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Global Materials Perspective 2025

October 2025

About this report

The *Global Materials Perspective 2025* is produced by McKinsey's Global Energy & Materials Practice. Building on the previous year's report, this year's Perspective explores materials demand across three energy transition scenarios (as defined in our *Global Energy Perspective 2025*) as well as three supply scenarios, based on asset-level data modeled by MineSpans. Our aim is to provide insight into the changing availability, affordability, and sustainability of materials, including those that are critical to the energy transition and the expansion of digital infrastructure.

While the materials industry spans a broad range of subindustries—including metals and mining, building materials (concrete and cement, glass, and more), plastics, and pulp and paper—this report focuses primarily on metals and mining, which can be categorized along the following long-term demand trends driven by the energy transition:

- Materials for which demand is only to a small extent driven by the speed of the energy transition and that are consequently trending in line with the growth of global GDP and the growing middle class (for example, steel and aluminum)
- Materials for which demand is largely and positively affected by the energy transition because the materials are required in one or several low-carbon technologies compared with conventional technologies and are therefore frequently growing faster than in the previous decade (for example, copper, lithium, and rare earth elements [REEs])
- Materials for which demand is largely and negatively affected by the energy transition because these materials are fundamental to conventional technologies, which are likely to be gradually phased out in the coming decades (with thermal coal a prime example)

In the coming months, we plan to issue separate publications on the latest dynamics in the plastics and lumber industries.

The *Global Materials Perspective* is powered by MineSpans, which is part of McKinsey's Global Energy and Materials Practice. MineSpans is a leading and comprehensive metals and mining market intelligence solution, combining McKinsey's global expertise with proprietary data to provide an independent and holistic view on commodity markets. Built by our commodities experts and covering more than 14,000 global assets across more than 15 commodity value chains, our detailed bottom-up supply and demand forecasts, granular cost models, and environmental, social, and governance data form the basis of McKinsey's industry perspectives to help empower decision-makers.

About Energy Solutions by McKinsey: Energy Solutions is McKinsey's global market intelligence and analytics group focused on the energy sector. The group enables organizations to make well-informed strategic, tactical, and operational decisions by using an integrated suite of market models, proprietary industry data, leading industry benchmarks, advanced analytical tools, and a global network of industry experts. It helps leading companies across the entire energy value chain manage risk, optimize organization, and improve performance.

About McKinsey & Company: McKinsey is a global management consulting firm committed to helping organizations accelerate sustainable and inclusive growth. The firm works with clients across the private, public, and social sectors to solve complex problems and create positive changes for all their stakeholders. It combines bold strategies and transformative technologies to help organizations innovate more sustainably, achieve lasting gains in performance, and build workforces that will thrive for this generation and those to come.

Foreword (1/2)

In the past year, the materials industry has once again seen several shifts: increasing resource nationalism and protectionism, the rise of new demand vectors from AI and defense, emerging signs of a productive rebound, and the slowdown of decarbonization in selected regions. Looking ahead, success likely requires capturing growth while improving productivity and delivering sustainable solutions.

Overall, the materials industry contracted in 2024, with metals and mining revenues down 6 percent to approximately $3 trillion, partially offset by growth in other materials sectors, while profitability remained resilient at about $1.3 trillion (with metals and mining accounting for $700 billion), coming with a shift in profit pools from thermal coal and steel toward gold, copper, and aluminum, a shift that has been ongoing for several years.

Geopolitical focus on materials has intensified, with new tariffs, incentives, and export barriers,[1] while supply concentration continued to rise for several commodities in both mining and refining. Our analysis shows that measures primarily focus on commodities that appear on countries' critical minerals lists and have high supply concentration (except for US tariffs).

Meanwhile, decarbonization progress has slowed in some regions. In Europe and the United States, for example, battery-electric-vehicle (BEV) sales as share of total car sales flattened or slowed compared with previous years. At the same time, bold innovation in technology, processes, and electrification has accelerated.

Against this backdrop, capital markets have remained strong, with total shareholder returns (TSR) growing 3.5 times and market capitalization doubling since 2015.

In summary, the materials industry has seen four significant shifts since last year's report:

— *Geopolitics and a global landscape where globalization is changing but not disappearing* have led to increased resource nationalism or protectionism.[2] This has created additional risks, such as inaccessible end markets and the need for local supply integration, as well as opportunities, such as financial incentives for new projects in resource-importing regions.

— *Accelerated demand from the expansion of AI technologies* will likely have a material impact on demand profiles, especially for copper—for example, projections show an increase in copper demand related to data centers of 3 percent by 2030, partially offsetting slowdown in demand from lower-carbon technologies.

— *A recent capital intensity and productivity rebound* is becoming visible in the mining industry—and several new technologies and practices have emerged that hold promise for continuing this trend, including generative AI.

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[1] For more, see "Restricted: How export controls are reshaping markets," McKinsey, April 3, 2025.
[2] For more, see "A new trade paradigm: How shifts in trade corridors could affect business," McKinsey, June 18, 2025.

Foreword (2/2)

- *Decarbonization is slowing in selected regions and commodities*, most notably in the European steel industry, in which nearly a third of announced projects have been put on hold or canceled. At the same time, thermal coal demand has continued to increase, with record production of eight metric gigatons (Gt).

Looking ahead, the demand outlook through 2035 appears robust across all scenarios. Primary reasons for this include an increasing population and the development of the middle class as well as the deployment of low-carbon technologies—with energy transition materials driving more than half of the growth. In addition, demand growth could come from new applications, such as AI data centers, as well as potential additional upside from the defense sector. Together, China and the rest of Asia could account for more than 45 percent of this growth.

On the supply side, capacity ramp-up has kept pace with forecasts, with Chinese firms continuing to grow their market share outside of China. However, supply remains highly concentrated, and several key commodities (such as REEs) face persistent constraints. Although the global supply–demand gap is narrowing, closing it completely could require trillions of dollars in investment, massive new power capacity, and continued innovation.

In this context, we see three areas of opportunity:

- *Pursue growth in the multilateral world* by expanding into new geographies and critical materials—where you have a clear "right to play," with possible tailwinds from government incentives—or unlocking value from scrap, recycling, and niche high-growth sectors and products related to digital infrastructure and defense.
- *Accelerate the productivity "rebound"* through gen AI, automation, next-generation operational excellence, and global sourcing to counter productivity declines and rising costs from lower ore grades; labor shortages; environment, health, and safety requirements; and project complexity.
- *Pursue targeted sustainability efforts* by advancing decarbonization with stepwise, cost-effective approaches that cut emissions while scaling low-carbon processes, recycling, and circular business models—but don't anchor business cases in green premiums (for now).

As 30 to 50 percent of TSR overperformance is driven by company operating decisions, top-quartile productivity and disciplined growth remain the clearest markers of long-term success, reflected in stronger margins, resilient returns, and lasting competitiveness. Although challenges ranging from tighter supply–demand balances to stricter decarbonization targets loom, bold innovators are already reshaping the competitive landscape.

Our *Global Materials Perspective 2025* provides a systemwide view of these shifts, spanning mines, manufacturing, infrastructure, consumer markets, and finance. Looking ahead, success in metals and mining will require not only capturing growth but also improving productivity and delivering sustainable solutions. Those willing to act decisively will be best positioned to seize the opportunities ahead.

Our insights are based on three supply scenarios, from base case to full pipeline

The supply scenarios explored in this publication are based on our research on the maturity and likelihood of individual projects in the metals and mining industry. The research is anchored on McKinsey's MineSpans database, which provides a comprehensive metals and mining market intelligence solution containing more than 14,000 assets across more than 140 countries. Recycled materials are included in the supply scenarios, based on assumptions about typical end-product lifetimes and collection and recovery rates. The findings in this report are based on the two specific scenarios:

- *The base-case scenario* includes all operating assets (corrected for depletion and for grade changes where relevant) and projects currently under construction. It also includes projects for which a feasibility study is being conducted or has been conducted as well as projects for which financing has been secured.
- *The high-case scenario* includes the previous cases as well as projects for which a prefeasibility study has been completed. Projects that have been announced but have not yet initiated a prefeasibility study are not included in the forecast.

Supply scenarios are based on announced projects—to the extent that they are available in the public domain—and do not consider theoretical capacity increases.

Research components	14,000+	140+	13	10+	1.8 million+
	assets	countries	cost and CO_2 factors	year outlook	data points

● Included in scenario ○ Not included

		Supply scenarios		
Project status	Status description	Base case	High case	Full pipeline
In operation	Projects currently operating; corrected for depleting assets	●	●	●
Certain	Projects currently under construction or with a feasibility study completed and financing secured	●	●	●
Probable	Projects with a feasibility study under development; start-up date adjusted for likelihood of execution	●	●	●
Possible[1]	Projects with a prefeasibility study completed; start-up date adjusted for likelihood of execution	○	●	●
Unlikely	Projects with a prefeasibility study completed but clear roadblocks identified	○	○	●
Unrealistic or in exploration	Any project that has been announced	○	○	●

[1] Some prefeasability study projects may also be included in the "probable" category if the projects' characteristics and expectations are robust.

Source: McKinsey MineSpans

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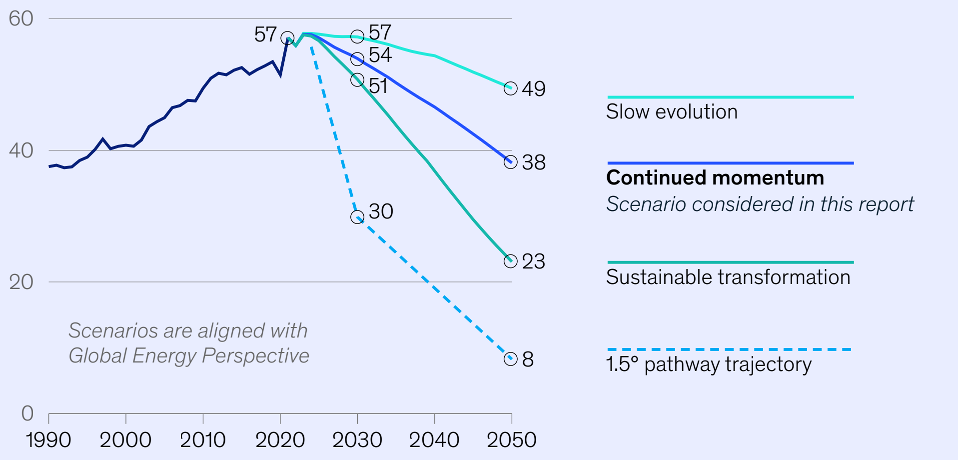
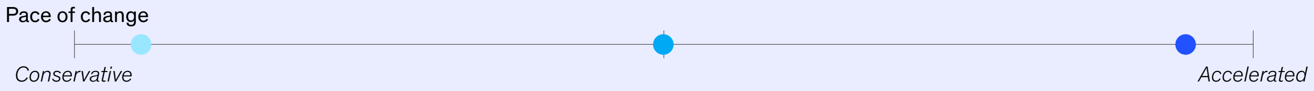
The demand outlook is based on our continued-momentum emissions reduction scenario

Global greenhouse gas emissions,[1] metric gigatons (Gt) of CO_2 equivalent per annum





Slow evolution ●

Projected global temperature increase by 2100: 2.7°C

- Local energy decisions prioritize affordability and supply security; investments in low-carbon stall and CO_2 prices don't change
- Cross-regional clean-energy financing declines, and emerging economies opt for cheaper energy sources
- Decarbonization targets are missed, innovation slows, and the energy transition relies completely on mature technologies
- There are persistent bottlenecks, including grid delays, resource shortages, and labor gaps

Continued momentum ●

Projected global temperature increase by 2100: 2.3°C

- Nations balance affordability, supply security, and sustainability; CO_2 prices gradually increase, and new schemes are introduced
- Cross-regional clean-energy financing expands, and mature economies support the decarbonization of emerging economies
- Decarbonization targets are met with a delay only for individual sectors in specific countries, innovation continues at historically high rates, and pilot-stage technologies reach maturity
- Bottlenecks ease, and grid expansion and infrastructure improvement progress to meet rising electricity demand

Sustainable transformation ●

Projected global temperature increase by 2100: 1.9°C

- Nations prioritize sustainability and accelerate decarbonization efforts, while ensuring affordability and supply security remain balanced; CO_2 prices and social costs align; and global energy trade is fully liberalized
- Cross-regional clean-energy financing expands, fostering collaboration among mature and emerging economies
- Decarbonization targets are met, investment drives major efficiency and tech gains, and advanced solutions are widely adopted
- Bottlenecks are fully resolved, and grid expansion aligns with demand

Note: Warming estimate is an indication of global rise in temperature by 2100 vs preindustrial levels, based on MAGICCv7.5.3 as used in Intergovernmental Panel on Climate Change *Sixth Assessment Report* given the respective energy and nonenergy (eg, agriculture and deforestation) emission levels and assuming continuation of trends after 2050 but no net-negative emissions. The remaining emissions in 2050 (ie, ~4 Gt) are compensated by negative emissions from direct air capture with carbon storage, bioenergy with carbon capture and storage, and reforestation.

[1] Includes process emissions from cement production, chemical production, and refining as well as negative emissions from applying carbon capture, utilization, and storage.

Source: IEA *Global Energy Review 2022*; IEA World Energy Balances; McKinsey *Global Energy Perspective 2025*

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While coal and steel price corrections have triggered a cyclical revenue decline, gold, copper, and aluminum kept profitability and capital market performance strong, with projected demand expected to stay robust, fueled by the energy transition and the expansion of digital infrastructure.

State of the industry: Key messages

1

Growth and profitability

The sector is experiencing a cyclical reset, with value pools shifting from steel and coal to gold, copper, and aluminum.

The materials industry saw a 2 percent slowdown in 2024 due to a cyclical reset in metals and mining, in which revenue declined by 6 percent to $3 trillion. This decrease was primarily driven by falling prices in thermal coal (down 13 percent) and steel (down 12 percent).

However, overall profitability in materials ($1.3 trillion) and metals and mining ($700 billion) remained resilient thanks to robust demand across most commodities as well as increasing prices for gold, copper, and aluminum.

While value pools are shifting upstream for steel and copper, there is no general trend observed for the other commodities.

2

Geopolitics and supply concentration

There's been a step-up in efforts to protect supply chains in the face of increasingly concentrated supply and geopolitical risk.

Supply has become more concentrated[1] over the past 5 years, with mining supply concentration increasing by 3 percentage points and refining supply concentration by 5 percentage points.

In the past year, many governments have accelerated strategic actions to strengthen supply chain resilience and reduce dependence on imported materials—from export barriers and resource nationalization to import-side measures such as development funding and stockpiling.

Trade barriers are fueling short- term price volatility, especially for minor metals with limited short-term supply alternatives (such as antimony). However, most prices normalized shortly after spikes as alternative supply was brought online.

3

Decarbonization

Despite continued net-zero ambitions, decarbonization progress has slowed, especially in the European steel industry.

Thermal coal production reached a record high of eight Gt in 2024, despite global decarbonization efforts.

The volume of recycled materials has increased across commodities, with significant improvement in battery recycling. However, the share of recycled materials in total commodity volumes increased only for zinc and battery materials.

Low-carbon steel projects slowed, particularly in Europe. In fact, up to a third of announced projects are on hold or canceled as of June 2025.

4

Capital markets

Capital markets saw strong long-term growth and resilience in 2024 despite recent revenue declines.

Despite revenue declines, metals and mining capital markets delivered strong growth, with TSR growing 3.5 times since 2015. Structural shifts over this period include greater fragmentation, with China and North America increasing their shares of total market capitalization, and a shift in the top ten companies as steel's share declined and coal's share increased following the entry of a major Chinese coal producer.

Although the market is inherently volatile because of changing commodity prices, 30 to 50 percent of TSR volatility or overperformance remains, driven by company operating decisions. To achieve TSR outperformance, companies will likely need to combine top-quartile production growth with an above-median position in cost efficiency and productivity.

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[1] Supply concentration is measured by the volume share of the top 3 supplying countries for the largest 15 commodities globally.

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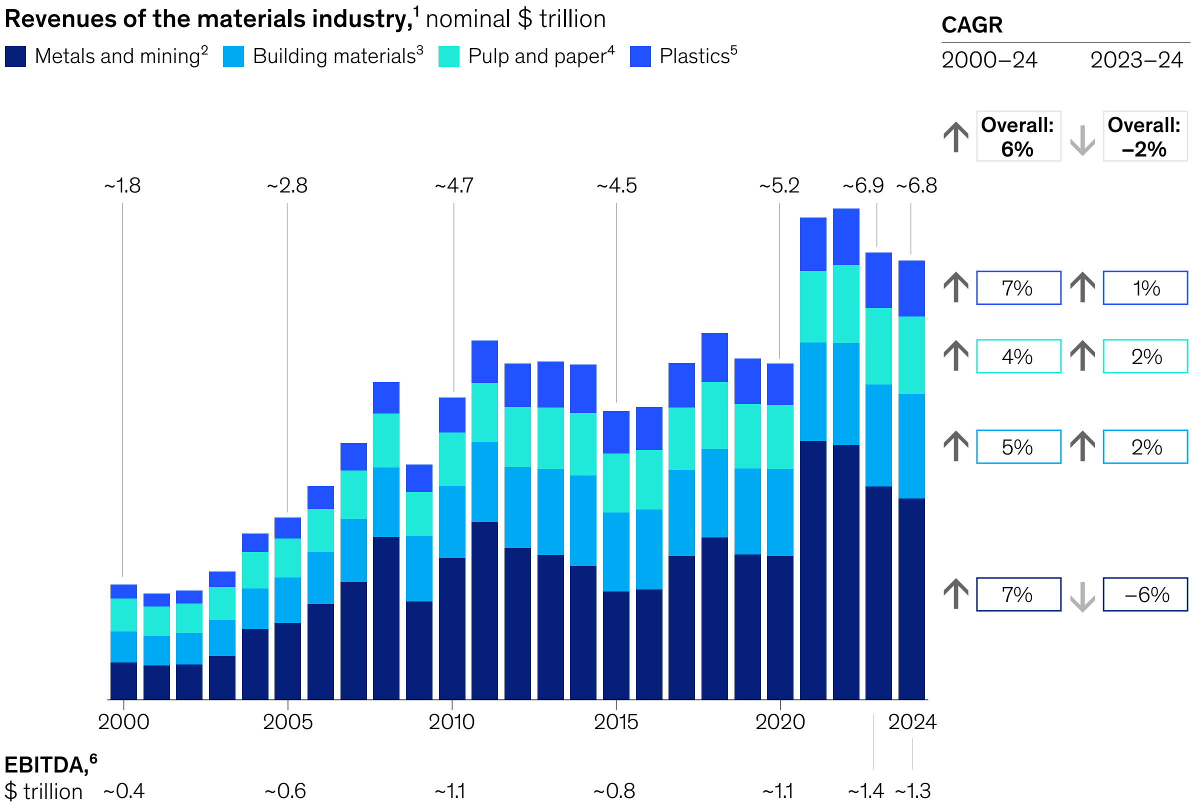
Materials revenues stagnated in 2024, driven by a decline in metals and mining

Following a period of high price volatility driven by increased supply chain disruption and volatility in energy prices, among other factors, materials revenues slightly contracted in 2024 to about $6.7 trillion.

A cyclical reset in metals and mining, which contracted by 6 percent to approximately $3 trillion, was almost fully offset by growth in other subsectors. The decline was primarily the result of price adjustments in thermal coal, steel, and battery materials.

Nevertheless, 2024 ranks among the sector's four highest-earning years in the past two decades.



Note: Historical revenues and profitability are different from our 2024 report primarily because of a change in the calculation methodology for thermal coal to better represent quality and regional price differences.

[1] Sum of revenues per material, using average yearly refined material market prices and demand volumes.

[2] Steel, thermal coal, base metals (aluminum, copper, lead, tin, and zinc), battery metals (cobalt, nickel, lithium, graphite, and manganese), precious metals (gold, silver, platinum group metals), and others (industrial minerals, rare earth elements, minor metals, fertilizers, and uranium).

[3] Wood, cement, sand and gravel, and glass.

[4] Pulp, paper, and carton board.

[5] Commodity plastics, engineering plastics, and high-performance thermoplastics.

[6] Calculated using total revenues and average adjusted EBITDA margin from MineSpans for a sample of 100 companies.

