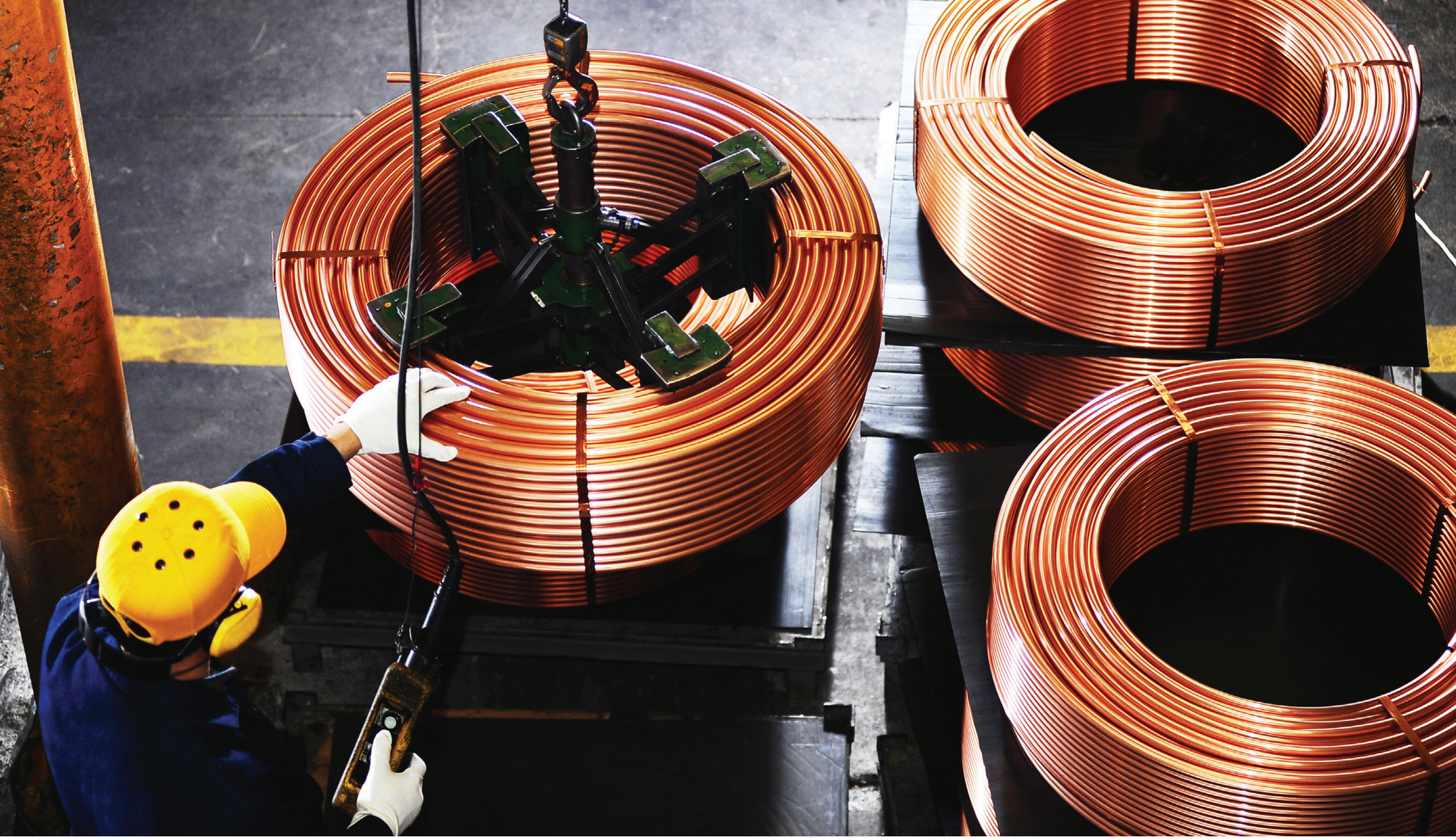

# The Future of Copper

## Will the looming supply gap short-circuit the energy transition?

Key findings and executive summary

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**For more information on this report, contact:**

Mohsen Bonakdarpour
Executive Director, Market Intelligence
mohsen.bonakdarpour@spglobal.com

Tabitha M. Bailey
Associate Director, Market Intelligence
tabitha.bailey@spglobal.com

**For media information, contact:**

Jeff Marn
Executive Director Public Relations, S&P Global
jeff.marn@spglobal.com

## Study objective

A number of authorities have expressed alarm as to whether there will be enough minerals to meet the requirements for the goal of Net-Zero Emissions by 2050. These include, among others, the US government, the European Union, the International Monetary Fund (IMF), the World Bank, and the International Energy Agency (IEA). The last, the IEA, has summarized the challenge as being driven by the move from "a fuel-intensive to a mineral-intensive energy system."

