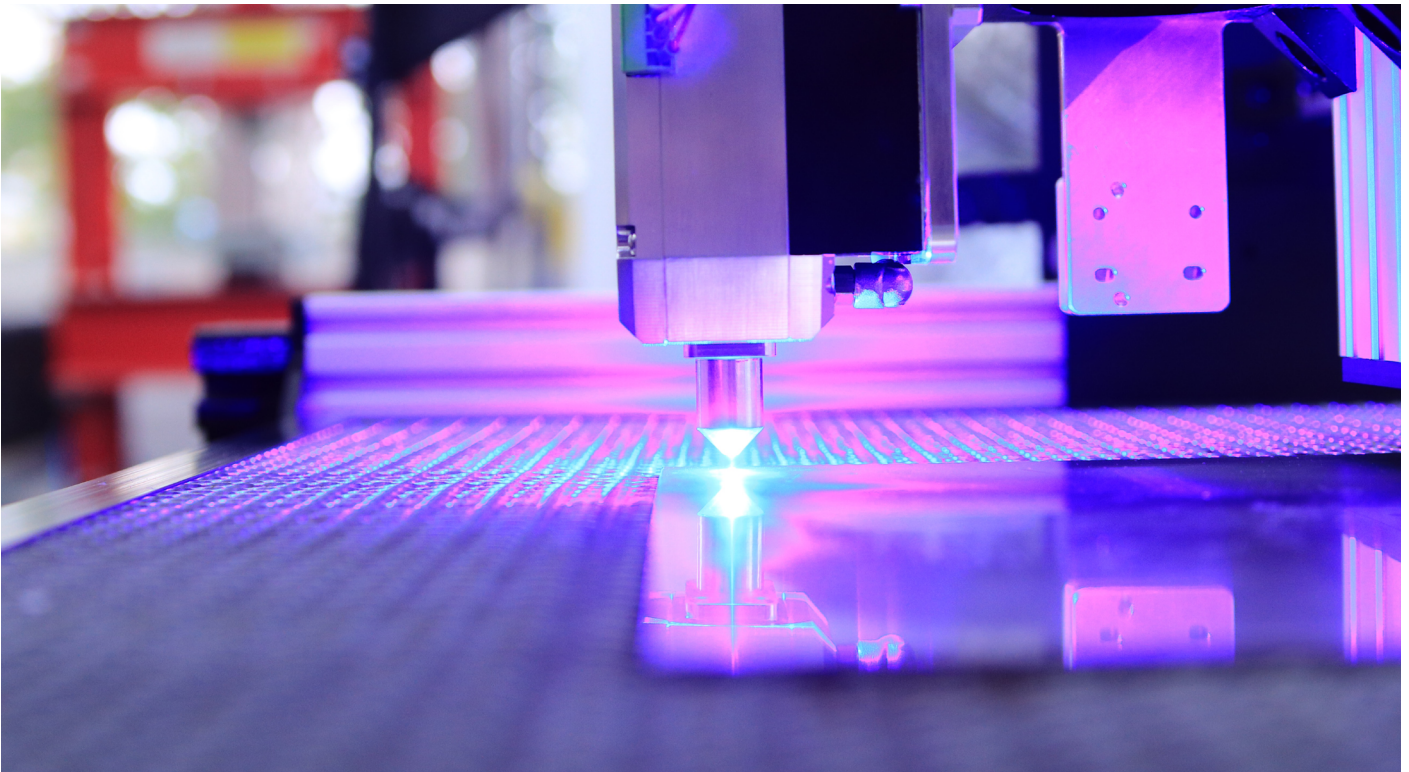
The industry is moving towards “customer obsession” in two ways:

1. Technology-led interventions, in which AI enables better customer interactions with the use of big data and “synthetic customers”.<sup>32</sup> AI provides insights from unstructured data and hyper-personalization, lead development/prioritization, dynamic quote generation and cross- or upsell.
2. Evolution in roles of value-chain partners, as models shift from production thinking to design thinking. Services can be mass-produced and routes to market overhauled as consultative selling takes centre stage.<sup>33</sup>

Steel processing has undergone significant changes in recent times, mainly due to two key factors. First, advanced quality control using measures such as POSCO's Frame,<sup>34</sup> which creates digital genomes for each product during the quality control process, and BMW's virtual factory that uses virtual reality (VR) tools for defect detection. Second, mass customization is now possible with large-scale additive manufacturing, which allows for the production of complex steel parts.<sup>35</sup> For instance, Rolls-Royce uses three-dimensional printing (3D printing) to produce jet engine components, which could potentially disrupt other industries like construction.