Source: American Chemistry Council; Eurostat; Fastmarkets; International Trade Center Trade Map; S&P Global; Statista; World Bank; McKinsey MineSpans

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The decline in metals and mining was mainly driven by price corrections in steel and thermal coal

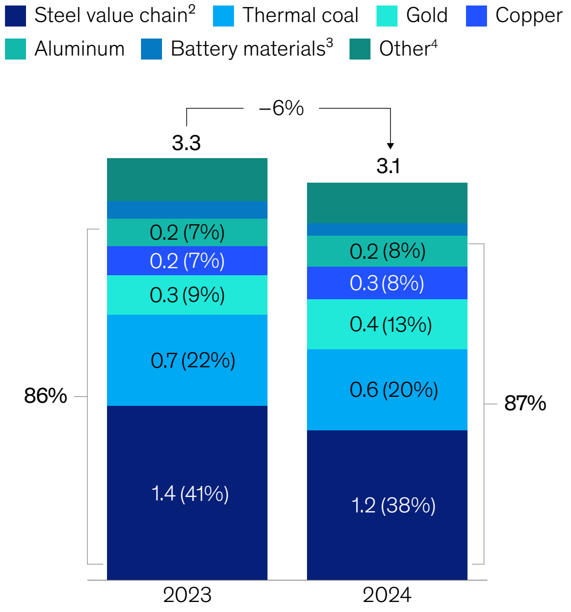
Metals and mining revenues decreased by 6 percent from 2023 to 2024. This was mostly because of weaker steel demand in China, driven primarily by a slowdown in the construction industry, alongside falling prices for steel, thermal coal, and battery materials.

The price correction in steel was partially driven by increasing exports from China (which saw a decline in domestic demand). For thermal coal, it was a normalization from “fly up” prices caused by tight supply in 2022. For battery materials, lower prices were driven by slower-than-expected growth in EVs while supply continued to scale up faster than expected. That said, most other materials experienced demand growth and price increases.

Change in price, volume, and revenue[1] from 2023 to 2024 for top commodities and battery materials, %

		Price	Volume	Revenue
Growing	Gold	↑ 23	↑ 3	↑ 27
	Aluminum	↑ 7	↑ 2	↑ 11
	Copper	↑ 8	↑ 4	↑ 12
Declining	Steel value chain[2]	↓ –12	↓ –2	↓ –14
	Thermal coal	↓ –13	↑ 2	↓ –12
	Battery materials	↓ –26	↑ 3	↓ –24

Metals and mining revenues by commodity, nominal $ trillions (% of total revenues)



Note: Figures may not sum to totals, because of rounding.

[1] Revenue calculated as product of average yearly refined material market prices and demand volumes; prices and revenues are nominal.

[2] Includes metallurgical coal, iron ore, and steel.

[3] Battery materials include lithium, nickel, cobalt, manganese, and natural graphite; weighted average of price, volume, and revenue of the 5 included materials are compared between 2024 and 2023.

[4] Includes a set of 30 other materials, incl lead, platinum group metals, potash, silver, uranium, and zinc.

Source: McKinsey MineSpans

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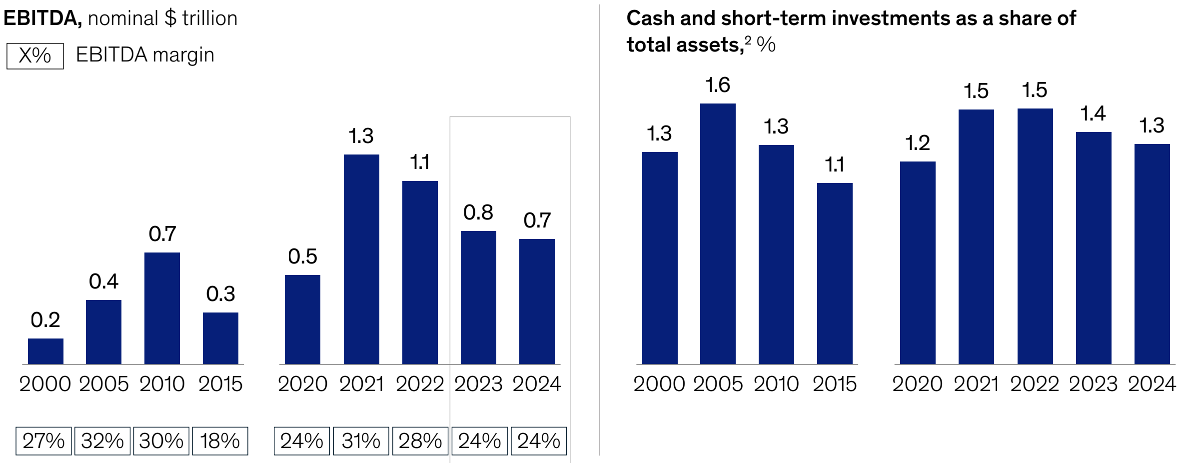
Profitability and cash positions stayed strong as value pools shifted from steel and coal to gold, copper, and aluminum

Profitability and cash position for the metals and mining industry[1]

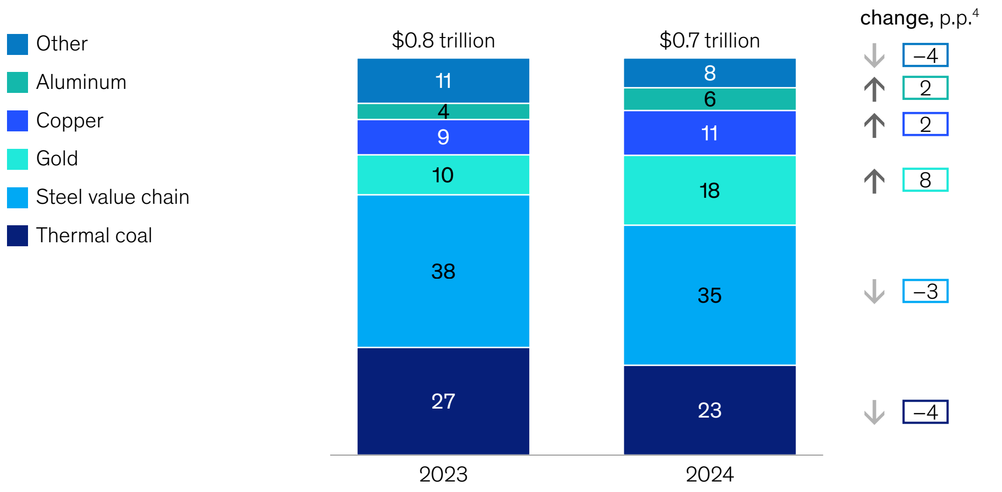


EBITDA, nominal $ trillion

X% EBITDA margin

Cash and short-term investments as a share of total assets,[2] %

EBITDA pools by commodity,[3] % of total EBITDA



Note: Figures do not sum to 100%, because of rounding.

[1] Calculated based on bottom-up McKinsey MineSpans global revenues and average adjusted EBITDA margin for sample of 100 metals and mining companies from the McKinsey Value Intelligence Platform, weighted based on revenue split by commodity.

[2] Calculated as sum of adjusted cash and short-term investments divided by sum of total assets, using data set of 355 metals and mining companies, by fiscal year.

[3] Calculated using average adjusted EBITDA margin by commodity for sample of 100 metals and mining companies from the McKinsey Value Intelligence Platform.

[4] Percentage points.

Source: McKinsey Value Intelligence Platform; S&P Global Market Intelligence; McKinsey MineSpans

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Countries are making strategic moves to reduce dependence on geopolitically sensitive materials

Some countries are taking actions to preserve their preeminent positions in the global supply landscape or improve local value addition by implementing export barriers or enforce local downstream integration (see sidebar "Recent export barriers have affected critical minerals with high supply concentration"). Recent years in particular have seen a trend of African nations imposing export barriers on ore and concentrates to stimulate local downstream processing.

At the same time, countries that are not self-sufficient are increasing efforts to stimulate local development through import barriers, resource development funds, and the announcement of strategic projects that have better access to funding and accelerated permitting. In addition, there is a trend toward stockpiling to mitigate economic effects of (temporary) disruptions to global supply chains.

Strategic moves mainly implemented by importing and exporting countries and regions, nonexhaustive

	Strategic moves	Examples of countries enacting strategic moves		Examples of opportunities for companies
Exporting countries	**Export barriers[1]**	Chile China DRC[2]	Gabon Indonesia Zambia	Accelerated development of alternative supply routes
	Domestic downstream integration requirements	DRC Gabon Guinea	Indonesia Zambia Zimbabwe	Established independent producers already benefiting or stand to benefit from gaining global foothold in downstream value chain
	Supply nationalization of strategic commodities	Chile DRC Indonesia	Mexico Saudi Arabia Zambia	Partnership with long-standing globally leading producers
Exporting and importing countries	**Bilateral agreements**	Canada China DRC	EU and UK Indonesia Saudi Arabia	
Importing countries	**Import barriers (tariffs)**	US		Shift in domestic project economics, enabling new investments (eg, EGA[3] announced investment in US aluminum smelter)
	Resource development funds	Australia EU and UK	Japan US	Boost to project timeline and economics (DFC and EXIM,[4] US Department of War[5] and Department of Energy)
	Strategic projects to secure access	Australia EU and UK US		Boost to project timeline and economics
	Development of strategic stocks	Australia China EU and UK	India Japan US	Temporary boost to demand

[1] Particularly applicable to primary material flows; China relaxing export barriers on materials with overcapacity in the market. [2] Democratic Republic of Congo. [3] Emirates Global Aluminium. [4] US International Development Finance Corporation and Export-Import Bank of the United States. [5] Formerly the US Department of Defense.

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Sidebar: Recent export barriers have affected critical minerals with high supply concentration

Recent export barriers have targeted almost all commodities with high concentration and economic importance, as reported in critical mineral lists by nine markets.[3]

Changes in Chinese export regulations have led to delays and shortages across the REE value chain, with some automotive OEMs experiencing (temporary) full production halts.

Price spikes have followed—for example, for antimony, with prices doubling from approximately $20 per kilogram (kg) to nearly $40 per kg after China imposed permit requirements.

Exporting barriers for commodities by importance, nonexhaustive

🔵 Trade barrier imposed since start of 2024 by a top 3 supplying country
◍ Trade barrier in place before 2024 by a top 3 supplying country
◌ Announced (not yet materialized) trade barriers by a top 3 supplying country
○ No trade barriers imposed by a top 3 supplying country

Commodity production concentration per share of top 3 supplying countries	**Commodity importance,**[1] by number of mentions on national critical mineral lists		
	Low (0–3 mentions)	Medium (4–7 mentions)	High (>7 mentions)
Very high (>90%)			Platinum Vanadium 🔵 Antimony ◍ Gallium
High (70–90%)	Metallurgical coal Thermal coal Bauxite Alumina	Aluminum Selenium 🔵 Molybdenum Titanium	🔵 Cobalt 🔵 Rare earths 🔵 Lithium 🔵 Tungsten ◍ Graphite ◍ Nickel ◍ Germanium ◌ Manganese[2] Palladium
Medium (50–70%)	Lead Steel Silver Phosphate rock Uranium Potash	Zinc Tin Zirconium	
Low (<50%)	Gold Iron ore	Copper	

[1] Based on critical mineral lists for Australia, Canada, EU, India, Japan, South Africa, South Korea, UK, and US.
[2] The Gabonese government has announced its intention to ban raw manganese exports from January 1, 2029.
Source: *Mineral commodity summaries 2025*, US Geological Survey, January 31, 2025; McKinsey MineSpans; McKinsey analysis

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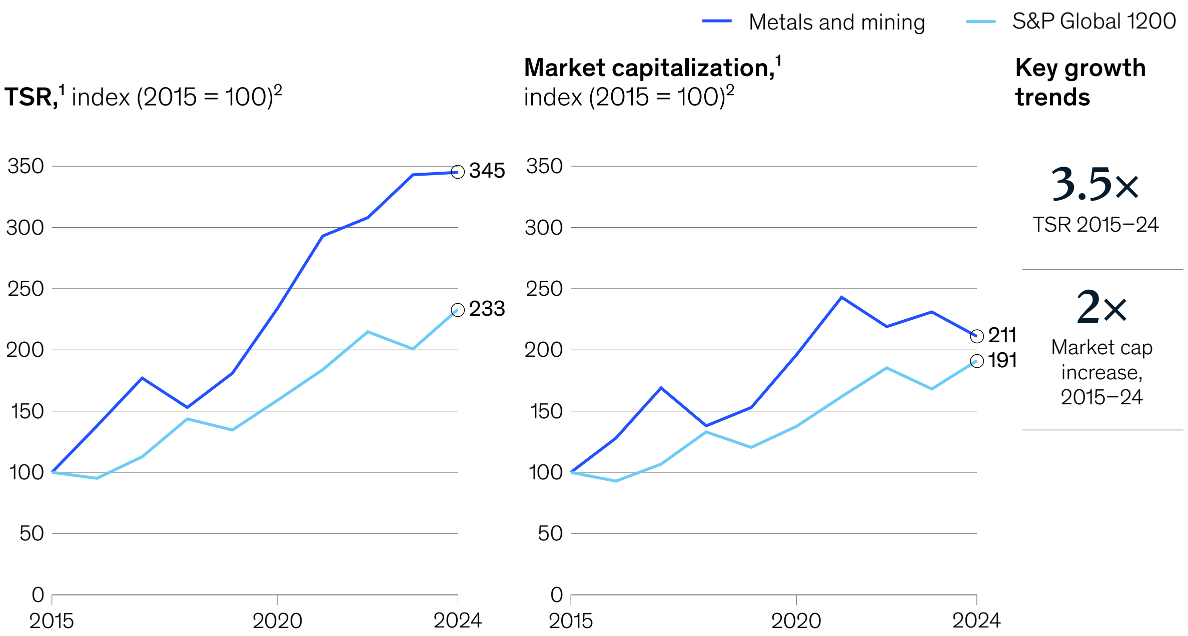
[3] Australia, Canada, the European Union, India, Japan, South Africa, South Korea, the United Kingdom, and the United States.

Metals and mining outperformed the S&P Global 1200 Index over the past decade

Despite recent declines in industry revenues, metals and mining capital markets delivered strong growth over the past decade, with TSR increasing 3.5 times from 2015 to 2024.

Market capitalization doubled over the same time period.



TSR,[1] index (2015 = 100)[2]

Market capitalization,[1] index (2015 = 100)[2]

Key growth trends

3.5×

TSR 2015–24

2×

Market cap increase, 2015–24

[1] Data set of 355 metals and mining companies, by fiscal year.

[2] Total shareholder value weighted average by market cap. TSR includes share price appreciation (capital gains) and dividends, with data from the end of each calendar year.

Source: S&P Global Market Intelligence; McKinsey Value Intelligence Platform

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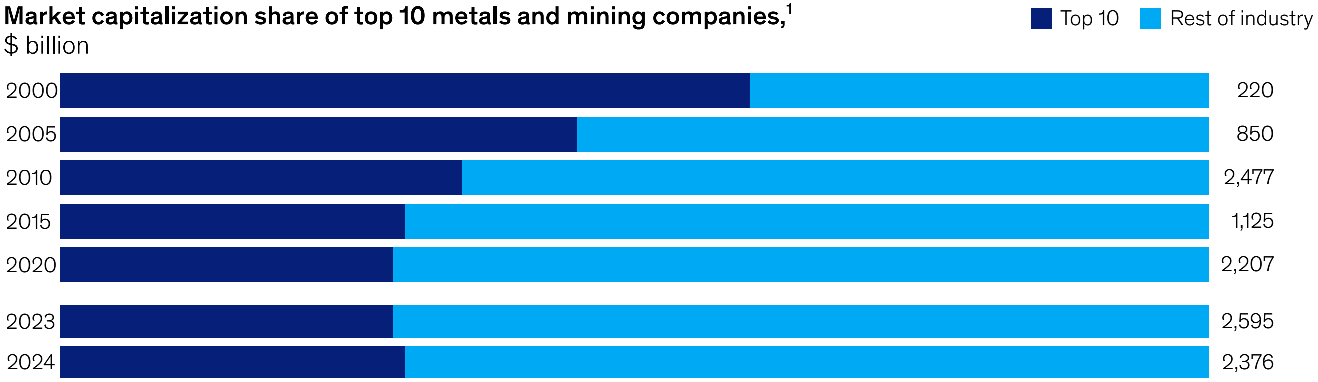
Macroeconomic trends show stabilization of market fragmentation after an increase from 2000 to 2015

In 2000, the top ten metals and mining companies accounted for 60 percent of the total market capitalization of the industry. By 2015, that number fell to 30 percent and has since stabilized.

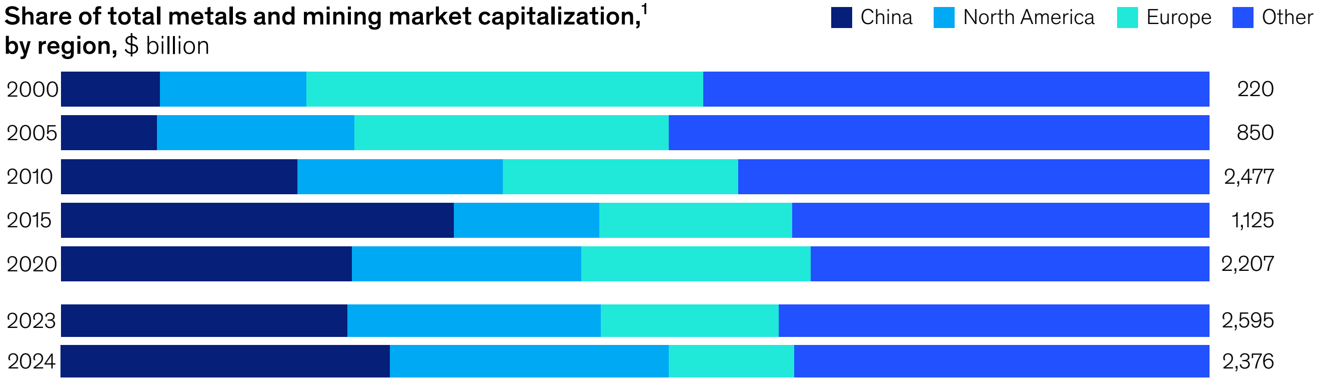
Over the 2000–24 period, companies based in China and North America significantly increased their share of total market capitalization of the industry, while Europe's share decreased to 11 percent.

Finally, among the top ten metals and mining companies by commodity type, the presence of steel decreased while coal increased, driven by a Chinese coal producer entering the ranking.