This study seeks to respond to that concern by focusing on copper, which can be described as the "metal of electrification." Many nations, including the United States and the European Union, have set Net-Zero Emissions by 2050 as their climate goal. Accordingly, this target was chosen as the basis for the study.

The study seeks to quantify the amount of additional copper that will be required by increased electrification and the energy transition—most specifically, the rapid move to electric vehicles (EVs) and renewable electricity and the need for increased electricity infrastructure. It concludes that copper demand will double by 2035 and continue to grow thereafter. On the supply side, it finds how challenging that will be, whether on the basis of current trends or with an unprecedented acceleration of supply from mining and recycling.

The study makes no policy recommendations. Rather, it seeks to respond to the urgent concern of the authorities above and others by quantifying the copper requirements of Net-Zero Emissions by 2050 and benchmarking them against the supply response. We hope that this study will be a contribution to the continuing dialog about achieving Net-Zero Emissions by 2050.

S&P Global is exclusively responsible for this report and all of the analysis and content contained herein. It represents the collaboration of S&P Global's Commodity Insights, Economics and Country Risk unit within Market Intelligence, and Mobility divisions.  The analysis and metrics developed during the course of this research represent the independent analysis and views of S&P Global and are intended to contribute to the dialogue on the copper required to meet the energy transition requirements under Net-Zero Emissions by 2050.

### Project Chairman

- Daniel Yergin, Vice Chairman, S&P Global

### Project Director

- Mohsen Bonakdarpour, Executive Director, Economics & Country Risk, S&P Global Market Intelligence

### Project Manager

- Tabitha M. Bailey, Associate Director, Economics & Country Risk, S&P Global Market Intelligence

### Project Team

- Mikhail Alekseenko, Consulting Principal, Upstream Consulting, S&P Global Commodity Insights
- Olivier Beaufils, Director, Energy Transition Consulting, S&P Global Commodity Insights
- Frank Hoffman, Consulting Principal, Economics & Country Risk, S&P Global Market Intelligence
- John Mothersole, Director, Non-Ferrous Metals, Economics & Country Risk, S&P Global Market Intelligence
- Keerti Rajan, Consulting Director, Economics & Country Risk, S&P Global Market Intelligence
- Nathalie Wlodarczyk, Vice President, Economics & Country Risk, S&P Global Market Intelligence

### Key Contributors

- Tristan Abbey, Consultant, Comarus Analytics LLC
- Veronica Burford, Senior Research Analyst, Economics & Country Risk, S&P Global Market Intelligence
- Jeff Marn, Executive Director Public Relations, S&P Global
- Eugenia Salazar, Consulting Analyst, Energy Transition & Strategy Consulting, S&P Global Commodity Insights
- Carla Selman, Principal Analyst, Economics & Country Risk, S&P Global Market Intelligence

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This report offers an independent and objective assessment of the role of copper in achieving the goals of Net-Zero Emissions by 2050. S&P Global is solely responsible for the analysis and conclusions in the report. This research was supported by the following organizations: Anglo American plc; Antofagasta plc; BHP Ltd; Compania de Minas Buenaventura S.A.A.; Freeport-McMoRan Inc.; Glencore plc; Ivanhoe Mines Ltd.; Rio Tinto Corporation; Sumitomo Metal Mining Co. Ltd.; Taseko Mines Limited; Teck Resources Limited; Lundin Mining Company; Trafigura Group Pte Ltd; and Vale Limited Mining Company.