Supply chain management has evolved in recent years, with the advent of big data analytics and blockchain technology. Data-driven decision support, enabled by big data analytics, has made it possible to optimize logistics routes, predict demand and schedule production. For instance, POSCO and Nucor have leveraged big data analytics to make intelligent sourcing decisions. On the other hand, blockchain and distributed ledger technology (DLT) have facilitated traceability, faster transactions, enhanced security and integration with financial institutions. A good example of this is the Steel Chain suite,<sup>36</sup> which utilizes DLT to track the movements of physical steel coils and rods.





## Transformation enablers

To realize these transformations, seven enablers are essential:

- **Digital:** The use of advanced technologies such as automation, digital twins and AI is becoming increasingly important in various sectors. For example, Rio Tinto's Mine Automation System uses AI to create orebody models, predict and control blasts, and organize equipment dispatches. To realize the benefits, businesses must collaborate with solution partners through data sharing and process integration. Networked manufacturing has the potential to revolutionize emerging markets, for instance.
- **Industry 4.0:** Collaborative robotic assistance, safety monitor stops, speed and separation monitoring, and hand-guiding functions are commonplace today. The United Nations Conference on Trade and Development (UNCTAD) has identified AI, the internet of things (IoT), big data, blockchain, fifth generation (5G) telecommunications, 3D printing, robotics and drones among these frontier technologies.<sup>37</sup>
- **Safety:** Automation and robotics have reduced human-machine interface; virtual reality (VR) can simulate events for root-cause analysis and exo-skeletons can reduce work-related injuries and fatigue.
- **Innovation:** AI shortens the research and development (R&D) cycle through ideation, prompt-based drafts, solution design iterations, simulations and efficient physical testing. The National Aeronautics and Space Administration (NASA) of the United States leverages generative design for digitally encoding standards and requirements and for obtaining ready-to-fabricate parts in around two hours.<sup>38</sup>
- **New products and services:** Margin pools are shifting towards sectors like energy and transportation, and products such as high-performance steels, hot stamped steel, electrical steel, multi-materials, advanced coatings, laser-aided forming and wide plates for wind towers. Lightweighting requirements are growing as new sectors like construction demand high strength steel; novel chemistry is being explored for mobility, defence and hydrogen infrastructure.
- **Circularity:** Material efficiency, recycling of steel, process efficiency and renewables-based primary production<sup>39</sup> can enable a mindset shift from “lowest upfront cost” to “lowest lifetime environmental impact”.
- **People:** Corporate cultures with interdisciplinary thinking, lifelong learning, and social and technical skills are becoming core competencies.

The next decade will be very exciting for steel as the transformation momentum builds up in all parts of the value chain. The customers and manufacturers who are agile in aligning to these transformations stand to benefit the most in the long run.

3

# Collective action and the way forward

Throughout history, metals and minerals have played an indispensable role in supporting each new generation of technological advances, economic growth and human progress. Today, the role of the mining and metals sector is more important and yet more challenging than ever. Collective leadership among mining companies and between the industry and other stakeholders will be essential to navigate the disruptive and transformative shifts underway in almost every country and commodity value chain. Embracing the future requires a collective vision and collaborative actions, themes explored in this concluding chapter.

For over 50 years, the World Economic Forum has been a strong believer in bringing together

stakeholders from all sectors of society to shape a better future and generate greater impact. The mining and metals industry's previous and current experiences reflect a propensity for collaboration, but much more will be needed to unleash its full transformational potential. Different forms of collaboration along the value chain and shifts in traditional business models, as well as different examples of collective leadership, are the pivots of what can be achieved with this collaborative spirit.