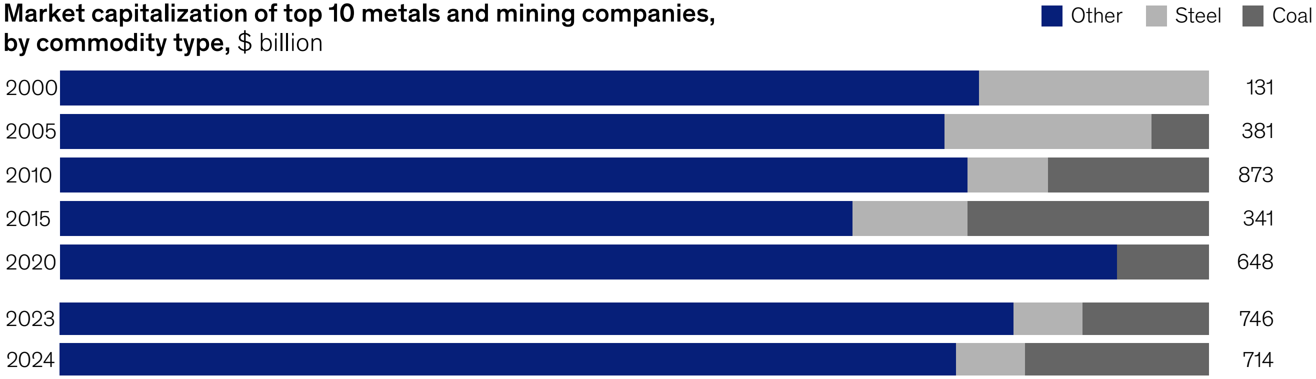
Market capitalization share of top 10 metals and mining companies,[1] $ billion



Share of total metals and mining market capitalization,[1] **by region,** $ billion



Market capitalization of top 10 metals and mining companies, by commodity type, $ billion



[1] Data set of 355 metals and mining companies, by fiscal year.
Source: McKinsey Value Intelligence Platform; S&P Global Market Intelligence

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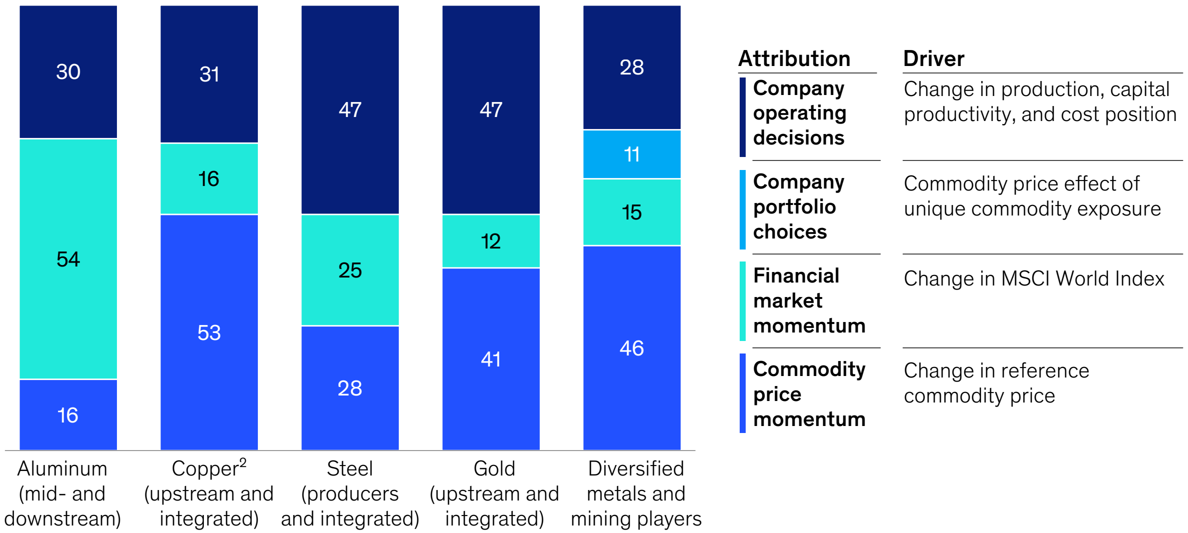
Management decisions drove 30 to 50 percent of TSR performance in metals and mining

Overperformance in metals and mining is not tied solely to commodity cycles. In fact, over the past 20 years, 30 to 50 percent of overperformance was driven by management decisions.

In steel, for example, operating decisions concerning change in production, capital productivity, and cost position have accounted for nearly 50 percent of TSR attribution.

Attribution of TSR volatility in the metals and mining sector,[1] %



Attribution	Driver
Company operating decisions	Change in production, capital productivity, and cost position
Company portfolio choices	Commodity price effect of unique commodity exposure
Financial market momentum	Change in MSCI World Index
Commodity price momentum	Change in reference commodity price

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[1] Top-down regression-based analysis of 224 metals and mining companies with available data from 2001 to 2023. Variance in company TSR is decomposed into relative contributions by the MSCI Global Index, commodity price, and fundamental variables adjusted by commodity price (growth, margins, and capital productivity). Commodity price effects have been removed from fundamental variables in first-stage regressions on current and two lagged variables of commodity price index; the MSCI index is used as measure of market momentum; hot-rolled coil steel prices by region for Brazil, China, Europe, India, Japan, UAE, and US, used as measure of commodity price effect.

[2] The analyzed copper TSR variation by driver differed across 3 identified cycles. For this representation, the average TSR variation by driver across the 3 cycles is used.

Source: MSCI; S&P GSCI; McKinsey Value Intelligence Platform; McKinsey analysis

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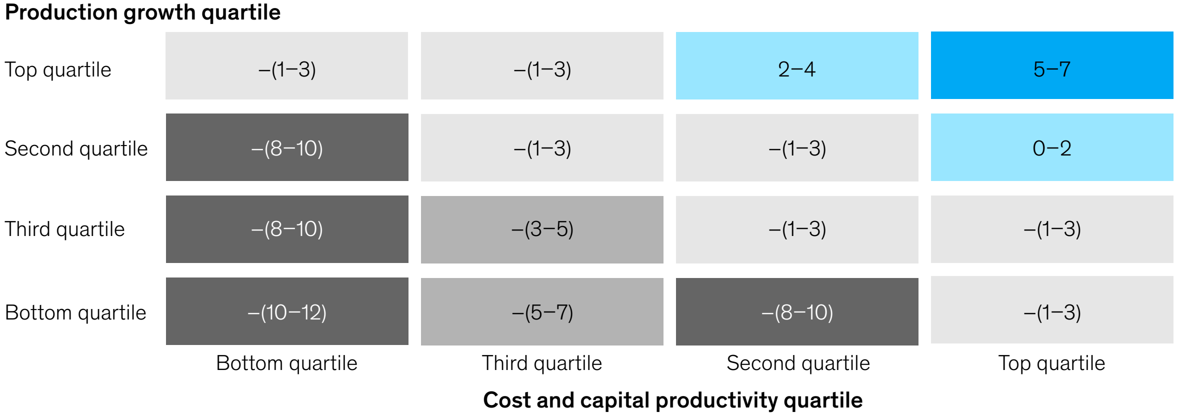
Top TSR performance requires top-quartile production growth and cost and capital productivity

Achieving TSR outperformance requires a combination of top-quartile production growth and an above-median position in cost and capital productivity.

Falling short on either dimension can significantly diminish the likelihood of delivering excess TSR.

CAGR of excess TSR[1] of metals and mining companies,[2] 2013–23, %, adjusted for commodity price and market volatility



Production growth quartile	Bottom quartile	Third quartile	Second quartile	Top quartile
Top quartile	–(1–3)	–(1–3)	2–4	5–7
Second quartile	–(8–10)	–(1–3)	–(1–3)	0–2
Third quartile	–(8–10)	–(3–5)	–(1–3)	–(1–3)
Bottom quartile	–(10–12)	–(5–7)	–(8–10)	–(1–3)

Cost and capital productivity quartile

Note: Results of a top-down regression-based analysis of 219 metals and mining companies with data from 2001 to 2023.

[1] Trend holds for every 10-year rolling period from 2005 to 2023.

[2] Quartile methodology: Production growth and cost efficiency and capital productivity are normalized within their respective commodity group sample, enabling cross-commodity comparisons in one matrix.

Source: McKinsey Value Intelligence Platform

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The global supply–demand gap is expected to narrow by 2035—driven by a more modest demand outlook compared with 2024’s *Global Materials Perspective*—while regional gaps narrow with the support of strategic projects to strengthen domestic supply chain resilience.

Availability and growth: Key messages

1

Demand outlook

Resilient growth is expected, particularly for energy transition materials.

The demand outlook toward 2035 remains robust, except for metallurgical coal, steel, iron ore, and platinum group metals (PGMs).

Slower-than-expected growth in decarbonization efforts (such as electric-vehicle [EV] uptake in the European Union and the United States) and shifts in technologies (such as battery chemistry) suggest a more modest demand outlook compared with our 2024 report. Still, more than 50 percent of demand growth from 2024 to 2035 could stem from the energy transition.

Asian countries could remain the largest drivers of demand globally, accounting for more than 45 percent of demand growth by 2035 across most commodities.

The defense sector and digital infrastructure are two additional areas of key growth, with defense potentially accounting for 2 percent of aluminum, 4 percent of steel, and 8 percent of copper demand from NATO Europe by 2030, and data centers potentially representing 3 percent of global copper demand by 2030.

2

Supply outlook

Supply ramp-up has been faster than predicted, yet mining supply expected to remain geographically concentrated.

Supply ramp-up in 2024 exceeded or matched forecasts from 2020 for lithium (25 percent above expectations) and uranium (6 percent above), while copper continued to lag behind (1 percent below expectations).

New supply has concentrated ownership, with Chinese companies accounting for approximately 36 percent of new mining and refining assets brought online over the past five years, focusing on growth in sub-Saharan Africa and Asia.

Going forward, mining supply will likely remain geographically concentrated. Sub-Saharan Africa, China, and the rest of Asia are likely to continue leading production, despite the availability of 40 to 60 percent of global supply reserves situated outside the top three supplying countries.

3

Supply–demand gap

The global supply–demand gap is narrowing, yet focus is shifting to regional balances.

Looking ahead, the global supply–demand gap by 2035 is narrowing, with decreased expected supply because of because of low prices offsetting decreased demand as a result of the slowing energy transition (compared with our 2024 report).

Importing countries are aiming to increase self-sufficiency, supported by strategic projects. However, several announced projects are not likely to be cost-competitive, and even if all projects were to come online on time, the European Union and the United States would still be dependent on imports for most commodities.

Both demand- and supply-side innovations may further reduce the supply–demand gap and improve affordability. For example, 2024 and the first half of 2025 have seen further acceleration of battery chemistry innovation and increasing interest in deep-sea mining.

Achieving supply–demand balance by 2035 could require an estimated $4.7 trillion in capital expenditures and 270 gigawatts (GW) of additional power capacity.

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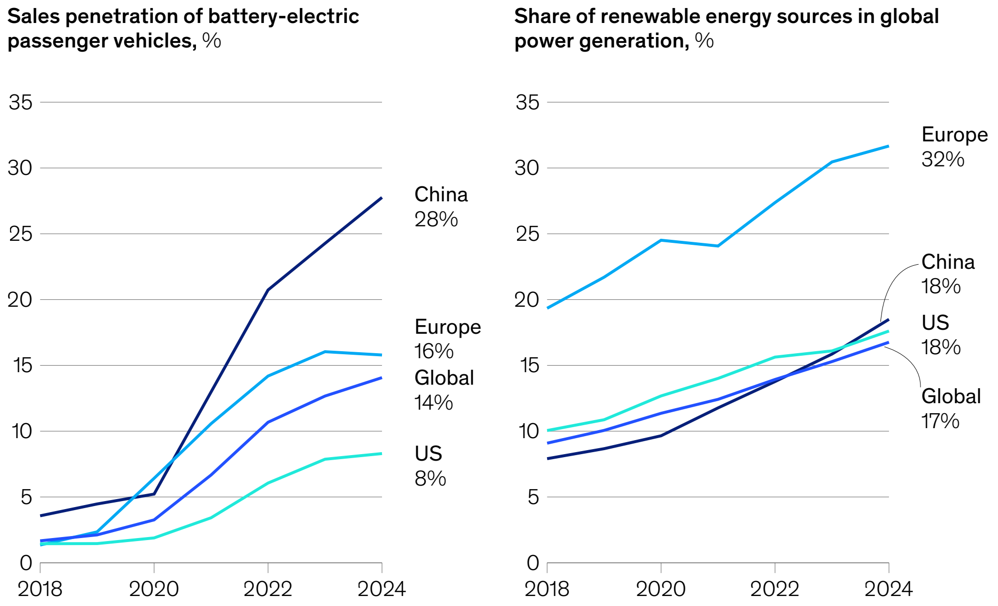
Slowing BEV sales and share of renewables in 2024 suggests a slower pace for the energy transition

Last year saw a slowdown in the deployment of low-carbon technologies in some regions, notably the European Union and the United States.

This slowdown, combined with other factors, such as higher financing costs, the macroeconomic shift toward the defense sector, and recent policy changes in some regions, resulted in a more conservative projection of future low-carbon technology deployment (compared with the previous year's report).

The projection for 2050 share of renewable energy sources was adjusted from a range of 60 to 80 percent to a range of 60 to 70 percent. The projected share of passenger BEV sales by 2035 decreased by five percentage points. Considering the slower-than-expected uptake of EVs, affected materials include lithium, nickel, and cobalt, among others.

Energy transition drivers by region


Sales penetration of battery-electric passenger vehicles, %

Share of renewable energy sources in global power generation, %

Updated *Global Energy Perspective* projection (2024 to 2025)	From **52–82%** to **47–76%** by 2035[1]	From **60–80%** to **60–70%** by 2050[1]

[1] Range from slow-evolution scenario, or the slowest decarbonization scenario, to sustainable-transformation scenario, or the fastest decarbonization scenario.
Source: EV Volumes; McKinsey *Global Energy Perspective 2025;* S&P Global; McKinsey Center for Future Mobility

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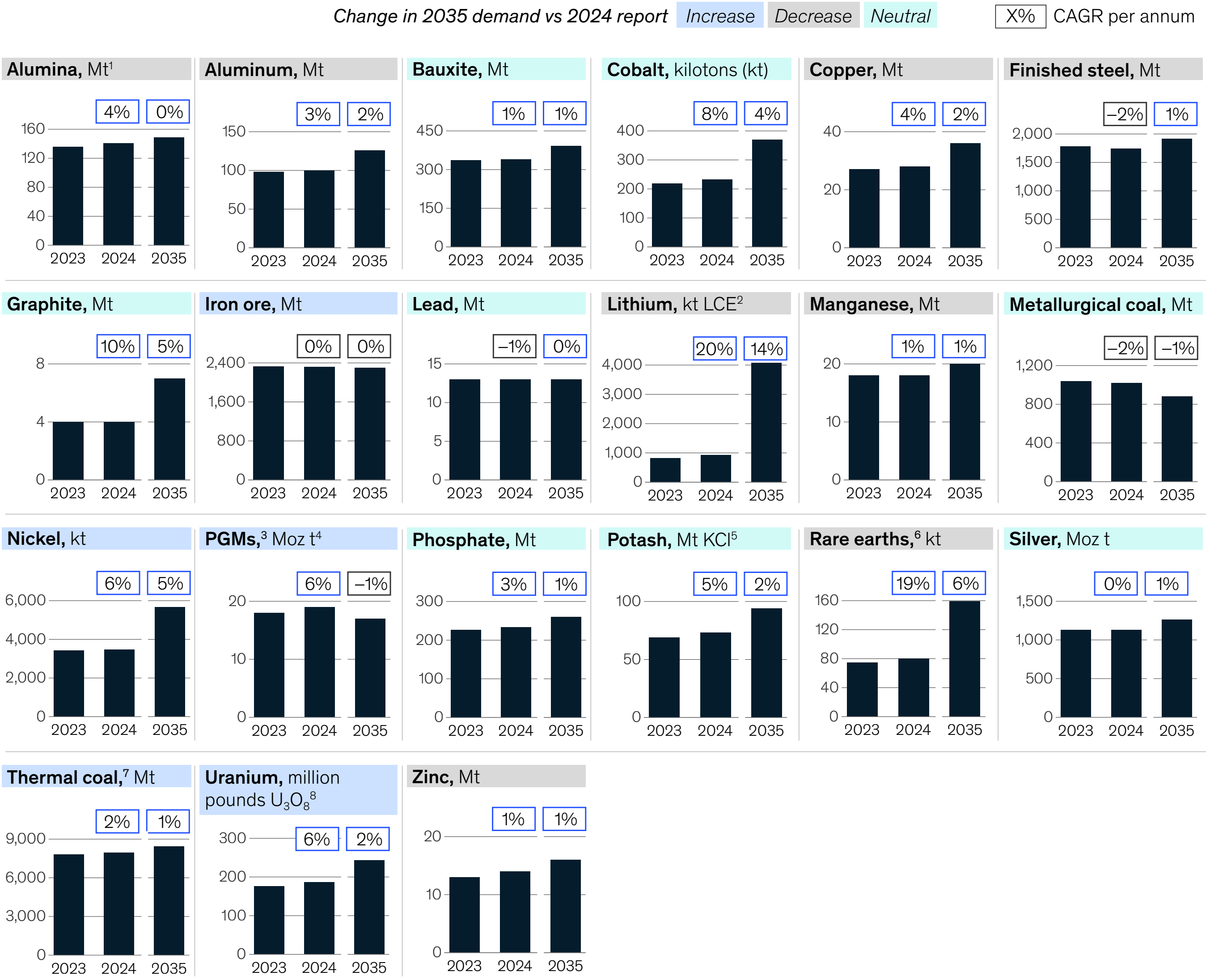
Demand outlook remains resilient across most commodities except for metallurgical coal, iron ore, and PGMs

Although projected demand growth until 2035 for several commodities (notably steel, copper, and aluminum) decreased compared with last year's report, overall materials demand remains resilient (except for metallurgical coal, iron ore, and PGMs).

Energy transition materials show strong momentum, with a projected CAGR of 4.5 percent through 2035. However, this momentum has been tempered by a slowdown in decarbonization efforts in some regions, leading to downward pressure on battery materials and REEs, alongside broader economic headwinds.

Looking ahead, defense and data centers are likely to be key sectors to drive increased material demand in the coming years (see sidebars "Defense could represent 2 to 8 percent of European demand for individual commodities by 2030" and "Data centers could become a sizable demand driver, particularly for copper").

Materials demand under the continued-momentum scenario



Note: Not to scale across commodities.

[1] Metric megatons. [2] Lithium carbonate equivalent. [3] Platinum group metals, incl palladium, platinum, and rhodium. [4] Million troy ounces. [5] Potassium chloride. [6] Incl dysprosium, neodymium, praseodymium, and terbium. [7] Thermal coal demand is based on observed market trends affecting the pace of transition momentum, rather than the continued-momentum scenario. [8] Triuranium octoxide.

Source: McKinsey MineSpans

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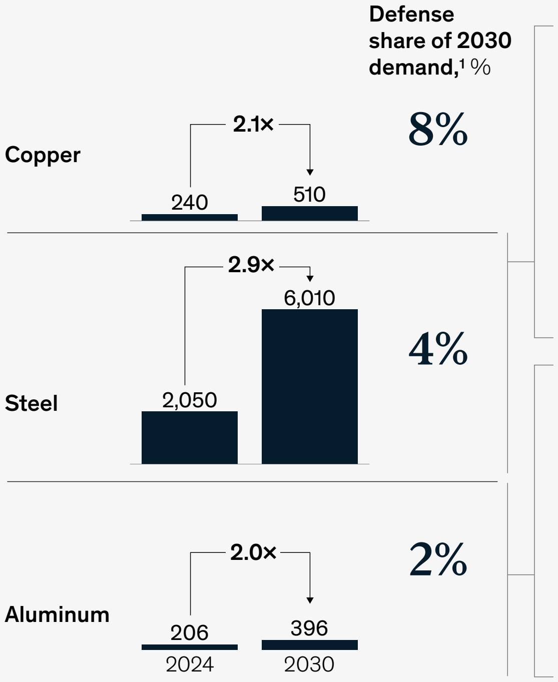
Sidebar: Defense could represent 2 to 8 percent of European end-use demand for individual commodities by 2030

By 2030, the defense sector could account for about 2 percent of aluminum, 4 percent of steel, and 8 percent of copper demand from NATO European countries, based on announced budgets.

In turn, this could create high-margin niche growth opportunities in steel and aluminum—for example, in specialized military steel grades for projectile bodies, tool steel for ammunition manufacturing, and ultrathin electrical steel for drones.

Although demand in this scenario originates in NATO Europe, equipment manufacturing could occur outside the region (likely in the United States).

Materials demand from NATO Europe's defense sector, metric kilotons (kt) (assuming 3.5% defense expenditure as a % of 2030 GDP)



Likely impact for steel sector	Demand in 2030, kt
Specialized military grades High-strength steels such as Eglin and Maraging for specialized projectile bodies	80
Tool steel Tool steels with high toughness and heat resistance for precision components in ammunition manufacturing	60
Electrical steel (NGO[2]) for drones Ultrathin electrical steel (<0.2 mm) for drones and other unmanned aerial vehicles	100

Notable opportunities for aluminum	
Flat-rolled products High-strength aluminum with high fatigue and corrosion resistance for aircraft skins, armor, and vehicles—requiring advanced rolling and heat treatment processing	200
Extrusions Aluminum extrusions with high strength, machinability, and versatility for fuselage frames, missile structures, and armor supports—requiring advanced extrusion and machining capabilities	90

Note: Demand estimates are based on the European defense budget forecast from McKinsey's Aerospace & Defense Practice. Figures reflect direct material demand in Europe, excluding inventories, infrastructure, and stockpiles.

[1] Following the continued-momentum scenario.

[2] Nongrain oriented.