# Contents

**Study objective** 3

**Key findings** 7

**Executive summary** 8

## Key findings

- Copper—the "metal of electrification"—is essential to all energy transition plans. But the potential supply-demand gap is expected to be very large as the transition proceeds. Substitution and recycling will not be enough to meet the demands of electric vehicles (EVs), power infrastructure, and renewable generation. Unless massive new supply comes online in a timely way, the goal of Net-Zero Emissions by 2050 will be short-circuited and remain out of reach.
- Copper demand is projected to grow from 25 million metric tons (MMt) today to about 50 MMt by 2035, a record-high level that will be sustained and continue to grow to 53 MMt by 2050. Power and automotive applications will have to be deployed at scale by 2035 in order to meet the 2050 net-zero targets.[1]
- The chronic gap between worldwide copper supply and demand projected to begin in the middle of this decade will have serious consequences across the global economy and will affect the timing of Net-Zero Emissions by 2050.
- The shortfall will reach as high as 9.9 MMt in 2035 in the Rocky Road Scenario, which is based on a continuation of current trends in capacity utilization of mines and recycling of recovered copper. This would mean a 20% shortfall from the supply level required for the Net-Zero Emissions by 2050 target.
- The gap arises even under assumptions of aggressive capacity utilization rates and all-time-high recycling rates in the High Ambition Scenario. Even with these aggressive assumptions, refined copper demand will outpace supply in the forecast period up to 2035.
- In the 21st century, copper scarcity may emerge as a key destabilizing threat to international security. Projected annual shortfalls will place unprecedented strain on supply chains. The challenges this poses are reminiscent of the 20th-century scramble for oil but may be accentuated by an even higher geographic concentration for copper resources and the downstream industry to refine it into products.
- In the United States, the nexus between a politicized regulatory process and the ubiquity of litigation makes it unlikely that efforts to expand copper output in the United States would yield significant increases in domestic supply within the decade. The prospects for any expansions are higher on state and private lands.
- Under the Rocky Road Scenario, the United States will have to import 67%—that is two-thirds—of its refined copper demand by 2035. Even in the High Ambition Scenario, the United States will still need to import 57% of the refined copper during the years of highest energy transition–related copper demand.
- The complexity of permitting mines in the United States is reinforced by the long lead times also required elsewhere around the world. Multidimensional challenges make the development of mines a generational endeavor, spanning decades and requiring hundreds of billions of dollars. Projects under development today would likely not be sufficient to offset the projected shortfalls in copper supply, even if their permitting and construction were accelerated.

1. A metric ton is a metric unit of mass equal to 1,000 kilograms. It is also referred to as a tonne. It is equivalent to approximately 2,204.6 pounds; 1.102 short tons; and 0.984 long tons.

## Executive summary

This report examines the looming mismatch, on a global basis, between available copper supply and future copper demand resulting from the energy transition. It highlights the increasing uncertainty surrounding whether burgeoning global climate change ambitions can be satisfied with existing and potential sources. Unless new supply for "the metal of electrification" comes online in a timely way, Net-Zero Emissions by 2050 will be short-circuited and remain out of reach.

Plentiful access to certain "critical minerals" is crucial to delivering on the widespread commitments to eliminate global net carbon dioxide ($CO_2$) emissions by 2050 (although major emitters like China and India are, respectively, targeting 2060 and 2070).[2] Paramount to achieving these goals is electrifying the global vehicle fleet and aggressively switching to renewable energies for power generation, which are two of the primary prongs of the energy transition.[3] While a variety of metals and rare earth elements have received a great deal of attention by governments, media, think-tanks, and universities, one of the most underappreciated critical minerals is also one of the most familiar and most fundamental—copper. Deeper electrification requires wires, and wires are primarily made from copper. Moreover, copper ore deposits often contain other critical minerals wherein those mining operations yield significant by-product production of other metals such as cobalt, molybdenum, and nickel.

The analysis in this report is built from a detailed bottom-up approach, technology by technology, and compares projected copper demand resulting from the energy transition against projected copper supply. It represents the collaborative work of groups within S&P Global, including the Economics and Country Risk team within Market Intelligence, Commodity Insights, and Mobility.

On the demand side, the analysis works "bottom up"–that is, in a granular way–technology by technology, from assumed implementation of the announced US and EU goals of Net-Zero Emissions by 2050. These policies are the starting point for the analysis, not recommendations. On the supply side, the study offers two views of the future: (1) the High Ambition Scenario, which is based on highly optimistic assumptions about advances in recycling and capacity utilization of mines and refineries; and (2) the Rocky Road Scenario, which is based on a continuation of recent recycling and capacity utilization rates, which are lower.