This chapter offers an invitation to leaders to envision and capitalize on opportunities for collective action, fostering a shared commitment to positive transformation amid global challenges.

## 3.1 Strategic partnerships: Rethinking business models for the green transition

Trond Olaf Christophersen, Executive Vice-President, Corporate Development, Norsk Hydro

“ While the previous decade has focused primarily on carbon emissions, the decade to come will see increased focus on our impact on nature and on societies around us, ensuring a just transition for all.

Business models have evolved to meet the needs and challenges of businesses and the geopolitical environment over time. In recent decades, the dominant trend has been the emergence of intricate global supply chains based on the relative cost advantages of outsourcing. A typical motor vehicle, for example, contains nearly 30,000 parts sourced from a multitude of suppliers across the globe.<sup>40</sup> Looking forward, it is uncertain that this model is the best response to the greatest challenge of our time – the global climate crisis. This will undoubtedly shape business and society in the coming decades.

The green transition is driving fundamental changes, from the rapid buildout of renewable power generation to the switch from combustion engines to battery EVs. Consequently, the world will need significantly more raw materials but also different, lighter materials such as aluminium to build the greener infrastructure of tomorrow. For new technologies to be solutions to the climate crisis, attention must turn from emissions during the use phase to embedded emissions. Hence, in addition to speeding up the rollout of transformative technologies, we also need to think about how these raw material-intensive enablers are produced.

It is key that critical metals and other raw materials needed for the green transition be produced in the most sustainable and responsible way possible. While the previous decade has focused primarily on carbon emissions, the decade to come will see increased focus on our impact on nature and on societies around us, ensuring a just transition for all.

Achieving this will require a different approach. Stronger traceability and transparency is a given, but we foresee a larger paradigm shift in business models through partnering with raw material providers. In the short term, by bypassing many layers of sub-suppliers and going directly to upstream producers, manufacturers can gain comfort in the provenance and sustainability credentials of the materials they are purchasing. On a more strategic level, this shift towards strategic partnerships along the value chain enables several more fundamental changes:

- Linking providers and purchasers of raw materials helps to solve the supply/demand conundrum where producers and consumers are waiting for each other to make the first move. This makes demand for sustainably produced

materials visible and supports significant investments in, for example, low-carbon technologies, while giving manufacturers access to scarce materials. Overall, this helps to de-risk commitments and aid a full-scale transition.

- Partnerships allow engagement to address common challenges outside of one’s own value chain. Challenges relating to impact on nature and societies concern all those using a product, not just those directly involved in upstream activities. By uniting across the value chain, new solutions can emerge to help address these challenges and deliver real improvements.
- In the longer term, partnerships between industry front-runners help to establish joint roadmaps and push the frontier of what is possible and affordable. One such example is the Polestar 0 project,<sup>41</sup> which aims to eradicate all emissions stemming from production by partnering with raw material providers, to ultimately produce the first truly climate-neutral car by 2030. Joint research and better understanding of requirements and concerns allows the development of new products and solutions; for example, more recycled post-consumer metal content in EVs to lower the embedded emissions.

This new approach requires a new way of working both within and across organizations. At its very heart is mutual trust in each party’s ability to help

the other solve challenges and drive change, and a commitment to openness and transparency. The strategic rationale must be established at the very highest level of the organization, with engagement and commitment right up to the C-suite. Top-level commitments, say between chief executive officers, will result in strong partnerships and a drive to achieve common goals. Value chain disruptions should also be expected, as manufacturers use partnerships to pull scarce materials through the value chain, delivering the product with the requisite sustainability credentials and traceability information. The aluminium industry has already taken the first steps on this journey, with front-runners looking beyond their own supply chains to reach their sustainability goals. Leading automotive players such as Polestar and Porsche are choosing to partner with fully integrated aluminium producers such as Hydro to pioneer this shift.

This switch towards strategic partnerships will shape the frontier of how sustainability leaders will source their critical raw materials over the next decade, a decade that will see increased demand for low-carbon metal for the green transition alongside an overdue awareness of the wider implications of metal and mining activities on nature and societies. Strategic partnerships will be a key enabler to solve these challenges as a united and mutually dependent value chain.