Source: McKinsey MineSpans; McKinsey analysis

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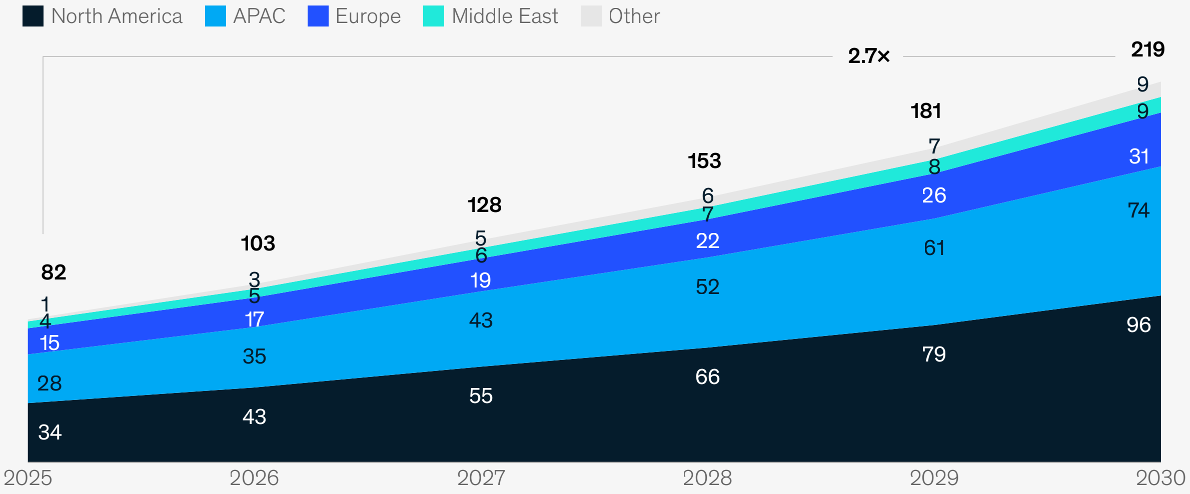
Sidebar: Data centers could become a sizable demand driver, particularly for copper

Data center capacity could expand by 2.7 times from 2025 to 2030, driven by accelerated adoption of AI technologies, among other reasons.

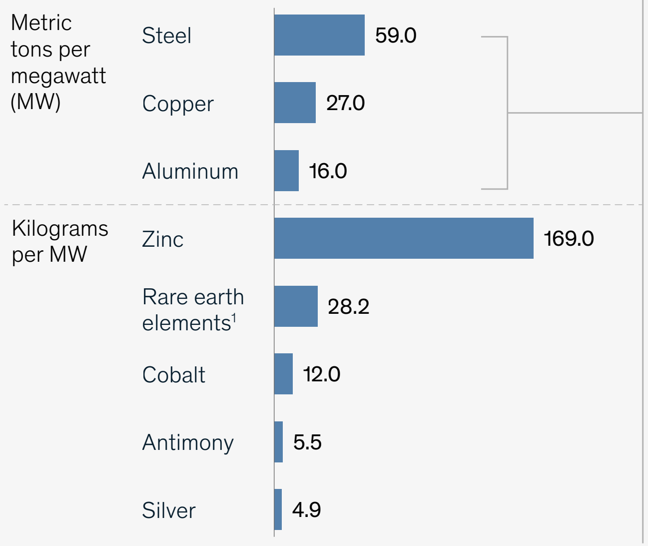
This expansion could accelerate the demand growth for several commodities—ranging from copper to REEs to antimony.

Considering only the demand from materials embedded in data centers (and not the demand coming from energy infrastructure required to power these data centers), this could account for up to 3 percent of global copper demand by 2030.

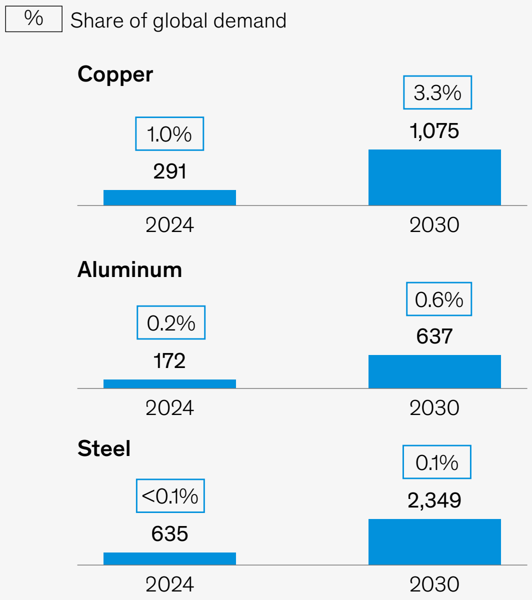
Global data center demand capacity by region, gigawatts



Demand intensity of materials required in data centers



Global material demand from data centers, kilotons



Note: Charts are nonexhaustive.
[1] Includes dysprosium, neodymium, praseodymium, and terbium.
Source: S&P Global; McKinsey MineSpans; McKinsey analysis

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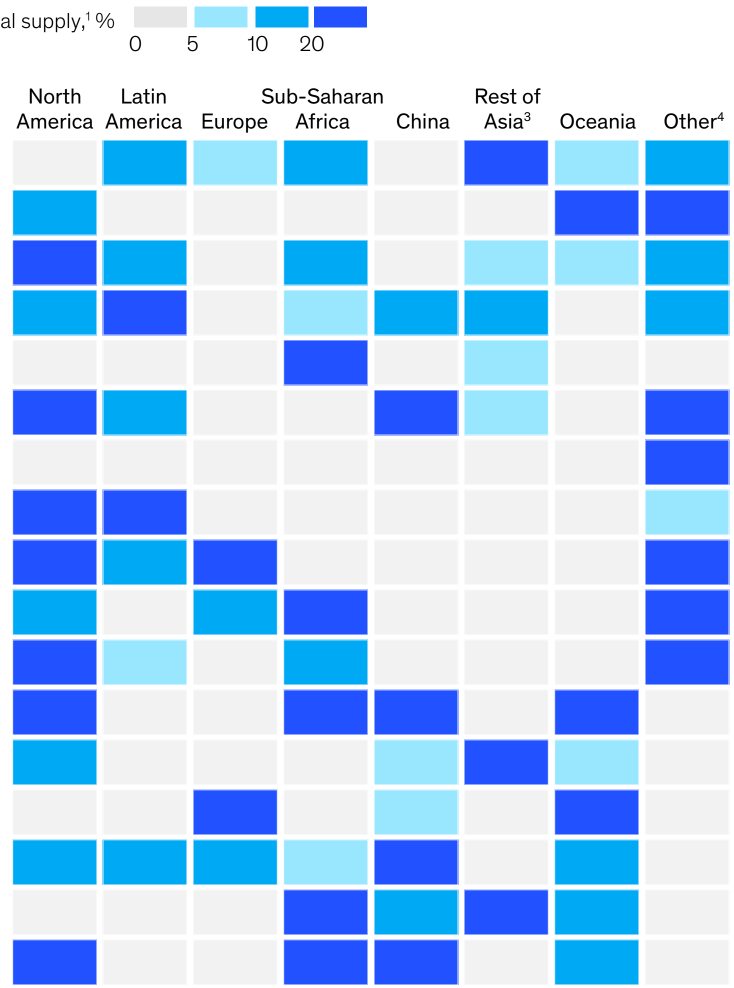
Mining supply is expected to remain concentrated, with some diversification of supply within the top three supplying countries

Looking at the project pipeline, the next decade promises growth opportunities across regions for many commodities.

There are some signs of large-scale diversification, with changes in the top three supplying countries for more than half of the world's largest commodities (based on revenue). With up to 60 percent of global reserves located outside the top three supply countries—including 62 percent of copper, 44 percent of REEs, and 36 percent of lithium—significant opportunities for future reserve development are likely to emerge beyond today's announced projects.

Announced projects of additional mining supply, 2035, high-case scenario



Share of incremental supply,[1] % ░ ▒ ▓ █ 0 5 10 20

Commodity[2]	North America	Latin America	Europe	Sub-Saharan Africa	China	Rest of Asia[3]	Oceania	Other[4]	**Top supplying country,** 2024	**Expected change in top 3 supplying countries by 2035**
Iron ore	░	▓	▒	▓	░	█	▒	▓	Australia	*No*
Metallurgical coal (seaborne)	▓	░	░	░	░	░	█	█	Australia	*No*
Gold	█	▓	░	▓	░	▒	▒	▓	China	*Yes*
Copper	▓	█	░	▒	▓	▓	░	▓	Chile	*No*
Bauxite	░	░	░	█	░	▒	░	░	Guinea	*No*
Zinc	█	▓	░	░	█	▒	░	█	China	*Yes*
Phosphate	░	░	░	░	░	░	░	█	Saudi Arabia	*Yes*
Silver	█	█	░	░	░	░	░	▒	Mexico	*Yes*
Potash	█	▓	█	░	░	░	░	█	Canada	*No*
PGMs[5]	▓	░	▓	█	░	░	░	█	South Africa	*No*
Uranium	█	▒	░	▓	░	░	░	█	Kazakhstan	*No*
REEs[6]	█	░	░	█	█	░	█	░	China	*Yes*
Nickel	▓	░	░	░	▒	█	▒	░	Indonesia	*Yes*
Manganese[7]	░	░	█	░	▒	░	█	░	South Africa	*No*
Lithium	▓	▓	▓	▒	█	░	▓	░	Australia	*Yes*
Cobalt	░	░	░	█	▓	█	▓	░	DRC[8]	*Yes*
Natural graphite	█	░	░	█	█	░	▓	░	China	*Yes*

[1] Share of total announced projects' capacity increase between 2024 and 2035. [2] Excl steel and aluminum, which are refined products, and lead because of limitations in modeling. [3] India and other Asian countries. [4] Commonwealth of Independent States and Middle East and North Africa. [5] Platinum group metals, incl palladium, platinum, and rhodium, based on weighted average approach. [6] Rare earth elements, incl dysprosium, neodymium, praseodymium, and terbium, based on weighted average approach. [7] Total increase from regions with increased supply is <5%. [8] Democratic Republic of the Congo.

Source: McKinsey MineSpans

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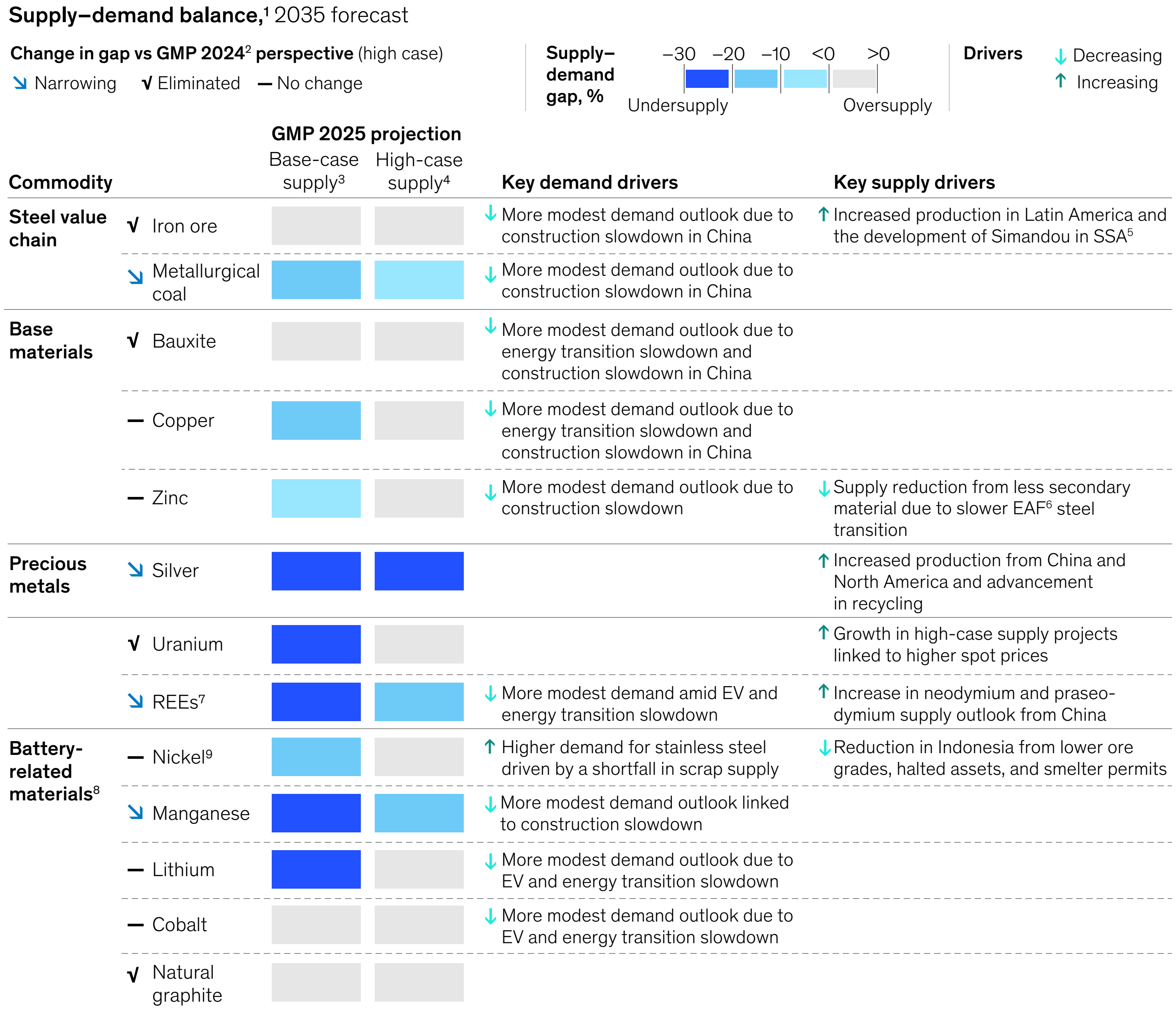
A more modest demand outlook is narrowing the expected global supply–demand gap for several commodities

In 2024, forecast supply–demand balances for nickel and cobalt shifted from projected shortages to possible surpluses.

Today, a similar trend is emerging in the high-case supply scenario for several other commodities, including uranium, REEs, and manganese. For instance, the moderation of EV adoption led to decreased demand for REEs. Meanwhile, China's construction slowdown reduced demand for steel and, consequently, demand for metallurgical coal and manganese.

Supply–demand imbalances are still expected for most commodities, especially in a base-case supply scenario and for four commodities in a high-case supply scenario (metallurgical coal, silver, REEs, and manganese).



Supply–demand balance,[1] 2035 forecast

Change in gap vs GMP 2024[2] **perspective** (high case)
↘ Narrowing √ Eliminated — No change

Supply–demand gap, % −30 🟦 −20 ▦ −10 ▤ <0 ⬜ >0
Undersupply Oversupply

Drivers ↓ Decreasing ↑ Increasing

Commodity			**GMP 2025 projection** Base-case supply[3]	**GMP 2025 projection** High-case supply[4]	**Key demand drivers**	**Key supply drivers**
Steel value chain	√	Iron ore	⬜	⬜	↓ More modest demand outlook due to construction slowdown in China	↑ Increased production in Latin America and the development of Simandou in SSA[5]
	↘	Metallurgical coal	▦	▤	↓ More modest demand outlook due to construction slowdown in China	
Base materials	√	Bauxite	⬜	⬜	↓ More modest demand outlook due to energy transition slowdown and construction slowdown in China	
	—	Copper	▦	⬜	↓ More modest demand outlook due to energy transition slowdown and construction slowdown in China	
	—	Zinc	▤	⬜	↓ More modest demand outlook due to construction slowdown	↓ Supply reduction from less secondary material due to slower EAF[6] steel transition
Precious metals	↘	Silver	🟦	🟦		↑ Increased production from China and North America and advancement in recycling
	√	Uranium	🟦	⬜		↑ Growth in high-case supply projects linked to higher spot prices
	↘	REEs[7]	🟦	▦	↓ More modest demand amid EV and energy transition slowdown	↑ Increase in neodymium and praseodymium supply outlook from China
Battery-related materials[8]	—	Nickel[9]	▦	⬜	↑ Higher demand for stainless steel driven by a shortfall in scrap supply	↓ Reduction in Indonesia from lower ore grades, halted assets, and smelter permits
	↘	Manganese	🟦	▦	↓ More modest demand outlook linked to construction slowdown	
	—	Lithium	🟦	⬜	↓ More modest demand outlook due to EV and energy transition slowdown	
	—	Cobalt	⬜	⬜	↓ More modest demand outlook due to EV and energy transition slowdown	
	√	Natural graphite	⬜	⬜		

[1] Considering mined supply in final product equivalents. [2] McKinsey *Global Materials Perspective 2024*. [3] Includes all announced projects that are deemed certain or probable to come online. [4] Includes projects for which feasibility is not yet confirmed, such as announced early-stage projects. [5] Sub-Saharan Africa. [6] Electric arc furnace. [7] Rare earth elements, incl dysprosium, neodymium, praseodymium, and terbium. [8] Incl supply and demand for battery and nonbattery uses. [9] Forecast based on currently announced projects; undersupply is unlikely because oversupply is expected until 2030, with additional projects anticipated thereafter.

Source: Bloomberg; CNBC; *Global Materials Perspective 2024*, McKinsey, September 14, 2024; MIT; McKinsey MineSpans

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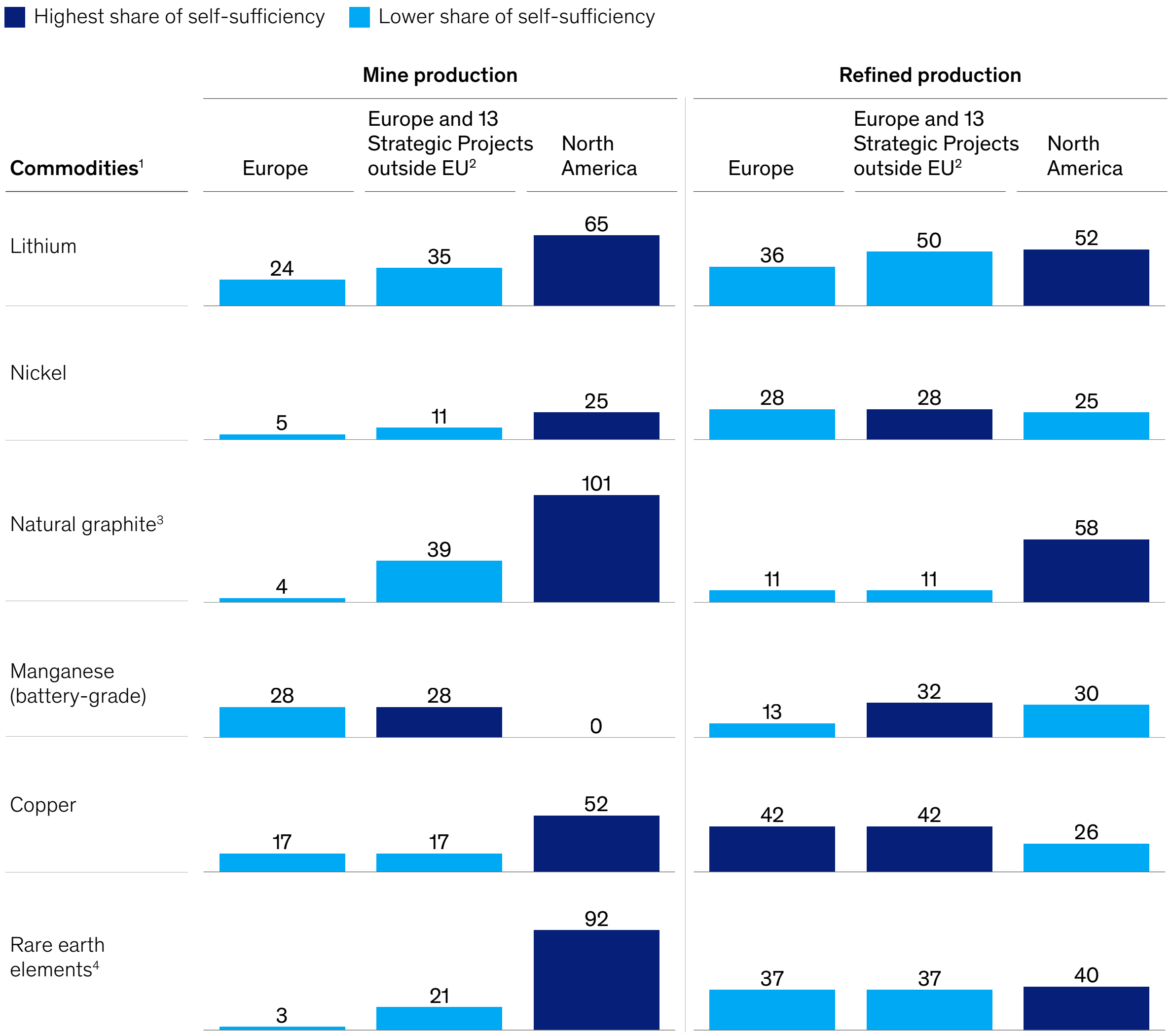
North America has the opportunity to become significantly more self-sufficient in mining

Mining and refining share of final use demand in 2035, % (high-case supply scenario, nonexhaustive)



[1] Key commodities that are of focus on Europe's Strategic Project list, with data availability for a detailed value chain analysis.
[2] Includes projects in Europe and 13 additional projects outside the EU that are strategic to Europe's self-sufficiency strategy.
[3] Refined production considered as active anode material.
[4] Refined production based on 4 rare earth oxides' supply–demand balance: neodymium, praseodymium, dysprosium, and terbium.
Source: McKinsey MineSpans

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Supply–demand balances are likely to shift in the coming years, driven by continued innovation

Both demand- and supply-side innovations could significantly affect the supply–demand balance and marginal cost (C90[4]) for several key materials.

