

FEBRUARY 2024

Copper: The Red Metal's Central Role in Powering Our Net-Zero Carbon Future

Copper's exceptional electrical conductivity and contribution to energy efficiency make it a critical element in energy transmission.



Sprott

Copper is the oldest metal known to civilization and derives its name from the Latin word Cuprum, for the island of Cyprus where Romans first found the red metal.

This white paper introduces the trends that are driving copper markets and copper miners, and explains our positive outlook for growth. The case for copper and copper mining equities comes down to five converging factors.





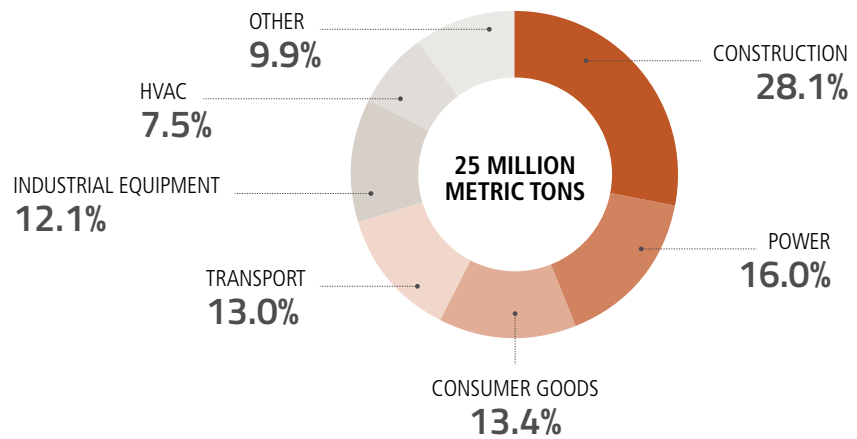
Copper: An Ancient Metal Crowned King of Electrical Transmission

Our connection with copper stretches back over 10,000 years.¹ This chemical element, symbolized as Cu and atomic number 29 on the periodic table, was among the earliest metals harnessed by humans. For nearly 5,000 years, it stood as the sole metal known to our ancestors. Beginning possibly in Cyprus, copper found its initial applications in crafting coins, jewelry, tools and weaponry, playing a pivotal role in societal progression. During the Bronze Age, copper's significance escalated, with the era characterized by the transition from stone tools to those made of bronze, a blend of smelted tin and copper. Its valued properties include durability, malleability and dependability.

Copper's excellent electrical conductivity first came into play in the 1810s, when it was used in early telegraph systems. Today, in the United States alone, copper is a crucial element in nearly 7 million miles of electrical transmission and distribution wires.²

The extensive market for copper and its varied applications across a myriad of industries have historically positioned its price as a gauge of the global economy. As of 2022, the copper market holds a value of \$183 billion, ranking as the third-largest metal market (behind iron ore and gold) in terms of U.S. dollar value.³ While copper has traditionally been instrumental in fields ranging from construction to electronics, its current demand focus has shifted toward aiding clean energy. Presently, this sector accounts for 25% of the worldwide copper demand, a figure projected to soar to 61% by 2040.⁴

Figure 1. Copper: The Multi-Purpose Red Metal



Source: BloombergNEF. Note: "HVAC" refers to heating, ventilation and air conditioning. Included for illustrative purposes only.

¹ Source: Copperalliance.org. <https://copperalliance.org/sustainable-copper/about-copper/>.

² Source: BNEF U.S. Power Grid Buildout Dampened by Piecemeal Strategy. August 2023.