## 3.2 Three transformational opportunities for collective leadership

Jane Nelson, Director, Corporate Responsibility Initiative, Harvard Kennedy School of Government

“ It will be impossible to effectively address these challenges without collective industry leadership, ranging from pre-competitive coalitions among mining companies to multistakeholder alliances between mining and other sectors.

No generation of mining leaders has faced a greater complexity, speed or scale of change than today’s. The business of mining is essential to enabling the global energy and digital transitions and the Fourth Industrial Revolution. At the same time, the industry is itself being transformed by these transitions. As mentioned before in the report, access to and development of critical minerals is both influencing and being influenced by rising geopolitical competition and tensions, supply chain disruptions and economic uncertainty. Stakeholder expectations and scrutiny of mining companies continue to grow unabated, while at the same time, even the most responsible companies continue to grapple with high levels of stakeholder mistrust.

A 2023 survey by GlobeScan of 30,565 people in 32 countries and interviews with 50 sustainability experts, rated mining as the worst of 18 industries surveyed when it comes to “fulfilling responsibilities to society”.<sup>42</sup> Despite the well-documented contribution of mining companies to the Sustainable Development Goals, they are rarely included in

ESG-focused investment funds. In October 2023, Blackrock argued that investor reticence towards mining risks is starving the sector of capital and threatening the energy transition.<sup>43</sup> Governments and communities in many countries are delaying permits for critical mining projects, while at the same time, increasing revenue demands and resource nationalism. The industry also faces a skills shortage at a time when it needs to attract a more highly skilled and motivated workforce than ever before.<sup>44</sup>

It will be impossible to effectively address these challenges without collective industry leadership, ranging from pre-competitive coalitions among mining companies to multistakeholder alliances between mining and other sectors. Over the past two decades, the sector has been a pioneer in building such coalitions and alliances. These have ranged from the increasingly strategic role of national mining associations to the creation of global platforms such as the International Council on Mining and Metals (ICMM),<sup>45</sup> commodity-specific responsible mining standards, and multistakeholder

alliances such as the Extractive Industries Transparency Initiative (EITI),<sup>46</sup> the Voluntary Principles on Security and Human Rights,<sup>47</sup> and the more recent Global Industry Standard on Tailings Management.<sup>48</sup> Now is the time to draw on lessons learned and drive even more ambitious and effective collective action.

The following three areas of collective industry leadership offer great potential for achieving transformational impact.



## 1 Increased coordination on safety and sustainability standards and performance

Industry-wide principles, goals, standards, metrics and reporting frameworks can be essential in building stakeholder trust if they are credibly and consistently implemented and independently verified. Most importantly, industry participants must continue to challenge themselves, and each other, to eliminate fatalities and injuries. Collectively, more must be done to acknowledge and change workplace cultures and practices where people do not feel safe, included or respected. There is also untapped potential for greater coordination in setting ambitious industry pathways for decarbonization and aligning climate, energy, nature and water goals.

One challenge for both companies and their stakeholders has been the proliferation of different “corporate responsibility” and “responsible mining” initiatives over the past few decades. Performance

improvement will need greater alignment between these frameworks and more effective accountability and shared learning mechanisms.

A 2020 report compared the requirements of the ICMM’s mining principles with the World Gold Council’s Responsible Gold Mining Principles (RGMPs), the Mining Association of Canada’s Towards Sustainable Mining (TSM) programme, the Aluminium Stewardship Initiative’s ESG requirements, the Responsible Mineral Initiative’s Risk Readiness Assessment (RRA) and the Copper Mark.<sup>49</sup> A joint effort among some of these initiatives is now underway to achieve further coordination, consistency and accountability. Within different mining jurisdictions, national mining associations and councils also have an increasingly vital role in embedding and spreading responsible mining norms and standards beyond the sector leaders.

2

## Invest in pre-competitive innovation at the nexus of transformative technologies and talent development

The immense speed and scale of advances in digital, materials and life sciences are transforming almost every aspect of the mining and metals value chains from exploration to operations, processing and recycling. Over the next few years, the effective and responsible deployment of these disruptive technologies will be a generational game-changer for the industry. It will have long-term implications for safety, productivity, sustainability, decarbonization, nature-based solutions, circular economy models, jobs, the nature of work, equality, just transition, and corporate and national competitiveness.