On the demand side, sodium-ion batteries—particularly with recently announced production from OEMs by 2025 and 2027—offer a potential alternative to lithium-ion batteries. Another key development is advancements in electric motor technologies for passenger vehicles, with the potential to reduce reliance on REEs. However, these improvements could increase the marginal cost C90 of copper because these motors have higher copper intensity.

On the supply side, several disrupting technologies are emerging. Innovations such as primary sulfide leaching and direct lithium extraction (DLE) could lower production costs and unlock previously uneconomic resources. In addition, deep-sea mining potentially presents an alternative pathway to address materials imbalances, yet this remains subject to clarity on the global regulatory framework and environmental implications, as well as the technical solutions and econonomic implications for processing of deep-sea nodules. (see sidebars “Deep-sea mining could be a major disruptor for several commodity markets” and “Value distribution of deep-sea nodules is more differentiated than land-based ores”).

Accelerating momentum ▮ ▯ Decelerating momentum

↗ Positive impact = increasing

↘ Negative impact = decreasing

	Description	Momentum	Potential barriers for scale-up	Potential impact	
				S/D gap[6]	Commodity price C90[7]
Key demand-side innovations[1]					
Ⓐ **Sodium-ion batteries**	**Lithium-, nickel-, and cobalt-free battery cells**	▮ High momentum in China with announced production from OEMs by 2025 and 2027	• **Low energy density** compared with LFP or NMC[3] chemistries limiting competitiveness in high-performance applications	No gaps	Lithium and nickel ↘
Ⓑ **Solid-state batteries**	**Lithium-metal anodes** and solid electrolytes with lower cobalt intensity	▮ Announced production from OEMs by 2026, 2027, and 2028	• Stability, conductivity, and compatibility with electrodes • More **complex and expensive manufacturing processes** • **Long-term stability of battery cell**	No gaps	Lithium and nickel ↗
Ⓒ **Electrically excited synchronous motors (EESMs)**	Motors with electromagnetic excitation **eliminating REE[2] magnet dependency**	▯ Announced production from OEMs by 2027, with others in the prototype phase	• **Complex control systems** increasing costs and complicating scalability • Dependence on **high-quality electrical steel** • **Heat management** in high-performance EESMs	REE ↘	Copper ↗
Key supply-side innovations					
Ⓓ **Direct lithium extraction**	Advanced separation techniques for **efficient lithium recovery from brine**	▮ Already ~11% market share, with new assets and technologies developing	• Limited applicability to noncontinental brines • **No standardized technology** for all brines • Potentially high **freshwater use[4] and capital expenditure intensity** • Challenges in achieving battery-grade specs	No gaps	Lithium ↘
Ⓔ **Primary sulfide leaching**	Electrochemical and bio-leaching methods for **copper recovery from primary sulfide ores**	▯ Field scale pilot testing at various copper producers	• **Lower recovery rates,** mostly focused on valorizing waste • Environmental risks due to **harmful by-products** • Lack of clarity on economics	No gaps	Copper ↘
Ⓕ **Deep-sea mining**	Remotely operated underwater mining systems for recovery of seafloor **mineral deposits**	▮ Pilots and changes to regulatory framework	• Unfinalized, **pending global regulatory framework** • **Uncertainty on environmental and ecosystem impact** • **Strong opposition** from NGOs,[5] scientists, and some governments	Manganese ↘	Manganese, copper nickel, and cobalt ↘

Note: Innovations are nonexhaustive.
[1]Technologies are prioritized based on their ability to deliver impact on materials facing possible supply–demand imbalances and their strong potential for mass-scale production by 2035. [2]Rare earth element. [3]Lithium iron phosphate battery or nickel manganese cobalt. [4]Freshwater usage depends on technology because some pilots are operating without freshwater use. [5]Nongovernmental organizations. [6]Supply–demand gap; based on high-case supply scenario and Continued Momentum demand scenario. [7]C90 denotes the cost of the 90th percentile asset to meet the 2035 demand.
Source: Public announcements; McKinsey MineSpans

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[4] C90 denotes the cost of the 90th percentile asset to meet the 2035 demand.

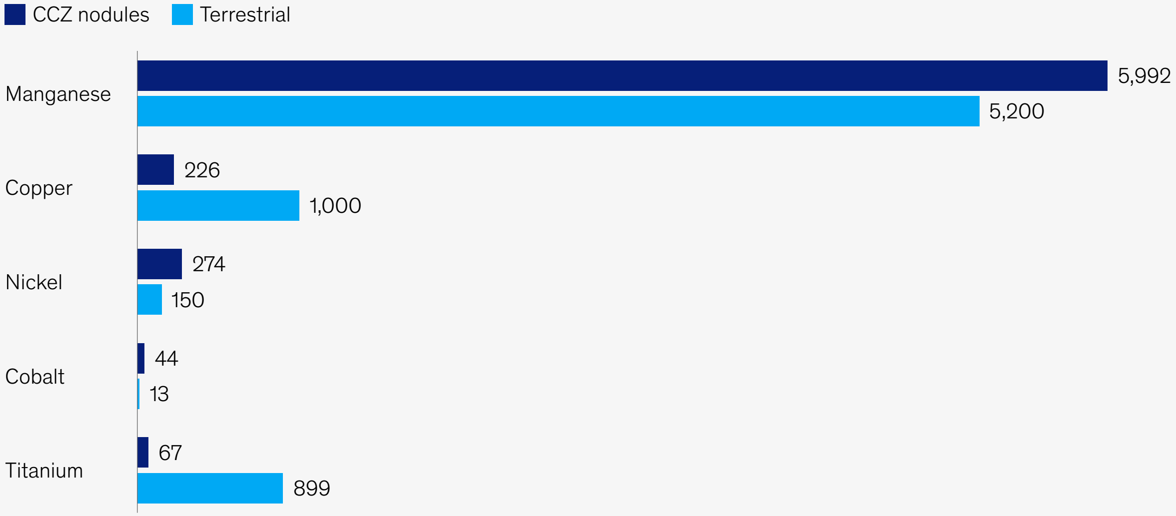
Sidebar: Deep-sea mining could be a major disruptor for several commodity markets

Deep-sea metallic nodules occur either within national exclusive economic zones (EEZs) or in international waters regulated by the International Seabed Authority (ISA), with significant undersea reserves of manganese, copper, nickel, cobalt, and titanium identified globally.

The Cook Islands are moving fast, advancing multiyear exploration of the world's largest cobalt-rich nodules within its EEZ. Multiple ISA exploration permits have been issued for the Clarion–Clipperton Zone (CCZ) in the Pacific, and the United States signaled new momentum with a 2025 executive order supporting seabed mining. By contrast, Norway has paused licensing amid environmental and legal challenges.

Although the resource potential for deep-sea mining is vast, challenges remain regarding how these materials will be processed at scale as well as the uncertainty of environmental impact.

Estimated reserves in the Clarion–Clipperton Zone (CCZ) vs terrestrial sources, metric megatons (nonexhaustive)



Note: The International Seabed Authority has already granted "exploratory" permits for nodules in the CCZ, which contains manganese, copper, nickel, cobalt, and titanium.
Source: James R. Hein et al., "Deep-ocean mineral deposits as a source of critical metals for high- and green-technology applications: Comparison with land-based resources," *Ore Geology Reviews*, June 2013, Volume 51; Kathryn A. Miller et al., "An overview of seabed mining including the current state of development, environmental impacts, and knowledge gaps," *Frontiers in Marine Science*, 2017, Volume 4; McKinsey analysis

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Sidebar: The value distribution of deep-sea nodules is more differentiated than land-based ores

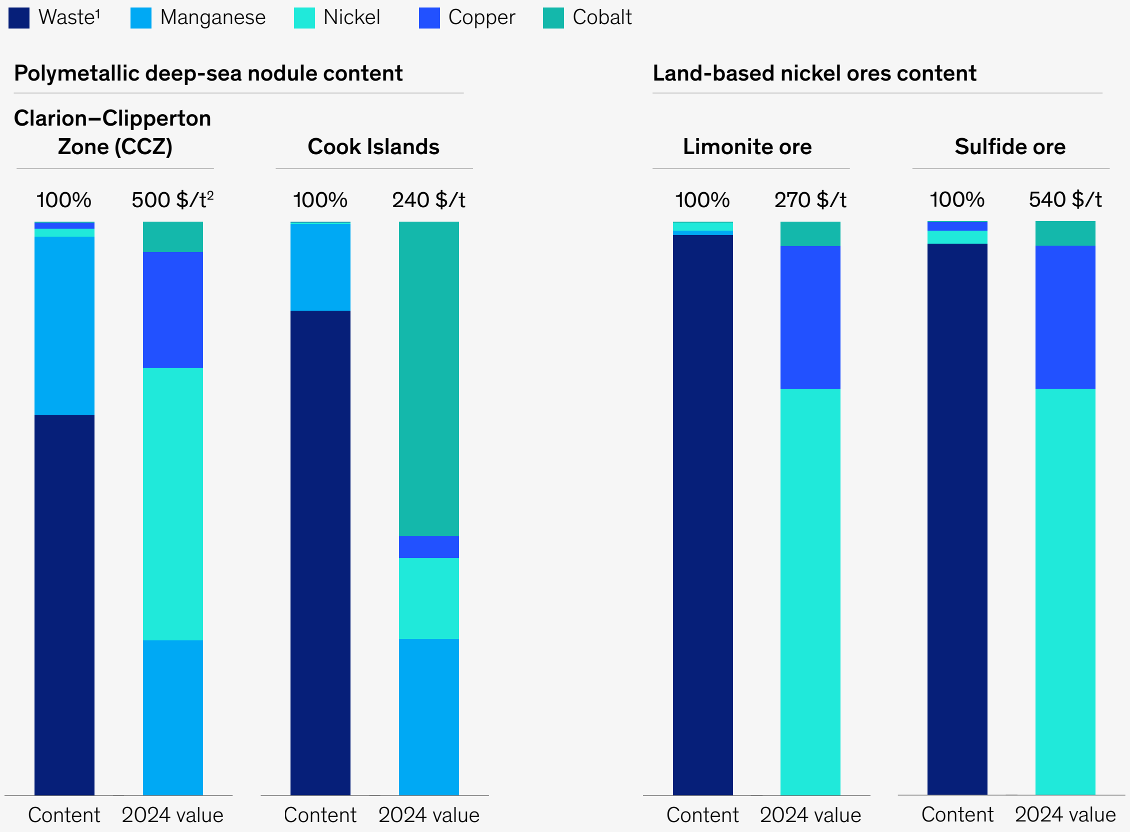
Deep-sea nodules are rock concretions found on the ocean floor containing nickel, cobalt, manganese, copper, and other metals.

Nodules from the CCZ show significant manganese content and richer nickel concentrations, while those from the Cook Islands are more cobalt-rich.

The central question lies in determining how much value can be extracted at scale, as deep-sea processing technologies remain largely unproven. In addition, there is a lack of environmental clarity and regulatory consensus.

A key uncertainty is whether manganese from nodules can serve as a viable alternative to land-based mining. Today, trials have not yet succeeded in converting manganese waste into alloys.

Estimated nodule and ores content



Note: Value per t of nodule or per t of ore based on 2024 prices at 100% recovery.

[1] Not valuable material—typically stored on processing site.

[2] $ per metric ton.

Source: 2021 investment summary for The Metals Company; Colin Seaborn; Fastmarkets; Hans Smit and John Halkyard, "Harvesting nodules from the seabed surface and extracting cobalt nickel copper and manganese," ATLA Metallurgical Services, November 2020; McKinsey analysis

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Increases in energy, people, and investments are needed by 2035

The outlook remains largely unchanged from last year. On this point, closing the supply–demand gap by 2035 will require approximately 270 GW of new low-carbon power capacity, 350,000 new jobs, and $4.7 trillion in capital.

Mining capital expenditures rebounded to $186 billion per year in 2024, and sustaining this momentum is critical to counter resource depletion and declining ore grades and reach the $260 billion required per year until 2035.

This challenge is compounded by a shrinking talent pool, with, for example, mining and metallurgy graduates decreasing by 75 percent in Australia and 40 percent in the United States from 2011 to 2021.

Meanwhile, decarbonizing the industry's power supply could demand an additional 1,100 GW of clean energy capacity, adding further complexity to the transition.

Power required by 2035 to address supply–demand gap (includes thermal coal outlook from GMP[1] 2024)

	Energy	People	Investments
GMP 2025	**~270 gigawatts (GW)[2]**	**~350,000 new jobs[3]**	**~$4,650 billion in capital expenditures[4]**
Change vs GMP 2024[5]	**No change** → Regional demand shifts balance one another, resulting in no significant change in overall net power demand (<1 GW/yr)	**40,000** ↑ Driven by a shift in expected supply for lithium and copper toward regions with higher-labor intensities, particularly sub-Saharan Africa	**$200 billon** ↓ Driven by a more modest demand outlook of, eg, nickel and copper linked to energy transition slowdown
Challenge	An additional 1,100 GW[6] is needed to decarbonize current industry power supply	Mining and metallurgy graduates are decreasing by 75% in Australia and 40% in US between 2011 and 2021	For mining, this implies at least $260 billion per year, matching the highest levels last seen at the 2011–13 investment peak

[1] McKinsey *Global Materials Perspective*.
[2] Assuming renewable power at 90% utilization and 25% capacity factor.
[3] Excluding thermal and metallurgical coal.
[4] Incl exploration, sustaining, and project capital expenditures for both mining and processing, a ~10% increase compared with previous decade.
[5] Total change over 10-year period.
[6] Assuming renewable energy to fuel operations, requiring higher power than fossil fuels due to lower capacity.

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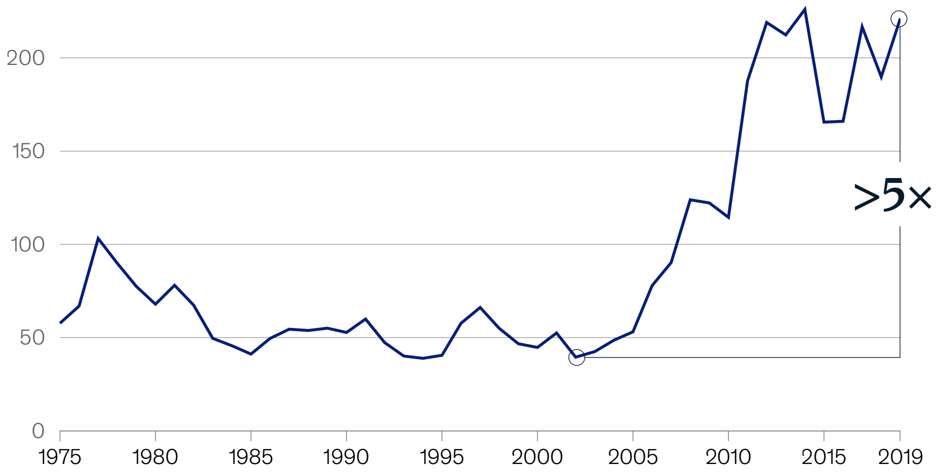
Exploration investment remained flat over the past decade while cost per discovery increased more than fivefold

Exploration spending rebounded from 2016 to 2022, growing at a CAGR of 7 percent, with only a brief dip during the COVID-19 pandemic. The recovery was driven by higher commodity prices, supply security concerns, and favorable policy signals, particularly in North America, where spending surged at a CAGR of 17 percent. By contrast, Asia–Pacific and the "rest of world" category[6] declined by 4 and 2 percent, respectively.

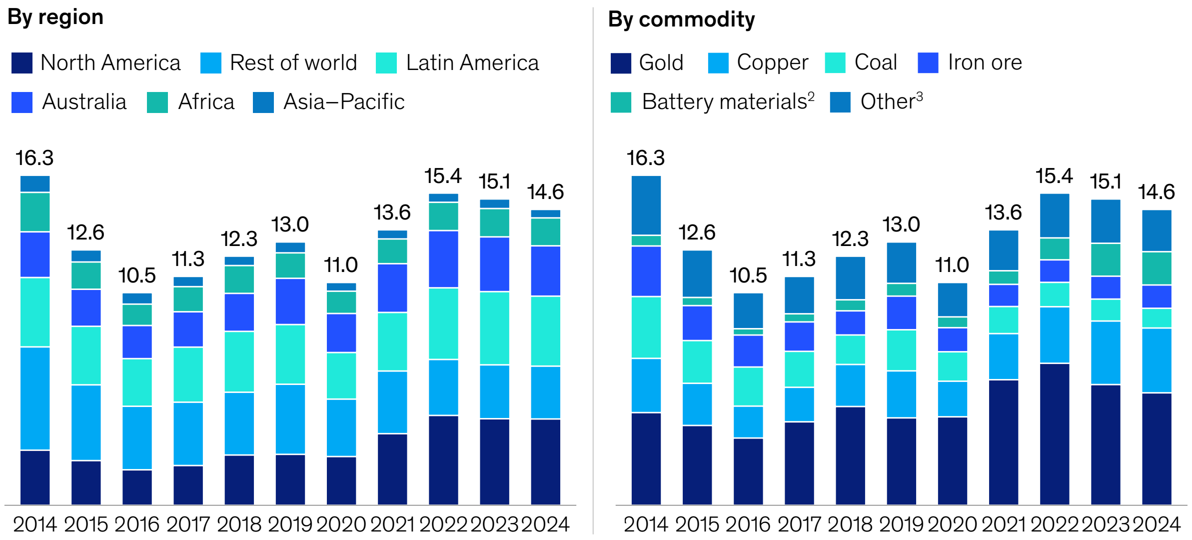
Growth was strongest in battery-related materials, with lithium exploration increasing at a CAGR of 28 percent. By contrast, most other commodities grew modestly at 2 to 5 percent, while zinc, potash, and coal decreased.

Since 2022, exploration investment moderated through 2024 as prices softened, financing tightened, and companies prioritized capital discipline.

Exploration cost per discovery,[1] nominal $ million



Exploration capital expenditures, $ billion



[1] Based on deposits "moderate" or larger in size, ie, >100,000 oz of gold, >10 metric kilotons (kt) of nickel, >100 kt of copper, >300 kt of zinc and lead, >5 kt triuranium octoxide, >5 megatons (Mt) of heavy minerals, >20 Mt of iron, >20 Mt of thermal coal, >10 Mt of metallurgical coal, >3 Mt of phosphorus pentoxide, and >3 Mt of potassium oxide. [2] Lithium and nickel. [3] Potash, silver, zinc, uranium, platinum, and other.
Source: MinEx Consulting; S&P Global Market Intelligence; McKinsey analysis; McKinsey Value Intelligence Platform

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[5] Excluding Asia–Pacific, Africa, Australia, Latin America, and North America.