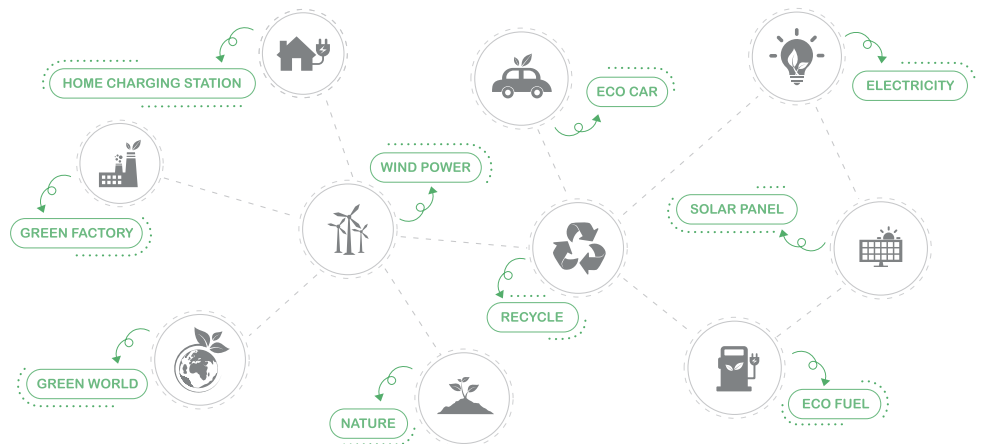
³ Source: Visualcapitalist.com, How Big Is the Oil Market, 6/30/2023. <https://www.visualcapitalist.com/how-big-is-market-for-crude-oil/>.

⁴ Source: BloombergNEF, a leading provider of forward-thinking primary research and analysis on the trends driving the transition to a lower-carbon economy.

Key Trends Supporting Copper and Copper Miners

- 1 Copper Is Essential for Decarbonization** – The push toward net-zero emissions by 2050, driven by global mandates and goals, is set to escalate the development of copper-intensive infrastructure, such as power grids, electric vehicles (EVs) and clean energy technologies.
- 2 Copper Demand Is Surging** – Emerging clean-energy technologies require significantly more copper than traditional systems. This surge in demand coincides with an anticipated 86% increase in global electricity consumption by 2050 (see Figure 5).
- 3 Copper Supply Faces Challenges** – The global copper supply faces significant hurdles, including decreasing ore quality, prolonged lead times for opening new mines and an extended period of underinvestment. These factors underscore the critical role of copper mining companies in meeting demand.
- 4 Copper Price Dynamics Spurring New Production** – Rising copper prices may be the catalyst needed to motivate the development of new projects aiming to help satisfy the growing appetite for copper.
- 5 Copper Miners May Offer Opportunities** – The widening gap between supply and demand may likely translate into benefits for both copper prices and the mining companies involved. Additionally, an uptick in mergers and acquisitions (M&A) within the industry could further strengthen the position of copper miners.

NET-ZERO DEFINED



“Net-zero” is a term often used for carbon neutrality. However, the phrase can also be used to indicate broader greenhouse gas impacts, including nitrous oxides and other greenhouse gases.

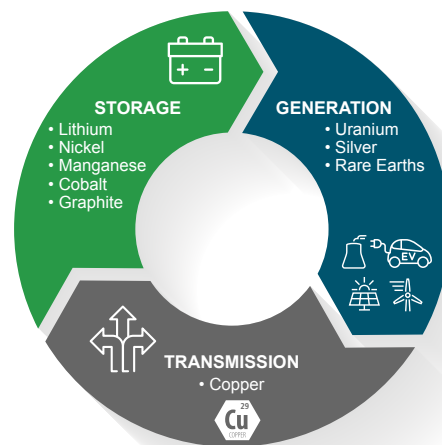
Source: <https://www.un.org/sg/en/content/sg/articles/2020-12-11/carbon-neutrality-2050-the-world%E2%80%99s-most-urgent-mission>.

1 Copper Is Essential for Decarbonization

Copper plays a pivotal role in the shift toward clean, carbon-free energy. Both power grids and electric vehicles heavily depend on copper for efficient electricity transmission. In recognition of its vital role, copper has been designated as a critical mineral by major global players, including the European Union, the U.S., Canada, Japan, China and India.⁵

The journey to global net-zero emissions by 2050 may likely see copper taking center stage in its role as the leading transmission metal.