Pre-competitive, private-private and cross-industry alliances can play a valuable role in accelerating and scaling R&D, creating market demand, advancing progress towards net-zero targets and circular value chains, and developing the future workforce. There is untapped potential to move beyond the traditional first-mover and fast-follower approach to collectively embrace transformative technologies that deliver a

step change in industry-wide leadership. Examples include global coalitions such as the World Economic Forum's First Movers Coalition, which aims to drive change at scale across hard-to-abate industry sectors, all of which are relevant for the mining and metals sector, the Global Battery Alliance, and R&D consortia focused on specific commodity value chains. Some of the initiatives with the highest potential are national-level, industry-led or public-private partnerships between government-funded scientific and research institutes, universities and mining and other companies. The Future Science Platforms and Mineral Resources programme of Australia's national science agency called the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and Canada's Mining Innovation Commercialization Accelerator Network, are just two examples of collaborative platforms to strengthen the innovation ecosystem and support industry-wide learning, skills and capabilities development.

3

## Jointly advocate for smart public policies and national transition strategies

“As we look to the future, it will be impossible to create shared and sustained value for the industry and its stakeholders without more ambitious pre-competitive coalitions and multistakeholder alliances.”

At a country or regional level, mining companies have the potential to work with their national mining associations and councils alongside other industries and civil society organizations to advocate for and support capacity-building for better resource governance and smart policies. These policies could enable more efficient permitting, setting a price on carbon and forging better links between national climate, nature and job-creation strategies.

The national multistakeholder platforms of EITI offer one long-standing example. More recent country-level platforms include the Just Energy Transition partnerships in several countries, the Interagency Working Group on Mining Laws, Regulations, and Permitting in the United States, and public-private alliances to ensure responsible development of critical or transition minerals.

In conclusion, collective industry leadership is needed at all levels as well as along key commodity value chains to address systemic challenges that no individual company can solve alone. These system-wide challenges lie in enhancing investment in decarbonization and nature-positive pathways, and developing innovative waste management and circular economy models. They also include tackling corruption and strengthening resource governance, developing future workforce skills and economic opportunities, and advancing respect for people's rights and dignity.

Building on two decades of evolving collaboration, leaders in the mining and metals sector are well-positioned to take collective industry leadership to the next level. As we look to the future, it will be impossible to create shared and sustained value for the industry and its stakeholders without more ambitious pre-competitive coalitions and multistakeholder alliances.



# A call to action

The landscape of the mining and metals industry is undergoing a profound shift as the energy transition, geopolitical shifts and intricate socio-economic dynamics play out. Minerals and metals are poised to play crucial roles in achieving global goals pertaining to the energy transition, food security and poverty alleviation. Together, these trends call for a re-evaluation of traditional stakeholder roles across supply chains.

Innovation and collaboration are central to this transformative journey.

Innovation is essential for both navigating current trends and propelling the industry's metamorphosis. It serves as a powerful catalyst for change, driving the development of new materials and more efficient technologies.

The collaborative spirit must intensify to pave the way forward as rethinking business models becomes imperative in the face of complex, interconnected challenges.

The World Economic Forum and the Mining and Metals Industry community are committed to taking forward such collaborative efforts in this transformative journey. By actively sharing valuable insights, providing a platform for leadership, and amplifying impact, the aim is to drive positive change. This report is an invitation to industry representatives and stakeholders from both the public and private sectors to join hands for shaping a sustainable and prosperous future. Together, the community can navigate the challenges of today and build a more resilient and sustainable tomorrow.



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45. See: <https://www.icmm.com/>.
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47. Created in 2000, the Voluntary Principles is a multistakeholder initiative that promotes the implementation of a set of principles to guide companies on providing security for their operations while respecting human rights.
48. See: <https://www.unep.org/resources/report/global-industry-standard-tailings-management>.
49. ICMM, *ICMM announces equivalency benchmarks with other responsible sourcing standards*, December 2020.



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