Despite a more balanced supply–demand outlook, higher commodity prices are still required to encourage sufficient supply to come online to meet demand.

Productivity and affordability: Key messages

1

Capital intensity and productivity

Productivity is on a rebound—driven by automation and efficiency gains—but challenges remain because of escalating costs and labor shortages.

Following a period of steep productivity decline (2004–10) and a flat phase (2010–18), mining productivity has begun to rebound, growing at 1 percent per annum since 2018, supported by the accelerated adoption of automation and digital technologies.

Improvements have been uneven across geographies, with Latin America leading in terms of factor cost gains, declines in labor productivity keeping North America flat, and Oceania only modestly positive. Sub-Saharan Africa's decline reflects losses in both labor and capital productivity.

Challenges remain to ensure productivity improvements continue and accelerate, considering ore grade declines, complex mining conditions, and labor shortages, all while balancing rising operational costs, environmental considerations, and managing timely project execution.

2

Price evolution

Price increases are still required to encourage sufficient supply to come online.

Despite a rebound in global mining productivity, increased prices are likely required for several commodities—notably copper and battery materials—to encourage additional supply to come online.

This upward pricing pressure could result in substituting other materials (such as moving from copper to aluminum when spreads are high), miniaturization, or demand destruction because rising input costs would put pressure on downstream sectors such as EVs, increasing the risk of slower adoption—all of which would affect demand projections.

This demand and, by extension, price uncertainty should be factored into project economics, especially for commodities with relatively flat cost curves such as nickel and lithium, for which even small demand shifts can make a large number of projects uneconomical. This demand and price uncertainty also calls for a relentless focus on continued productivity improvement.

3

The next frontier of productivity

Opportunity exists for aspirational players to leverage innovative methods to enhance productivity and lower costs.

Moving forward, there is an opportunity to further accelerate the productivity rebound by adopting new technologies and shifting toward global sourcing:

- *AI:* Improvements across the value chain, such as geospatial mapping, ore sorting, and hauling and process optimization
- *Gen AI:* Improvement in domains such as derisking capital expenditure deployment, maintenance, and operator assistance
- *Automation:* Opportunities for cost and productivity improvement in labor, energy, and fuel and maintenance
- *Energy efficiency:* Utilization of renewables and electrification of mines to reduce costs
- *Global sourcing:* Gradual shift away from incumbent suppliers, which could however entail increased geopolitical risk

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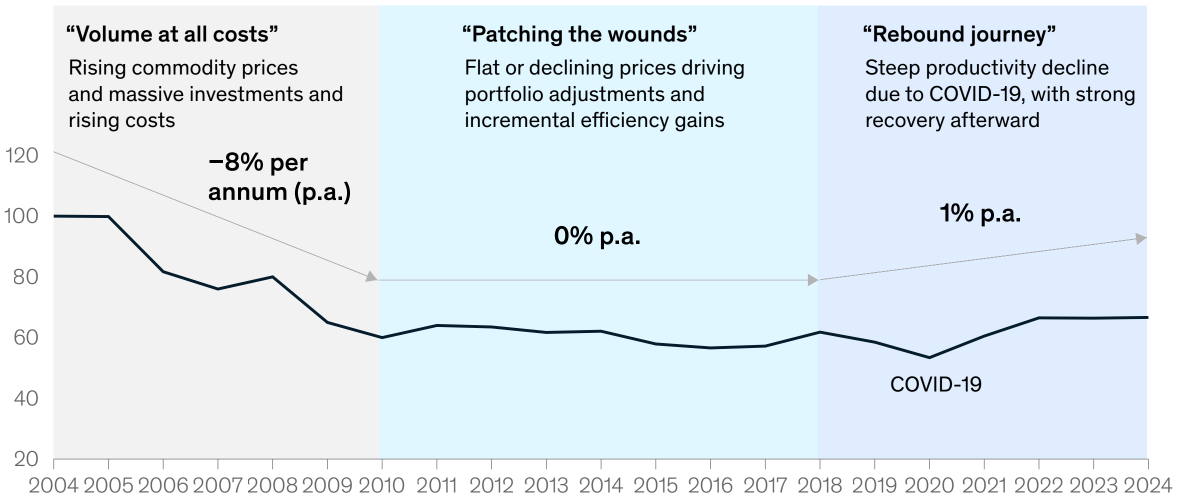
Global mining productivity has seen a modest rebound since around 2018

The commodity supercycle from the early 2000s to early 2010s was marked by massive investment and rising costs. Yet this period delivered only limited production growth, leading to a sharp decline in productivity.

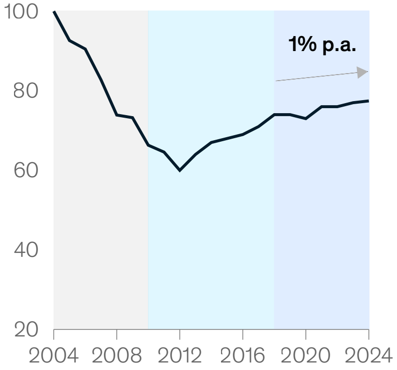
As commodity prices declined in the first half of the 2010s, mining companies shifted focus toward operational efficiency, primarily targeting labor productivity to offset persistent cost inflation, which put downward pressure on capital productivity in particular.

The industry entered a recovery phase around 2018, though the COVID-19 pandemic temporarily interrupted progress. Notably, gains have extended beyond labor to include improvements in capital and productivity in factor cost, supported by the accelerated adoption of automation and digital technologies.

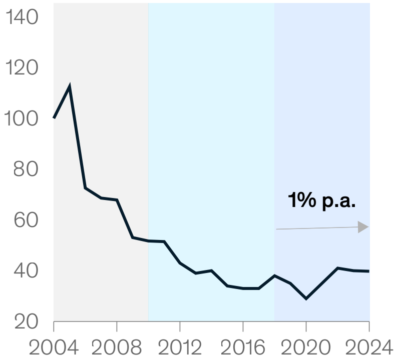
MineLens Productivity Index, 2004 = 100



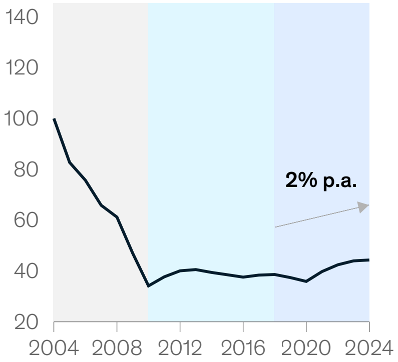
Labor productivity, index (2004 = 100)



Capital productivity, index (2004 = 100) in real terms[1]



Factor cost productivity, index (2004 = 100) in real terms[1]



[1] Capital expenditures and operating expenditures adjusted for mine cost inflation. Capital expenditures include book value of property plant and equipment.
Source: McKinsey MineLens; McKinsey MineSpans

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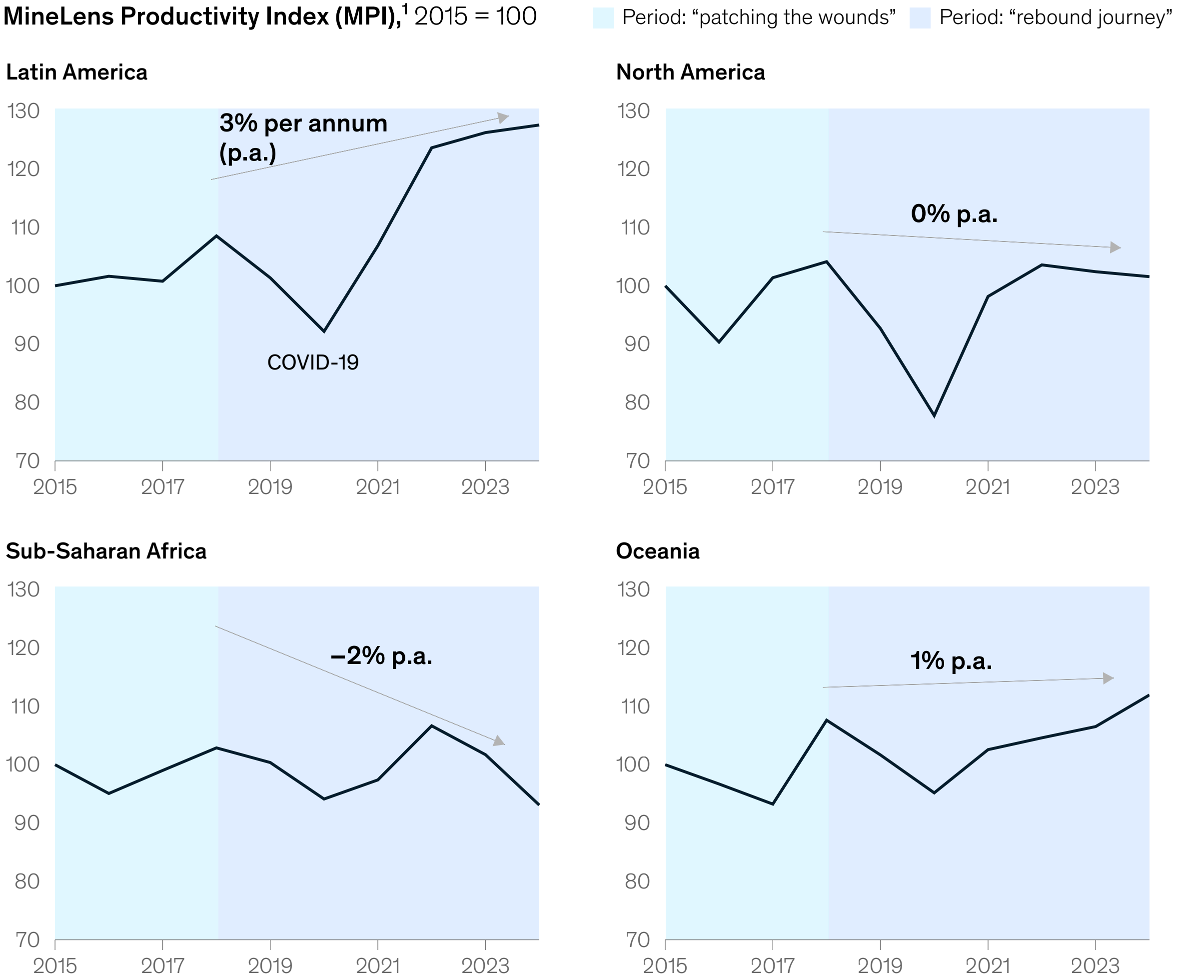
Productivity increase has been uneven, led by Latin America and constrained by labor and capital declines in other regions

Despite the COVID-19 pandemic, productivity in Latin America and Oceania has increased since 2018. North America shows a flat trend, even after the post-2020 rebound, while sub-Saharan Africa experienced a decline.

In Latin America, post-2018 gains were largely driven by factor cost and capital productivity. By contrast, North America's flat trend and Oceania's modest rebound reflect declines in labor productivity of approximately 4 and 2 percent CAGR, respectively, from 2018 to 2024, which have offset improvements in factor-cost productivity.

These patterns highlight that while operational efficiencies can deliver short-term improvements, sustained growth requires strengthening capital and labor productivity—through modernization, better asset management, and more efficient use of resources.

MineLens Productivity Index (MPI),[1] 2015 = 100



[1] The MPI database covers an estimated 55% of total material moved in 2024 in Latin America, 54% in Oceania, 37% in North America, and 24% in Sub-Saharan Africa.
Source: McKinsey MineLens; McKinsey MineSpans

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Future productivity is under pressure from several factors

Illustrative examples

Declining ore grades requiring more energy, processing, and exploration spending	**~17%** Absolute copper mill-head grade reduction (2012–24)
Deeper pits and sustained underground mining increasing complexity, safety risks, and capital intensity	**28 percentage points** Increase in underground nickel over the next 10 years
Labor shortages affecting productivity and project timelines	**2.3×** Increase in mining job vacancies from 2010 to 2023
Rising operational costs including inflation in labor, energy, water, and equipment costs	**23%** Increase in copper costs forecast to 2035
Environmental and community considerations requiring more mitigation measures	**~40%** Share of mines in water-stressed areas by 2040
Project cost and timeline overruns affecting productivity and project timelines	**78%** Share of projects with cost or time overruns (2003–23)

Source: Australian Bureau of Statistics; Aqueduct Water Risk Atlas; DARES (France); Eurostat; International Labour Organization; Job Openings and Labor Turnover Survey, US Bureau of Labor Statistics; Ministry of Health, Labour and Welfare of Japan; Statistics Canada; UK Office for National Statistics; UN Population Prospects; World Bank; World Resources Institute; McKinsey Global Institute analysis; McKinsey MineSpans

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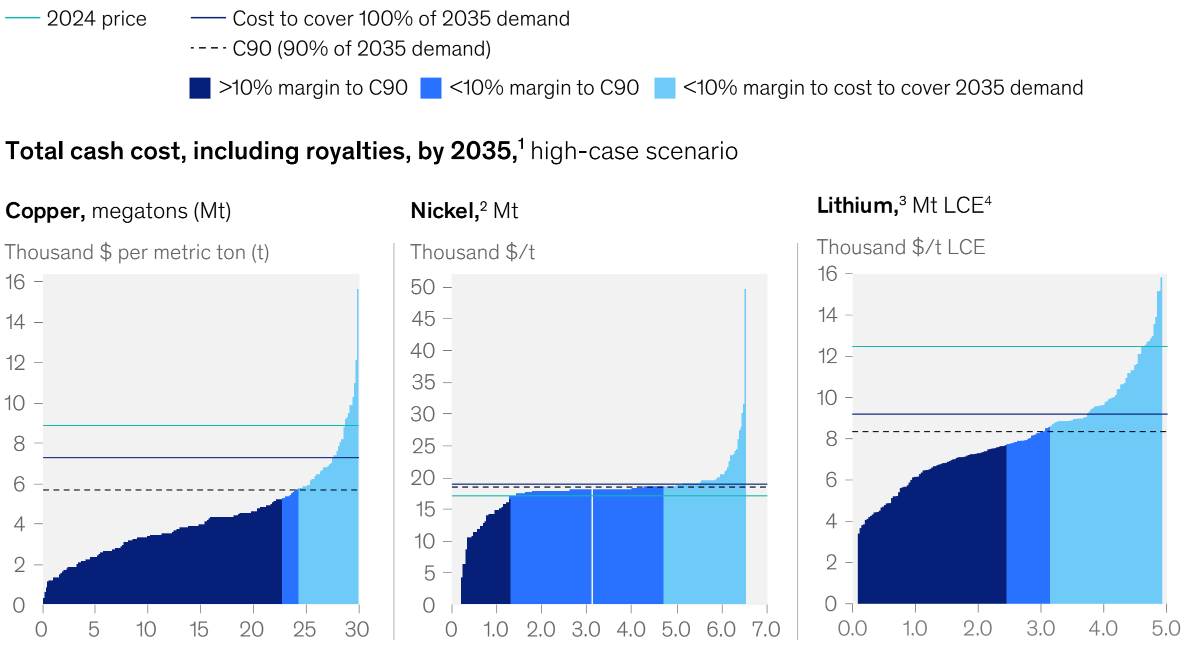
Flatter cost curves for lithium and nickel (versus copper) indicates margins could be more sensitive to demand changes

In a high-case supply scenario, nickel and lithium cost curves are relatively flat across existing and announced capacity, with many projects clustered at similar cost levels. When the cost curve is flat, margins become highly sensitive to demand. In fact, small shifts can materially change the share of supply operating with narrow margins.

For nickel, this conclusion could still evolve. Although relatively few new projects have been announced under current oversupply, more low-cost projects are expected, which could reshape the cost curve and reduce sensitivity.

For copper, the cost curve is generally less flat, reflecting differences in deposit quality and location. This steeper curve means margins are less sensitive to small demand shifts while still generating strong margins at current price levels.



Total cash cost, including royalties, by 2035,[1] high-case scenario

Volume with <10% margin to cost to cover 2035 demand	● 17%	● 27%	● 35%
Volume with <10% to C90	● ● 22%	● ● 79%	● ● 55%

Note: Exhibit includes announced projects in operation by 2035 as well as still operating assets taking into consideration depletion; prices are real prices, rather than nominal prices; C90 denotes the cost of the 90th percentile asset to meet the 2035 demand.

[1] Assets with a negative cost (byproducts) or a cost above $13,000/t copper, $30,000/t nickel, and $16,000/t lithium carbonate equivalent are removed from the chart; prices are in real terms.

[2] Limited amount of nickel projects announced due to current oversupply, additional low-cost projects expected once supply–demand gap begins to close.

[3] Conversion cost considering value in use.

[4] Lithium carbonate equivalent.

Source: McKinsey MineSpans

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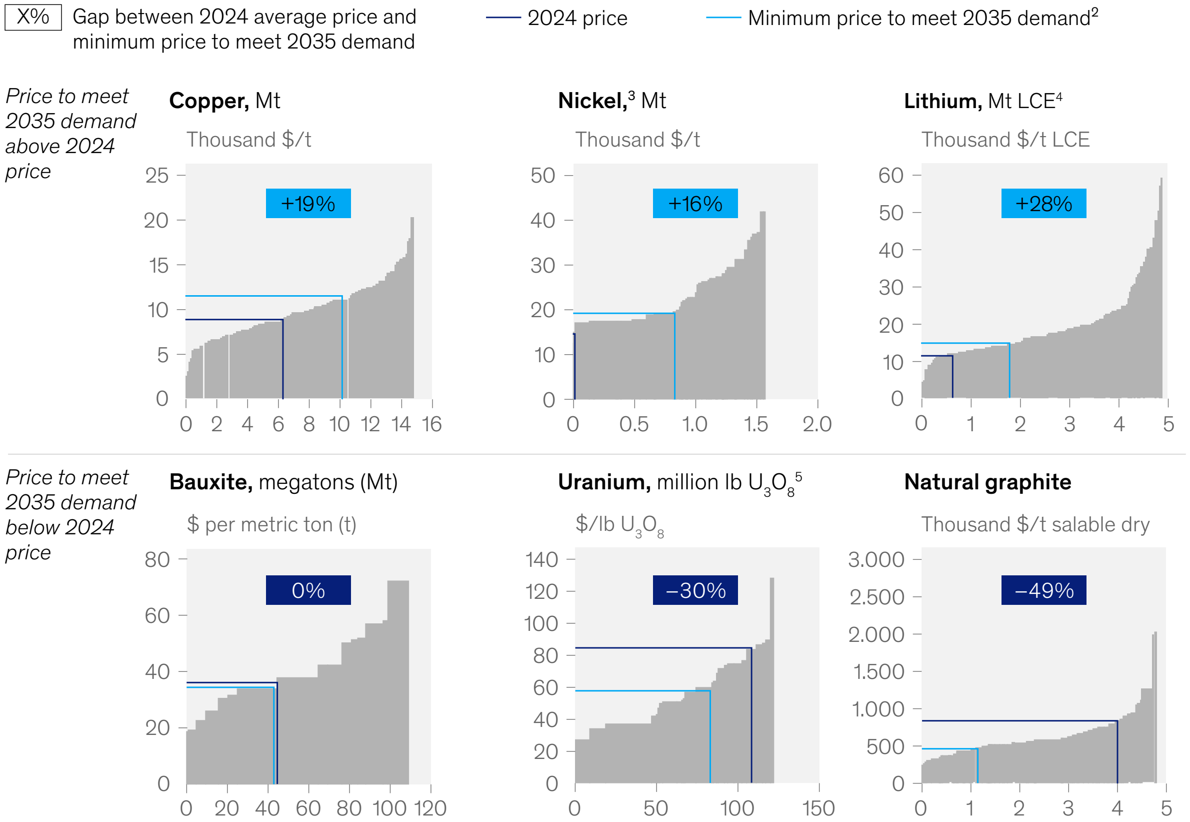
Price increases are required for several commodities to encourage sufficient supply

Incentive prices for copper, nickel, and lithium remain above current market levels to meet projected 2035 demand, leaving many new projects uneconomic at today's prices. Improving productivity, substituting commodities, or, in the longer term, exploring new projects are alternative pathways to resolve these higher incentive prices.