Critical Minerals Across Three Functions: Generation, Transmission, Storage



As countries commit to net-zero emissions by 2050, the world is gearing up for a massive energy overhaul, with copper being a key element. This global decarbonization effort is both ambitious and copper intensive.

Currently, about four-fifths of the world's energy is generated from fossil fuels. To align with the Paris Agreement's climate goals, a dramatic shift is needed, with the IEA (International Energy Agency) estimating that at least 80% of energy production must move to low-carbon sources. At the UN's COP28 climate summit in late 2023, 118 governments pledged to triple the world's renewable energy capacity by 2030 to help lessen the world's reliance on fossil fuels for energy production. This clean energy transition hinges on copper and other critical minerals.

The global energy shift toward reducing CO₂-intensive sources in favor of cleaner alternatives places a premium on critical minerals like copper. Establishing new copper production takes time, and with existing supplies dwindling, the race to meet the increasing demand is more urgent than ever.

⁵ Source: Metal Center News, 8/4/2023. Copper Included on Department of Energy Critical Minerals List. <https://www.metalcenternews.com/editorial/association-news/copper-included-on-doe-critical-minerals-list--/45142>.

Why Copper?

- Although silver is slightly more conductive, it's too expensive to be used widely. And while aluminum is used in some cases, it's only 61% as conductive, and it needs to be much thicker than copper in order to carry the same amount of current.
- Copper also has a role to play in modern computing technologies. While we've come to associate computers with silicon, copper is used as a semiconductor in many hardware components.

Source: <https://www.worldcoppersmith.com/articles/copper-in-history/> and https://en.wikipedia.org/wiki/Copper_interconnects.

Copper Powers Daily Life

Copper is an essential critical mineral that is found in a variety of everyday items:

[Electric Vehicles](#)

[Smartphones](#)

[Buildings and Roofs](#)

[Pipelines](#)

[Household Appliances](#)

[Dietary Supplements](#)

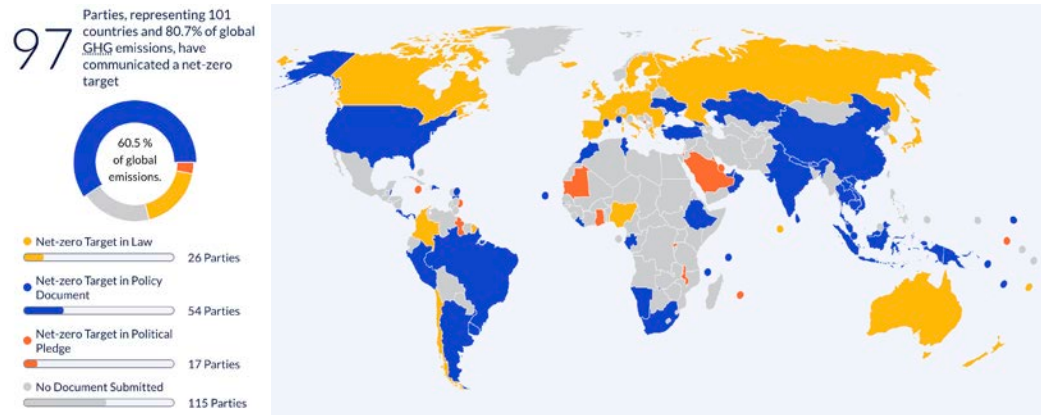
Interesting Copper Facts

Ötzi the Iceman – In 1991, archaeologists found the remains of a man dating to 3300 BCE in the Ötztal Alps. He was discovered with a perfectly preserved axe made of 99.7% copper.

Space: 1977 – NASA launched the Voyager Golden Records into space with sounds from Earth. The copper phonograph disks were designed to keep their data intact for a billion years.

U.S. Statue of Liberty – The Statue of Liberty is made out of copper that is 2.4 millimeters thick, and decades of exposure to the elements have led to its blue-green patina.