The key point is this: technologies critical to the energy transition such as EVs, charging infrastructure, solar photovoltaics (PV), wind, and batteries all require much more copper than conventional fossil-based counterparts. The rapid, large-scale deployment of these technologies globally, EV fleets particularly, will generate a huge surge in copper demand. Major investments in the power grid to support electrification will further amplify the trend. Meanwhile, copper continues to be a critical material for many other sectors of the economy not directly related to the energy transition but fundamental to overall economic growth and development, and from which copper consumption is projected to grow continuously. The result of the energy transition growth on top of traditional growth will be an overall more than doubling of copper demand by 2050.

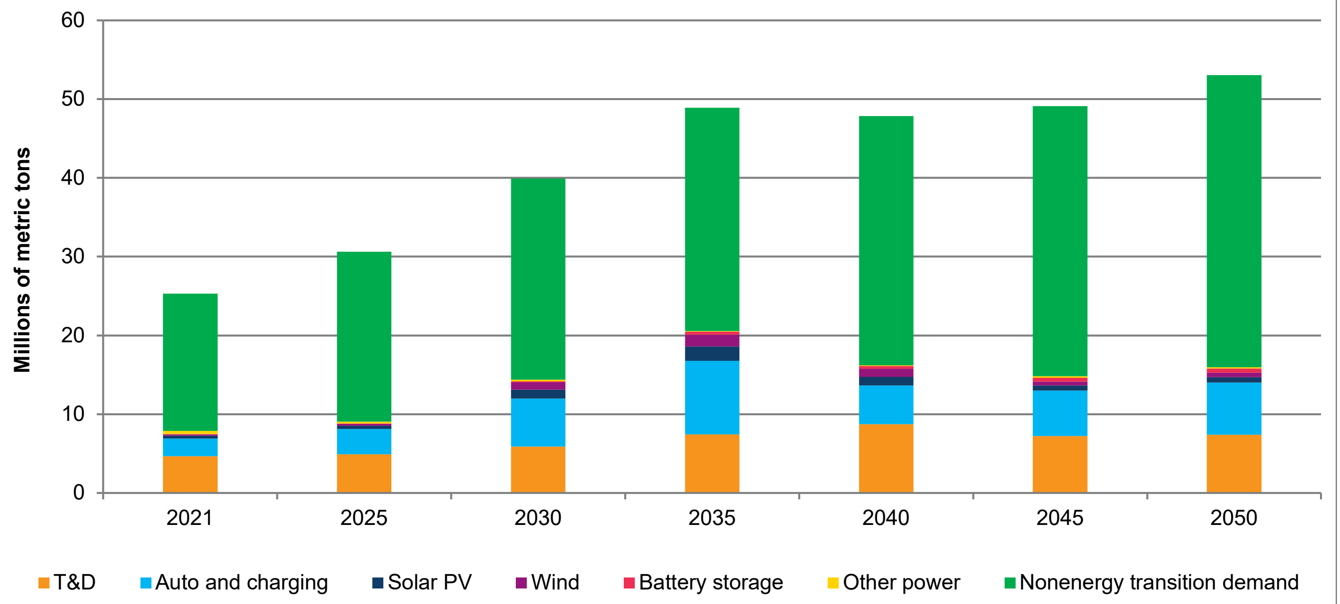
2. "Critical minerals" is a term often used in the United States. The list of 50 items (in 2022) produced by the US Geological Survey uses criteria defined in the (US) Energy Act 2020. Most of these are widely used across the industry and may or may not be used in carbon emission–reducing applications. The European Commission similarly produces a "critical raw materials" list; and China published a list of "strategic minerals" under its National Mineral Resources Planning, 2016-2020.

3. Assumptions for electrifying the global fleet includes the increased penetration of fuel-cell electric vehicles, powered by hydrogen.

This study finds that copper demand from the energy transition will accelerate steeply through 2035. Crucially, this dramatic escalation occurs well before 2050 while traditional growth continues to ramp up. The conclusion: achieving the stated climate ambitions will require a rapid and massive ramp-up of copper supply far greater than is visible in any private or public plan.