Incentive price of projects currently in pipeline for production by 2035, full-pipeline scenario[1]



[1] Each project's incentive price is an estimate of the average benchmark price, throughout the life of the mine, that sets the net present value of the investment to zero using a discount rate of 15%, including new project developments, excluding already operating assets; projects with prices from incentives that are above $20,000/t for copper and $45,000/t for lithium are removed from the charts.

[2] Remaining gap between 2035 demand and supply (operation assets and recycling) that needs to be bridged by new projects.

[3] Limited amount of nickel projects announced due to current oversupply; additional low-cost projects are expected once supply–demand gap begins to close.

[4] Lithium carbonate equivalent.

[5] Triuranium octoxide.

Source: McKinsey MineSpans

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Several new technologies and practices have emerged that could improve productivity

Next-generation technologies and operational excellence are creating new opportunities to increase productivity across the value chain:

- *Traditional AI* models continue to progress as access to low-cost computing power increases. For example, the technology can cut fleet fuel consumption by up to 10 percent by connecting fleet management, enterprise asset management, machine Internet of Things, and other operational data (such as tire pressure, road layout, and quality sensors).
- *Gen AI* use cases are becoming increasingly tailored to the materials industry, such as through real-time assistance in reactive-maintenance procedures.
- *Automation* is becoming more attractive as labor becomes scarcer, especially in remote locations—for example, by implementing autonomous haul trucks.
- *Electrification* is advancing rapidly across several use cases—for example, the use of electric haul trucks or scale-up of (thermal) storage solutions.
- *Global supplier diversification* is creating opportunities as the continued innovation of nonincumbent players increases the landscape of technical and cost-competitive industrial equipment.

Together, these levers can help offset rising costs, improve productivity, and enhance long-term competitiveness.

Improvement opportunities by cost category and technology or operational practice

🟦 Main improvement opportunities, with selected examples

Cost category[1]	AI	Gen AI	Automation	Electrification	Global supplier diversification
Labor 25–30%	Workforce forecast modeling	AI-assisted negotiant modeling	Robotization	Autonomous and electric hauling trucks	
Sustaining capital expenditures 20–25%	Predictive maintenance	Generative scheduling			Alternative suppliers to incumbents
Energy 15–20%	Real-time process and equipment feedback loops			Equipment electrification and (thermal) storage	
Consumables 15–20%	Real-time process feedback loops				
Maintenance and spares 10%	Predictive maintenance	Issue identification and resolution in reactive maintenance			Non-OEM spare parts sourcing

Note: Chart is exemplary and nonexhaustive.

[1] Excluding overheads, which typically account for 5% of total costs; based on a weighted average across coal, lithium, iron ore, zinc, uranium, nickel, copper, and gold.

Source: McKinsey MineSpans

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Mounting downward pressure on green premiums has slowed industrial decarbonization, with low-carbon technology relying on CO_2 taxes or subsidies to support deployment.

Sustainability: Key messages

1

An economic reality check

Ambitions remain but economic realities are driving a decarbonization slowdown, especially in steel.

Most companies and major economies remain steadfast in their long-term decarbonization commitments, even doubling down on enabling policies in some cases. For instance, China expanded its emissions trading system to include metals, India defined green steel standards, and the European Union introduced strict monitoring of scrap exports.

Customer surveys indicate growing demand for green materials, albeit with decreasing willingness to pay. This is also reflected in subdued green premium indices for steel and aluminum.

There has been slowdown in large-scale decarbonization projects, partly because of changing business cases. As an example, approximately 40 percent of direct reduced iron (DRI) and 33 percent of low-carbon steelmaking projects were put on hold or canceled in Europe in the past 12 to 18 months.

2

Outlook lags behind Paris Accord commitments

Emissions decline has slowed as decarbonization efforts are offset by increased production.

Metals and mining industry emissions were about 7.4 Gt CO_2 (approximately 20 percent of global emissions) in 2024 and are projected to decline by a modest 6 percent by 2035.

Global improvement in power grid emissions is the largest driver of the decline (making up approximately 40 percent), benefiting companies that source their power from the grid.

Continued energy efficiency improvements could lower emissions by an additional 30 percent (of the 6 percent total decline), which may be further accelerated by the shift toward next- generation technologies, such as autonomous electric haul trucks.

Continued uptake in recycled materials could also help reduce emissions accounting for about 20 percent of the projected decrease (which is lower than last year's estimate as the slowdown in Chinese construction industry reduces scrap availability, especially for steel).

3

Innovation and regulatory support

Many abatement levers are "in the money," but breakthrough could require innovation and regulatory support.

Previous years have seen accelerated deployment of some abatement levers, including electric haul trucks. Widespread adoption could not only accelerate decarbonization but also improve costs through economies of scale.

Most so-called deep-decarbonization levers continue to be uncompetitive. Stronger efforts in innovation (including pilot projects) are likely required to accelerate the path to cost parity with conventional technologies, possibly funded by the receipts from cost-effective abatement levers.

Regulation could create an additional boost in development by defining unified thresholds for low-carbon or sustainable materials and offering incentives for improved collection of scrap, which could, in turn, help strengthen regional self-sufficiency.

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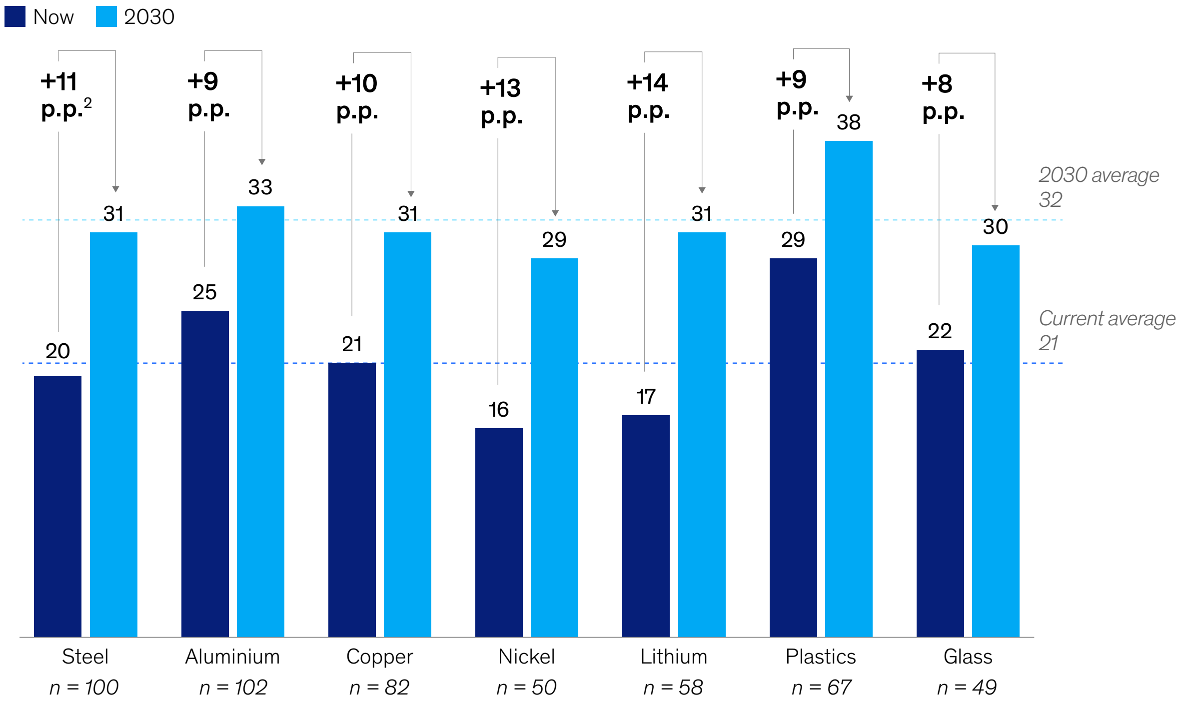
Demand for green materials is expected to increase to 30 percent of procured volume by 2030

By 2030, the share of green materials—based on companies' own definitions of the term—is projected to increase from 21 percent today to 32 percent on average, with relatively small variation across commodities. We estimate that nickel and lithium could see the strongest growth—13 and 14 percentage points, respectively—while both currently have the lowest share of demand for green materials (16 and 17 percent, respectively). This increase likely reflects their strategic role to meet energy transition commitments, with strong policy support and investment in recycling infrastructure to secure supply for batteries and clean energy technologies.

In contrast, commodities that already show higher adoption, such as aluminum (25 percent) and plastics (29 percent)—could see a more moderate increase of about nine percentage points. On this point, existing recycling practices are already mostly established, leaving less room for dramatic growth. Instead, progress could come from incremental improvements in collection systems, scaling of advanced-recycling technologies, and tightening regulatory standards.

Share of green materials in respondents' procurement volume,[1] %



[1] Adjusted for regional split of 2025 survey but not adjusted for buyer or seller size; green materials were defined by respondents.
[2] Percentage points.
Source: McKinsey global surveys of decision-makers in materials sales and purchases, April 2024 and June 2025

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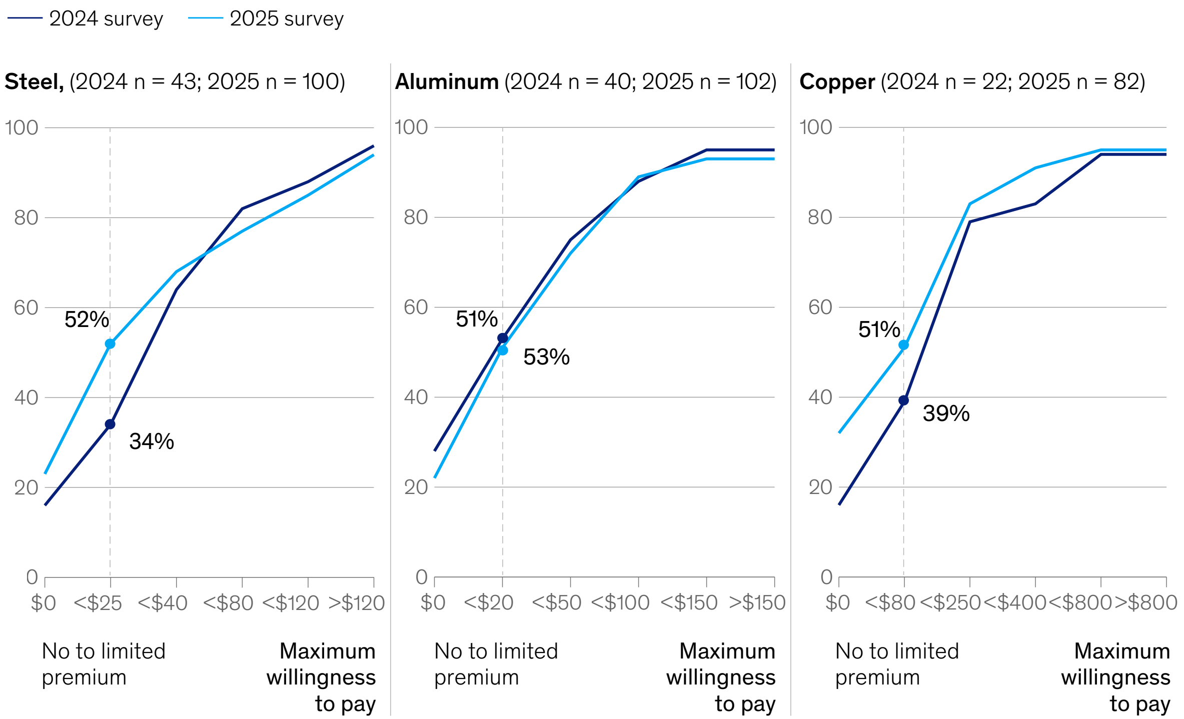
Our survey indicates willingness to pay for green products is decreasing, especially for steel and copper

Compared with 2024's survey of decision-makers in materials sales and purchases, there is an overall slowdown in willingness to pay premiums for green materials, with more customers preferring no or limited premiums. Aluminum remained relatively stable, with approximately 50 percent of customers unwilling to pay, while steel and copper increased from approximately 35 and 40 percent to around 50 percent.

The variation in willingness to pay premiums highlights the importance of customer segmentation in go-to-market approaches for sustainable materials. On this point, targeting the right customer segment with a win–win value proposition can improve the economics of decarbonization business cases.

Distribution of respondents by current premiums level, cumulative % of respondents



Note: The definition of material that is perceived as green is based on the average of participants' answers to a multiple-choice question: Steel as <0.6 metric tons (t) CO_2/t (2024 and 2025); aluminum as <1.9 tCO_2/t (2024) and <1.6 tCO_2/t (2025); and copper as <0.7 tCO_2/t (2024 and 2025). Survey participants could answer "not sure," and therefore cumulative share of respondents does not add up to 100%.
Source: McKinsey global surveys of decision-makers in materials sales and purchases, April 2024 and June 2025

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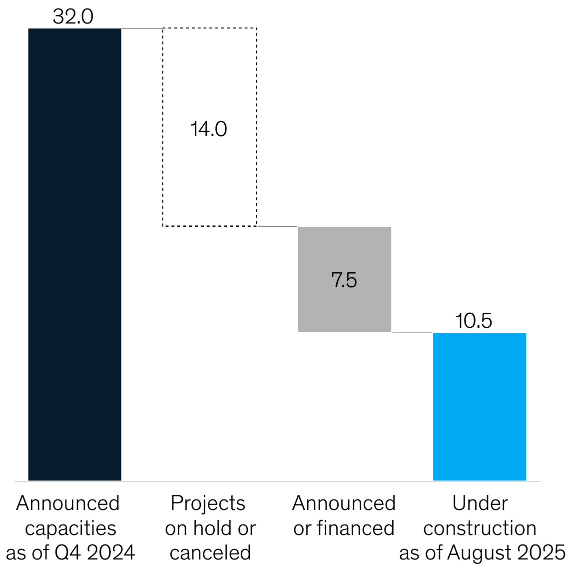
Momentum for low-carbon steel projects in Europe has slowed, with 30 to 40 percent of announced capacity on hold or canceled

Of all DRI projects planned in the European Union as of Q4 2024, approximately 40 percent (with a total capacity of 14 metric megatons per annum) are now on hold or canceled.

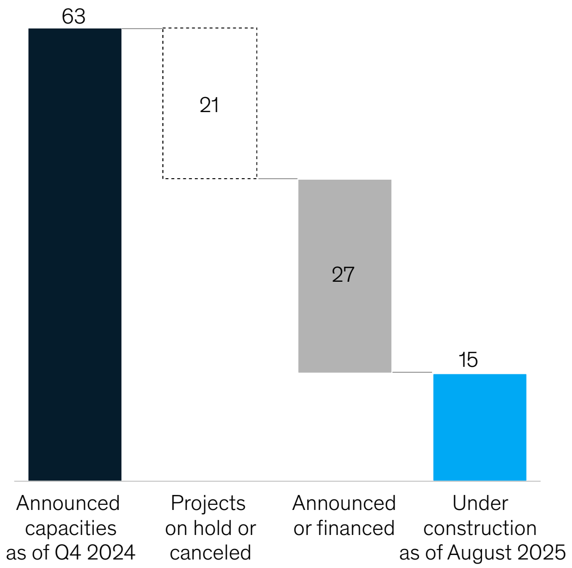
At the same time, nearly 30 percent of the low-carbon steelmaking initiatives in Europe face delays or suspension.

Both points highlight the growing challenges in advancing the EU's decarbonization efforts for steel, not in the least driven by low margins in the sector.

Current capacity of announced DRI[1] projects in Europe,[2] metric megatons per annum (Mt p.a.)



Current state of announced low-CO_2 steel-making initiatives in Europe,[3] Mt p.a.



[1] Direct reduced iron.

[2] Excluding 2nd and 3rd phases of multiphase projects merchant hot briquetted iron (eg, GravitHy) projects; includes both flat and long steel.

[3] Excluding 2nd and 3rd phases of multiphase projects; includes electric arc furnace (EAF), submerged arc furnace–basic oxygen furnace, and hybrid EAF projects; includes both flat and long steel.

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The business case for decarbonization is becoming more challenging in some regions

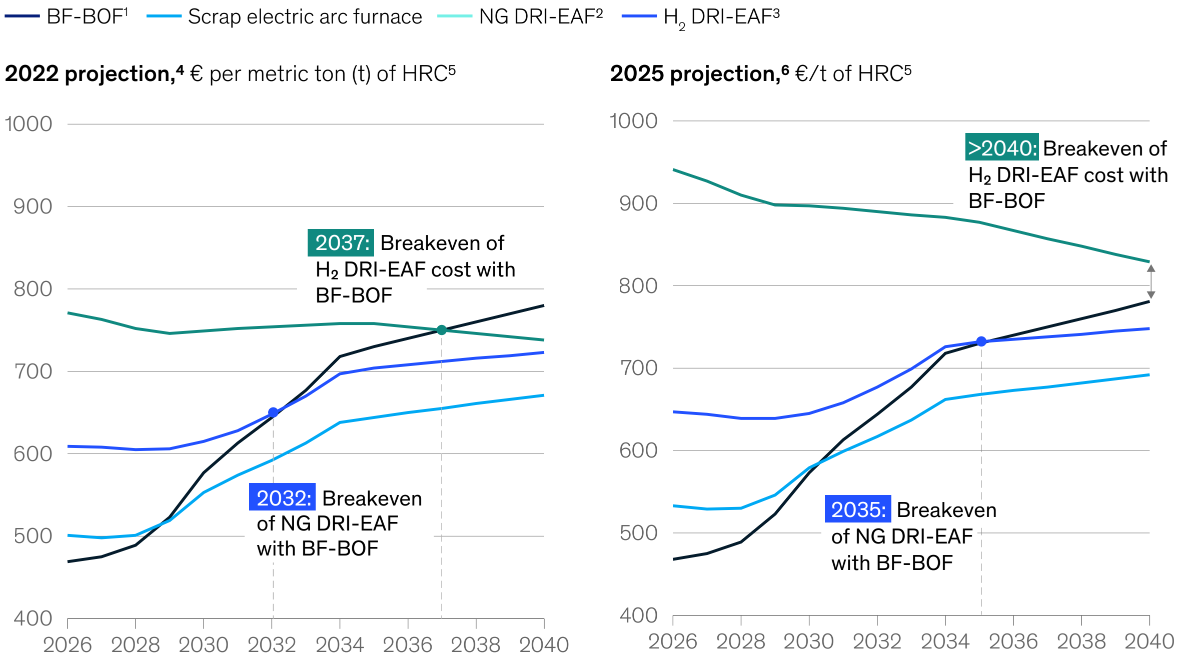
Forecasts of steel production costs in Central Europe highlight how the break-even point for low-carbon technologies is shifting.

Cost parity with the conventional blast furnace–basic oxygen furnace (BF–BOF) route is now expected to occur later than previously anticipated. Earlier projections placed hydrogen-based DRI with EAFs (H_2–DRI–EAF) at parity by 2037 and natural gas–based DRI–EAF by 2032. These milestones have since shifted to beyond 2040 and 2035, respectively.

The main reason for this change is the increase in projected electricity and hydrogen prices, which raises the overall cost.

This analysis suggests that without supportive policy measures or reductions in input costs, the competitiveness of green steel could be delayed by several years.

Case example: Projected steelmaking in Central Europe, as of July 2025



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[1] Blast furnace–basic oxygen furnace.
[2] Natural gas–based direct reduced iron–electric arc furnace.
[3] Hydrogen direct reduced iron–electric arc furnace.
[4] Cost assumptions: Electricity: €0.09 per kilowatt-hour (kWh) (2030) and €0.08/kWh (2040); H_2: ~€5.0/kg (2030) and ~€3.5/kg (2040); CO_2: ~€90/t (2030) and ~€150/t (2040).
[5] Including depreciation and amortization and excluding SG&A.
[6] Electricity: €0.13/kWh (2030) and €0.11/kWh (2040); H_2: ~€7.0/kg (2030) and ~€4.5/kg (2040); CO_2: ~€90/t (2030) and ~€150/t (2040).