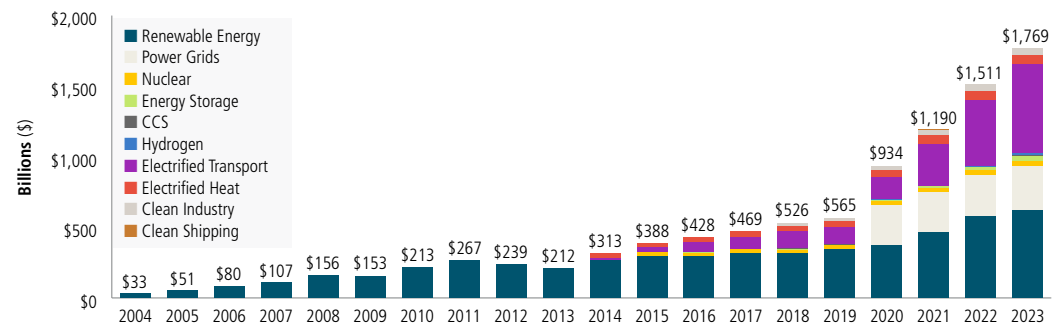
Figure 2. Global Decarbonization Goals Are Ambitious and Copper Intensive



Source: Climatewatchdata.org at <https://www.climatewatchdata.org/net-zero-tracker> as of 1/10/2024. Included for illustrative purposes only.

This shift to cleaner technologies has created a dynamic growing investment market. For the first time, substantial investment is following the rhetoric. Global investment in the energy transition has surged to \$1.8 trillion in 2023 and now far exceeds investments made in fossil fuels. Energy transition investments will need to average \$4.8 trillion from 2024 to 2030 to get on track for global net-zero targets by 2050. In the 2030s, it is estimated that average annual investment levels will approach \$7 trillion.⁶

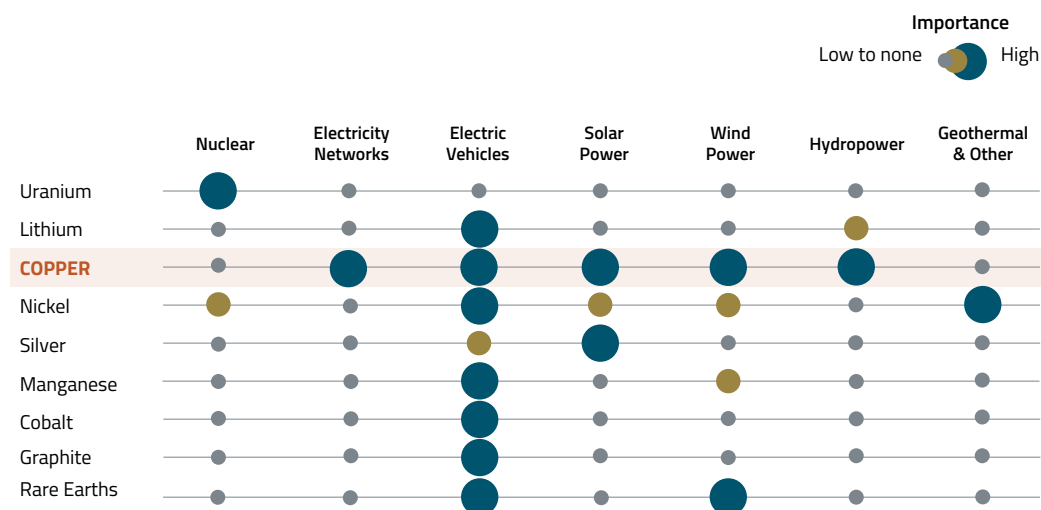
Figure 3. Surging Global Investment in Clean Energy



Source: BloombergNEF Energy Transitions Trends 2024. Included for illustrative purposes only.

⁶ Source: BloombergNEF is a leading provider of forward-thinking primary research and analysis on the trends driving the transition to a lower-carbon economy.