**Global refined copper usage**




Note: Based on S&P Global's Multitech Mitigation scenario; US values are adjusted to align with Biden administration's net-zero ambitions. T&D = transmission and distribution; PV = photovoltaics; other power includes conventional generation (coal, gas, oil, and nuclear), geothermal, biomass, waste, concentrated solar power, and tidal.
Source: S&P Global analysis



This energy transition demand growth will be particularly pronounced in the United States, China, and Europe. India will also exhibit strong copper demand growth, albeit more so from traditional copper applications. The High Ambition Scenario assumes that ramped-up demand growth will coincide with record-high rates of copper mine capacity utilization and recycling, but even these aggregated improvements will be insufficient to close the gap. In the Rocky Road Scenario, the shortfall will be much greater, and sooner.

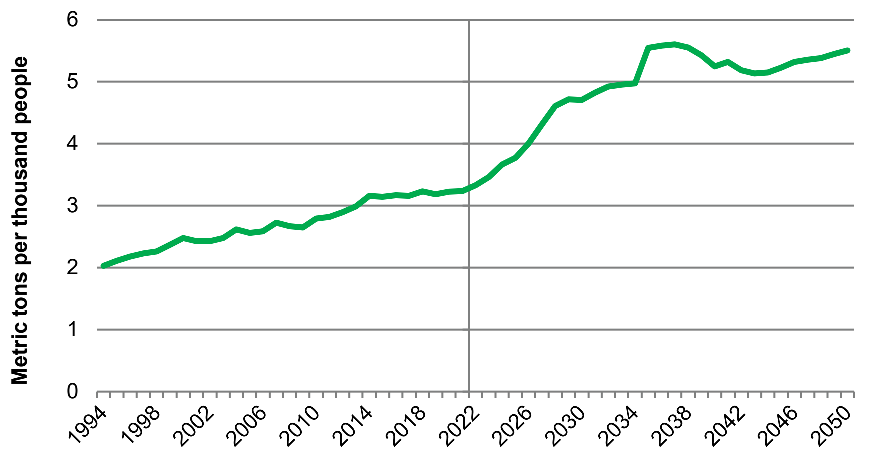
The initial increase in demand over the coming decade will be particularly challenging. Global refined copper demand is projected to almost double from just over 25 MMt in 2021 to nearly 49 MMt in 2035, with energy transition technologies accounting for about half of the growth in demand. The world has never produced anywhere close to this much copper in such a short time frame.

Demand from nonenergy transition end markets—such as building construction, appliances, electrical equipment, and brass hardware and cell phones, as well as expanding applications in communications, data processing, and storage—is also expected to continue to grow, rising at a compounded annual rate of 2.4% between 2020 and 2050. Altogether, total refined copper demand is expected to reach approximately 53 MMt in 2050. It is important to note that copper demand would see significant increases over the projection period even in a world that did not fully transition to net zero. Copper demand from energy transition end markets is expected to reach a maximum of almost 21 MMt in 2035. This surge in demand to meet Net-Zero Emissions by

2050 requires a near doubling of today's global copper supply by 2035, an expansion that current exploration trends or projects in the feasibility stage of development are incapable of meeting.

Per capita consumption of copper has been rising steadily since the early 1990s. Per capita consumption growth will accelerate markedly between 2024 and 2035 as investments to meet Net-Zero Emissions by 2050 targets are made and developing countries continue to industrialize. After the middle of the next decade, copper consumption per capita plateaus as EV sales begin to slow once fleets are mostly electrified. In a world moving to net zero, new copper supplies will be necessary to maintain this elevated level of consumption.