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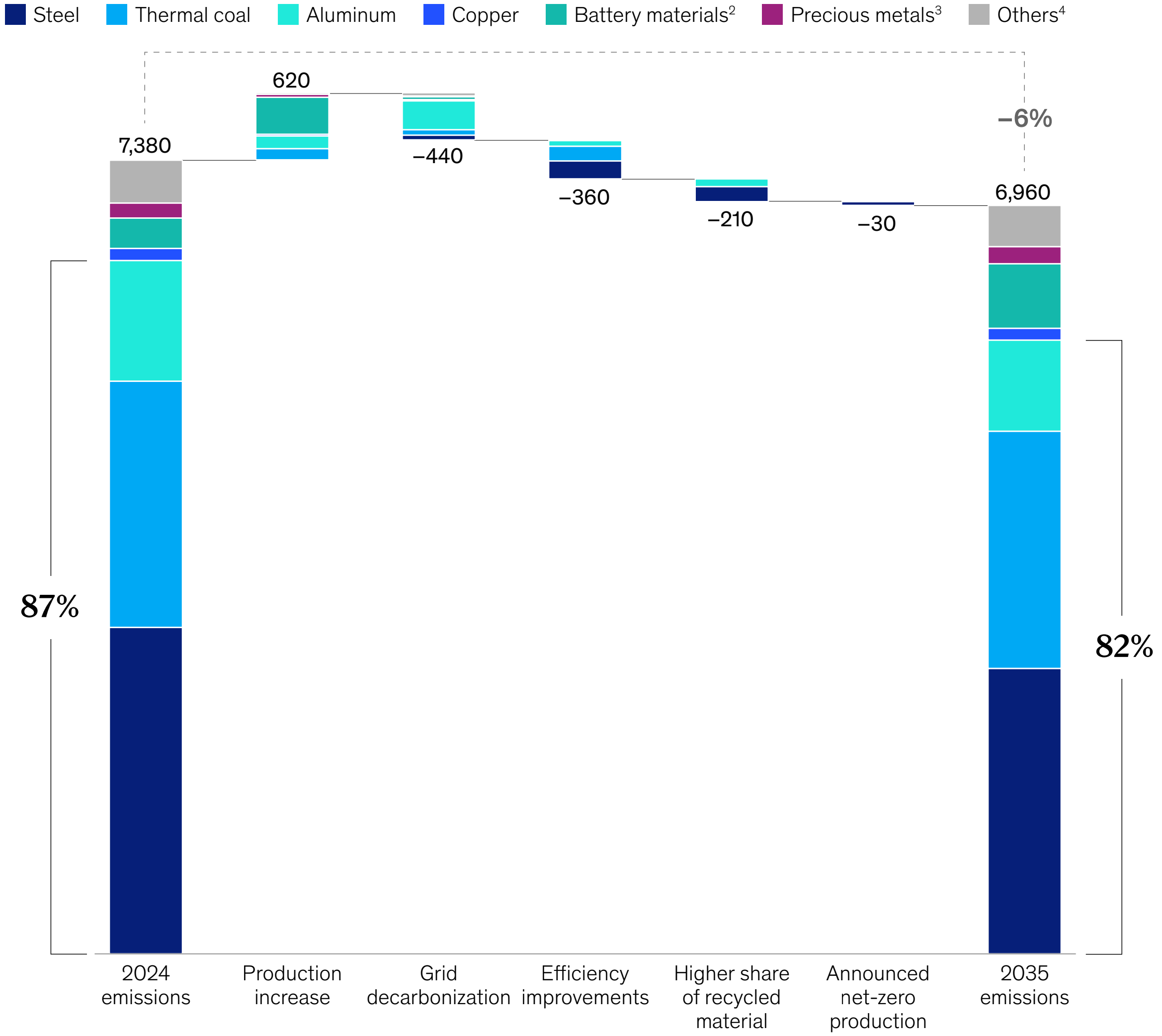
Metals and mining emissions are projected to decrease by a modest 6 percent by 2035

Over the next decade, total metals and mining emissions could decrease by a modest 6 percent. By 2035, demand growth is expected to add roughly 620 metric megatons of CO_2 equivalent per year, driven largely by the expansion of battery-material production. This increase is projected to be offset by grid decarbonization (responsible for about 40 percent of the emissions decline), efficiency improvements (30 percent), and greater use of recycled materials (20 percent), resulting in an overall net reduction in emissions.

Emissions from metals and minerals production,[1] metric megatons of CO_2 equivalent per year



Note: Figures are approximations; assumes long-term supply is equal to demand.

[1] Does not contain downstream Scope 3 emissions such as burning of thermal coal.

[2] Lithium, nickel, cobalt, manganese, and graphite.

[3] Gold and platinum group metals.

[4] Zinc, sulfur, uranium, etc.

Source: IEA; *Industrial transformation 2050: Pathways to net-zero emissions from EU heavy industry*, Material Economics, 2019; International Aluminium Institute; International Copper Association; Statista; World Steel Association; Transition Pathway Initiative; McKinsey MineSpans

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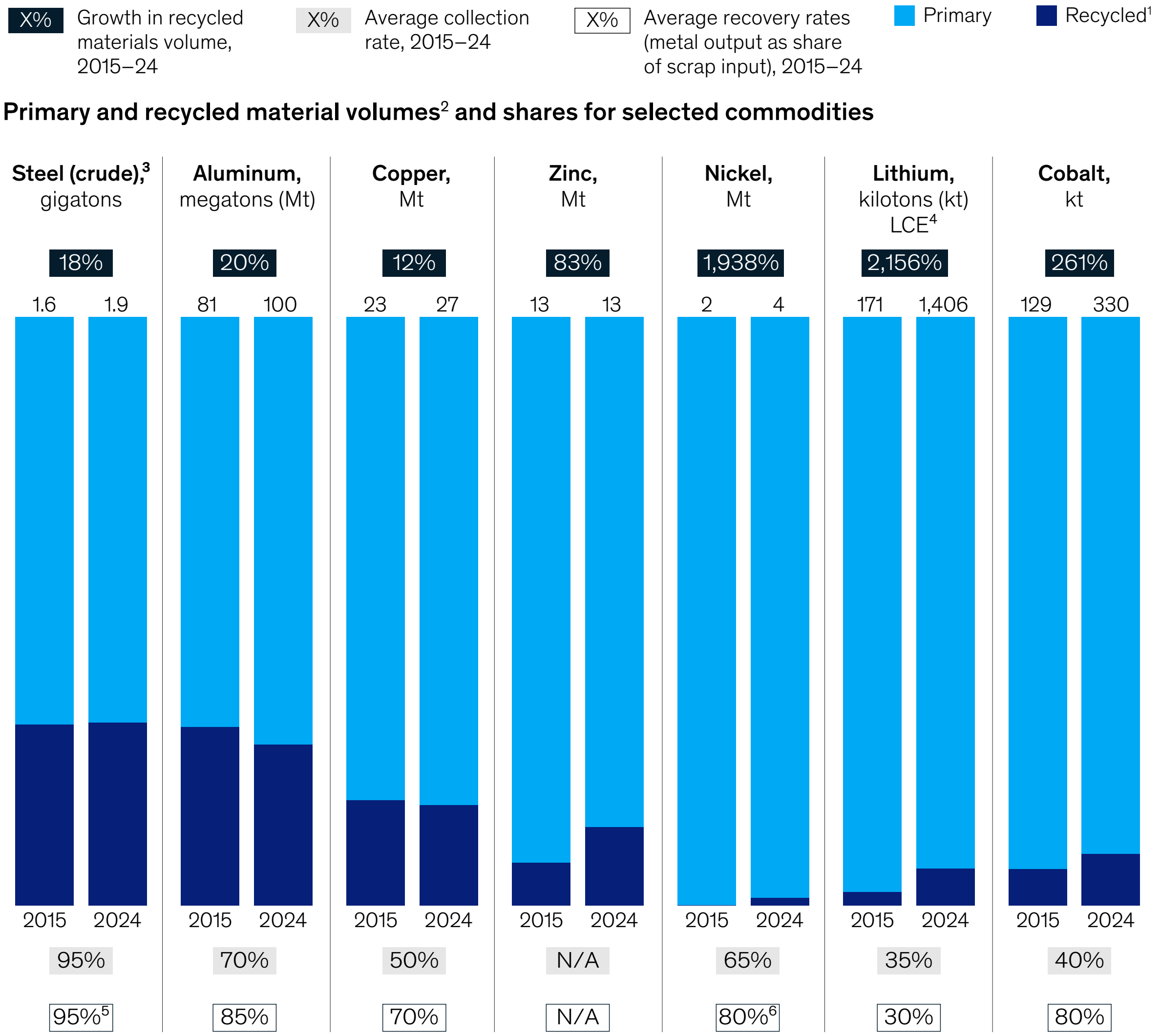
Scrap volumes have grown across materials, but total share of volumes only increased for zinc and battery materials

Since 2015, collection and recovery rates saw little improvement, with the exception of battery materials—cobalt, lithium, and nickel—because of growth in recycling initiatives.

For nickel and cobalt, the increase in recycled materials was driven by increasing collection rates, whereas the change for lithium was driven by both the collection and recovery rate. The share of recycled nickel remains low, given that recycling via stainless steel is excluded.

For zinc, both recycled materials volume and the share of recycled zinc increased, largely driven by China as more galvanized steel becomes available for recycling and the shift toward steelmaking with electric arc furnaces (EAFs) supports recovery.



Primary and recycled material volumes[2] and shares for selected commodities

Note: Tons are metric tons.

[1] Excluding runaround or "home" scrap. [2] Volume of total supply in metal units. [3] Total amount of crude steel produced in basic oxygen furnace and electric arc furnace steelmaking routes, using scrap, direct reduced iron, and pig iron. [4] Lithium carbonate equivalent. [5] Recovery rate for pure scrap. [6] Excluding stainless steel because it is not recycled as nickel.

Source: McKinsey Battery Insights; McKinsey MineSpans

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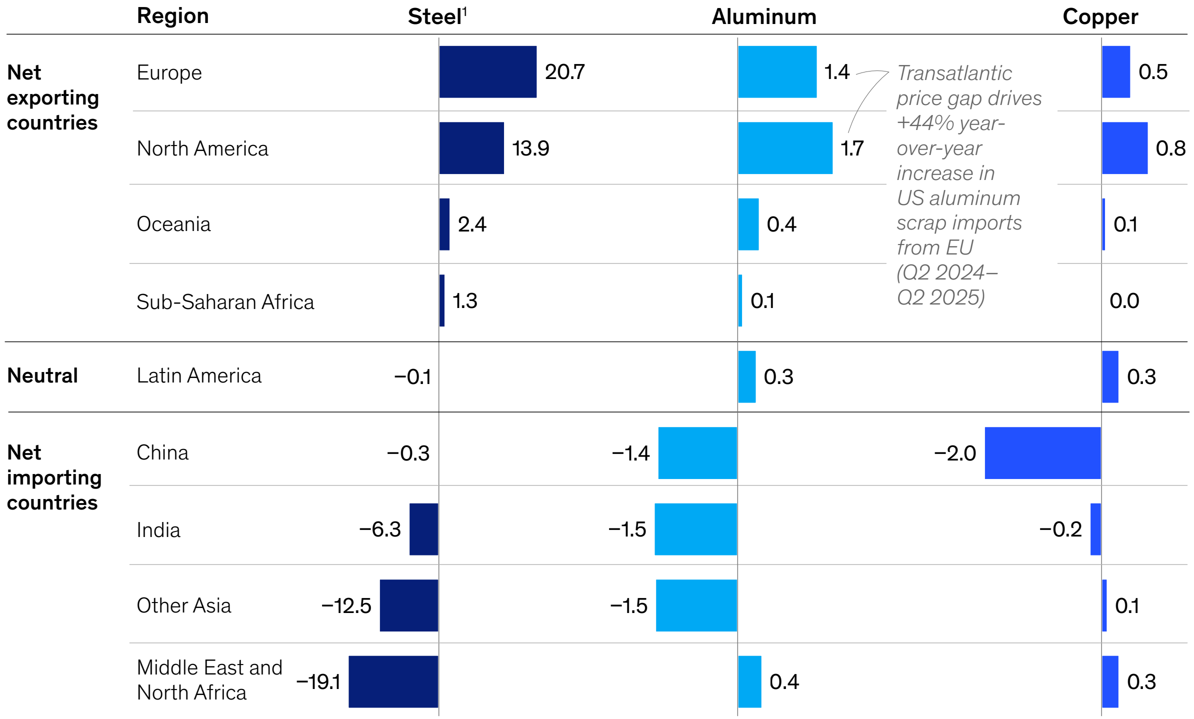
Western countries are exporting scrap across commodities to Eastern countries

Western countries remain net exporters of scrap, though patterns vary by material. Europe and North America ship steel scrap mostly to the Middle East and North Africa (MENA) and “other Asia” markets.[6] By contrast, the steel industries in China and India are based on basic oxygen furnaces, supported by domestic scrap, iron ore, and metallurgical coal, which limits their need for imports. Copper scrap follows a similar path, moving from Europe and North America to other Asia.

Aluminum scrap flows are more complex because aluminum scrap supply is limited and its quality is critical. High-quality scrap typically stays within mature markets, while lower-quality, mixed, or contaminated grades are exported to lower-cost countries for manual sorting and reuse. In China, a cap on primary aluminum production of approximately 45 metric megatons and rising decarbonization pressure are driving rapid expansion of secondary remelt capacity. This has boosted demand for high-quality scrap imports while restricting lower-quality material.

Annual net scrap trade flows, 2015–24 average, metric megatons



Transatlantic price gap drives +44% year-over-year increase in US aluminum scrap imports from EU (Q2 2024–Q2 2025)

[1]Not to scale with other commodities.

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[6] Asia excluding China, India, and MENA.

Various strategic moves—centered on availability and growth, productivity, affordability, and sustainability—exist to help players across the value chain navigate current uncertainties and capture opportunities.

Strategic moves mining players can consider

1. *Shingo Prize awards for mining companies committed to operating excellence.* Mining organizations are outperforming peers by focusing on adopting lean principles, technology integration, and culture change.
2. *Autonomous haulage systems proven at scale.* The number of autonomous haul trucks in operation worldwide surged by 84 percent from July 2024 to July 2025, increasing from approximately 2,000 to 3,800.
3. *Using AI to find the next tier-one mines.* A US-based start-up founded in 2018 leveraged AI to reveal overlooked mineral deposits and now runs more than 60 active projects across four continents.

Chapter	Priority themes	Potential strategic responses, nonexhaustive	
Availability and growth	*Geographic supply concentration*	**Diversify geographically** Target jurisdictions with incentives and partnership opportunities, or where you have a unique “right to play”	**Integrate vertically** Build or acquire integrated extraction and processing facilities closer to end markets
	Supply shortfalls and new growth horizons	**Expand in critical materials** Invest in high-growth materials, such as rare earth elements and copper, while remaining mindful of oversupply scenarios	**Build partnerships** Codevelop resilient supply chains with partners, such as data center developers or battery producers
Productivity and affordability	*Rising productivity challenges*	① **Strengthen lean operations principles** Strengthen culture of operational excellence, continuous learning, and improvement	② **Accelerate automation** Assess deployment of autonomous haulage, drilling, and systems to offset labor shortages
	AI and digital tools	**Deploy traditional AI** Apply geospatial mapping, ore sorting, and process optimization to boost recovery and cut waste	③ **Adopt gen AI solutions** Use gen AI for exploration, planning, maintenance, and operator support to lower costs and downtime
Sustainability	*An economic reality check*	**Decouple supply chains** Shift closer to end markets to manage exposure to tariffs, transport costs, and carbon regulations	**Collaborate downstream** Work with OEMs in developing low-carbon products to access shared financing or subsidies

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Strategic moves metals players can consider

1. *Government incentives leading to local supply chain opportunities.* Strategic projects can strengthen the local raw materials value chain and grant accelerated permitting and financing.
2. *Value chain reconfiguration for cost-competitive green transition.* Hot-briquetted-iron (HBI) hubs in low-cost energy regions could produce HBI locally and ship it to steel-producing regions with high energy costs, such as Europe.
3. *Expanded scrap collection infrastructure.* Opportunities exist to close the loop for recycling with OEMs, invest in technology to separate mixed scrap, set up take-back schemes (for old cars, for example), and establish deposit return systems (such as for aluminum cans in Europe).

Chapter	Priority themes	Potential strategic responses, nonexhaustive	
Availability and growth	*Geographic supply concentration*	① **Leverage incentives** Access government financing instruments to build out new local supply chains	**Strengthen scrap supply** Raise collection rates, invest in recycling tech, and assess location strategies to create sustainable growth opportunities
	Scrap availability	**Secure scrap access** Establish long-term contracts with scrap suppliers to mitigate volatility in availability and price	③ **Capture downstream flows** Work with OEMs, fabricators, and consumers to capture postindustrial and end-of-life scrap
	Supply shortfalls and new growth horizons	**Target niche growth sectors** Develop tailored offerings for the high-growth defense sector, such as specialty alloys	**Target niche growth sectors** Develop tailored offerings for high-growth sectors, such as defense (specialty alloys) and data centers
Productivity and affordability	*Rising productivity challenges*	**Source globally** Evaluate trade-offs between low-cost suppliers and incumbent OEM suppliers	**Diversify energy mix** Balance grid, renewables, and battery energy storage systems to reduce exposure to cost spikes and potentially create a revenue source
	AI and digital tools	**Deploy traditional AI** Apply process optimization to boost recovery and cut waste	**Adopt gen AI solutions** Use gen AI for planning, maintenance, and operator support to lower costs and downtime
Sustainability	*An economic reality check*	**Decouple supply chains** Shift closer to end markets to manage exposure to tariffs, transport costs, and carbon regulations	② **Reconfigure the value chain** Redesign operations to enhance efficiency, cost-competitiveness, and sustainability

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Strategic moves materials buyers can consider

Chapter	Priority themes	Potential strategic responses, nonexhaustive	
Availability and growth	*Geographic supply concentration*	**Stockpile critical inputs** Build inventory buffers and sign long-term agreements of key materials at the risk of cost and trade disruptions	**Secure local sourcing** Invest in domestic or regional suppliers to strengthen resilience and meet policy priorities
	Scrap availability	**Enable circularity** Partner with suppliers and customers to increase circularity and direct access to scrap	**Certify inputs** Adopt digital traceability platforms to prove ESG[1] credibility and provide competitive differentiation
	Supply shortfalls and new growth horizons	**Co-invest in supply** Provide financing or offtake guarantees to accelerate supply development for critical inputs	**Form innovation partnerships** Collaborate to codevelop tailored specialty products such as specialty alloys
Productivity and affordability	*Rising productivity challenges*	**Streamline specifications** Simplify material requirements to widen supplier options and reduce procurement complexity	**Adopt digital tools** Use traditional AI and gen AI to improve procurement efficiency and supplier management
	Increasing price and cost risks	**Hedge price risk** Use financial instruments or indexed contracts to reduce exposure to price volatility	**Enable new supply** Provide offtake guarantees or co-invest in projects to accelerate development despite higher prices
Sustainability	*An economic reality check*	**Leverage circular inputs** Increase use of recycled or secondary materials to reduce cost and carbon simultaneously	**Shape green demand** Signal clear requirements for low-carbon materials to encourage supplier investment

[1] Environmental, social, and governance.

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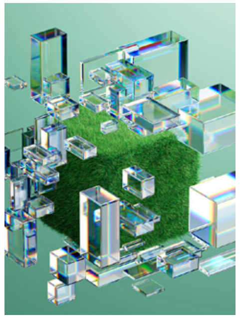

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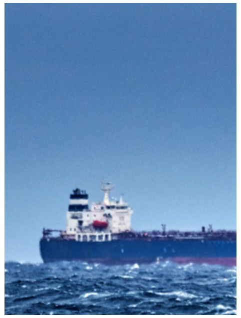

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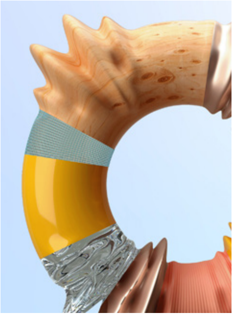

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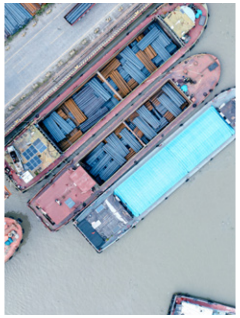

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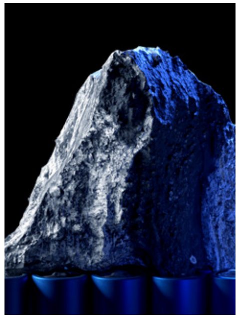

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