Figure 4. Cleaner Technologies Rely on Copper



Source: Critical raw materials for strategic technologies and sectors in the EU: A foresight study, European Commission, March 9, 2020; The role of critical minerals in clean energy transitions, IEA, May 2021; McKinsey analysis. Included for illustrative purposes only.

Figure 4 reflects Sprott’s critical minerals focus and is not inclusive of all critical minerals. For example, the U.S. Geological Survey (USGS) “2022 Final List of Critical Minerals” includes 50 minerals.⁷

2 Copper Demand Is Surging

By 2050, it’s projected that the global electric grid will need to double in capacity in order to meet the 86% increase in electricity demand (see Figure 5). Countries must shift their production mix to include a much higher share of greener energy sources to lower greenhouse gas (GHG) emissions from electricity production while accommodating expanding demand. This expansion is estimated to require an annual investment of \$1 trillion, accumulating to nearly \$21 trillion by 2050 (see Figure 6). These upgrades necessitate a substantial amount of copper, estimated at 427 million metric tons by 2050.⁸ Moreover, as urban areas grow, the shift toward underground wiring, which requires twice as much metal as overhead lines, is intensifying the demand for copper.

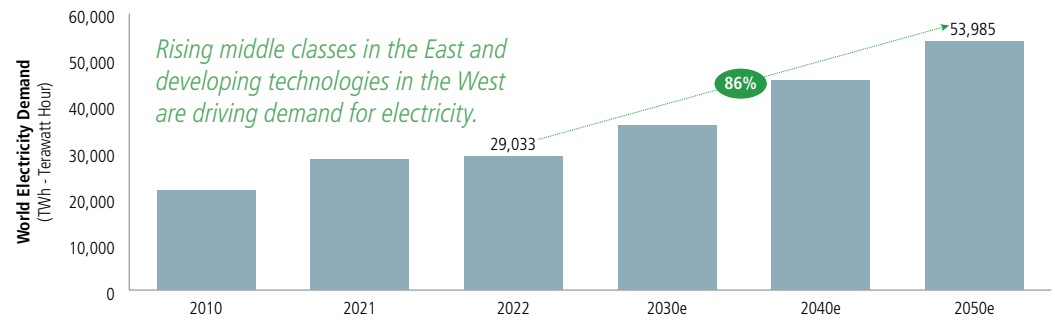
The drive toward carbon-free technologies further escalates copper’s significance. These technologies necessitate expanded electricity networks that heavily rely on copper. With the global increase in electricity production, there’s a corresponding rise in grid development to integrate new energy sources. Notably, renewable energy installations like wind and solar farms are often smaller than traditional coal and gas facilities, leading to a higher number of farms. Such energy sources are often located away from population centers, increasing the need for power lines.

⁷ Source: <https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals>.

⁸ Source: BloombergNEF, A Power Grid Long Enough to Reach the Sun Is Key to the Climate Fight, 3/8/2023. <https://about.bnef.com/blog/a-power-grid-long-enough-to-reach-the-sun-is-key-to-the-climate-fight/>.

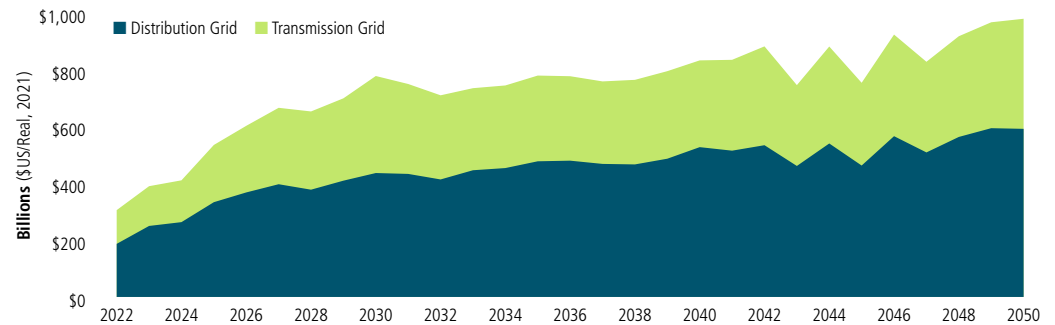


Figure 5. Global Electricity Demand Estimated to Increase 86% by 2050



Source: IEA World Energy Outlook 2023 Stated Policies. Included for illustrative purposes only.