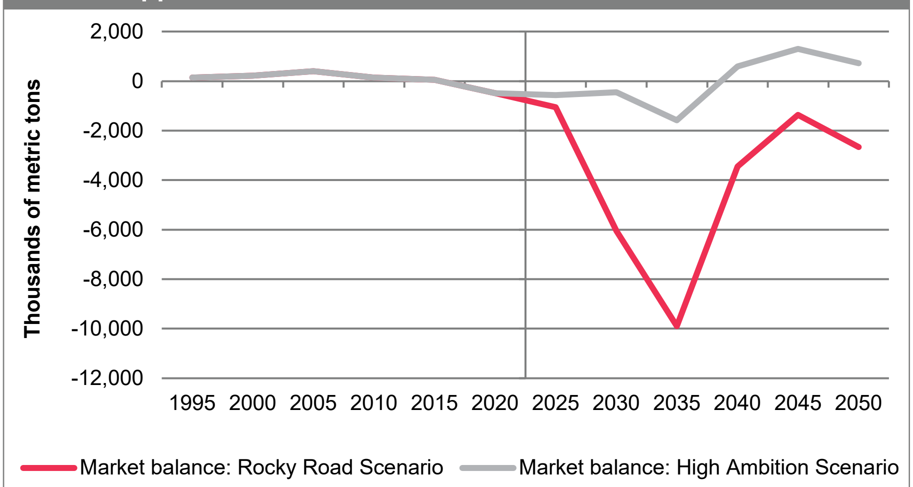
Global refined copper consumption per capita




Source: International Copper Study Group (ICSG), S&P Global © 2022 S&P Global

This study finds that copper supply shortfalls begin in 2025 and last through most of the following decade. In the High Ambition Scenario, surpluses will likely emerge in the 2040s as energy transition copper demand slows and secondary production (the refining of recycled copper) sees an upswing. If capacity utilization and recycling rates do not improve and instead reflect their average rates over the past decade—as in the Rocky Road Scenario—then these surpluses would not arise and a much steeper gap between supply and demand would persist through 2050. Unless the considerable gap between demand requirements and supply realities is closed, especially between 2025 and 2035, the 2050 target for net zero will be pushed further into the future.

Global copper market balance




Source: ICSG, S&P Global © 2022 S&P Global

The challenge will be compounded by increasingly complex global geopolitical, trade, and country-level risk environments. There are several dynamics that will have a particular bearing on copper access. China holds a preeminent position in copper smelting (47%), refining (42%), and usage (54%), in addition to its sizable position in production, making it the epicenter of world copper. Continued trade tensions and other forms of competition between the United States and China could affect the copper market going forward. Supply chain resilience has emerged as a strategic imperative, particularly after the COVID-19 pandemic and the war in Ukraine. The study finds that by 2035 the United States will be importing between 57% and 67%—that is up to two-thirds—of its copper needs. An intensifying competition for critical metals is very likely to have geopolitical implications.

In a period of high demand, prices will rise, which is a stimulus to investment. While price is a significant incentive, there are other considerations that also affect the pace of investment. These include the absence of actual development opportunities, as well as environmental issues, social license to operate, relationships with local communities, and locational accessibility.

The resulting challenge for all actors involved in the energy transition will be to manage sometimes competing and often contradictory priorities. To achieve Net-Zero Emissions by 2050 will likely require major innovations in technology and approaches to policies, including ones that encourage long-term investment, because there is no way to forestall the projected shortages in copper without taking steps to increase supply. Three priority areas stand out for consideration and further refinement given the findings of this study:

- **Policy:** Regulatory and fiscal regimes need to be stable and predictable to encourage investment and facilitate construction of new mines, processing facilities, and recycling plants. Mines are generational endeavors requiring billions, even tens of billions, of dollars with development timelines that span decades. Clear policy objectives that connect critical minerals production with clean energy end-use goals would provide investment stability and assure long-term political acceptance and social license—important steps for reducing the delay in developing new copper resources for the market.

- **Technology:** Innovation that enables cleaner, more efficient, and lower-cost extraction and refining of copper could help increase supply directly. If such innovation addressed environmental and social concerns of a growing portion of investors, then it would also attract more capital into the industry and increase supply indirectly.

- **Interdependencies:** The energy transition will require not only more copper but also other critical minerals, many of which are only produced as co-products or by-products of copper processing (smelting and refining). Some of these are already identified under nascent government initiatives—particularly in the United States and the European Union—while others are not. Understanding these wider interdependencies will be important to ensure that the path forward is not blocked by similar issues emerging for other critical minerals required for increased electrification.

## Customer Care

CustomerCare@ihsmarkit.com

**Asia and the Pacific Rim**

Japan: +81 3 6262 1887

Asia Pacific: +604 291 3600

**Europe, Middle East, and Africa: +44 (0) 1344 328 300**

**Americas: +1 800 447 2273**