Figure 6. Global Grid Spending Will Require Close to \$1 Trillion by 2050 to Reach Net-Zero Emissions



Source: Annual spending based on the Net Zero Scenario in BNEF's New Energy Outlook, as of 3/9/2023. Included for illustrative purposes only.

The shift from internal combustion engines (ICEs) to EVs is copper intensive and a critical component of decarbonizing transportation. Copper is essential in EVs, finding use in electric motors, batteries, inverters, wiring and charging stations. An EV requires 53 kilograms of copper, about 2.4 times more than a conventional combustion vehicle (see Figure 7). This volume of wire can extend up to a mile in length. Although efforts are underway to reduce copper in EVs, demand is still projected to hit 2.8 million metric tons by 2030.⁹

Additionally, renewable energy infrastructure including solar and wind power needs considerably more copper than fossil fuel-based technologies, typically ranging from 2.5 to 7 times more, depending on whether the installations are onshore or offshore, according to the IEA (see Figure 7). The capacity for solar and wind energy has been on an upward trajectory globally and is expected to continue growing. For instance, the U.S. Energy Information Administration (EIA) predicts that solar power might constitute over half of the new U.S. electricity capacity by 2024.

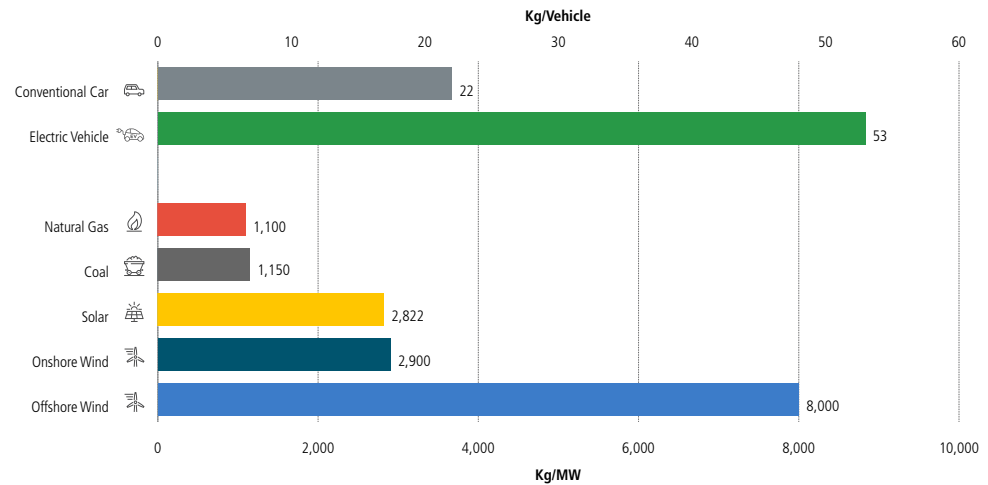
⁹ Source: Reuters, Innovation in EVs seen denting copper demand growth potential, 7/9/2023. <https://www.reuters.com/business/autos-transportation/innovation-evs-seen-denting-copper-demand-growth-potential-2023-07-07/>.

Did You Know?

- Copper is often known as “Dr. Copper” because of its history of being a leading indicator of global economic conditions.
- More than 400 alloys of copper are in use today.
- Copper is essential to the health of animals, plants and humans, and foods rich in copper include chocolate, soybeans, peas, beans, almonds, seafood and whole wheat.
- Copper production came into its own during the Industrial Revolution, when new technologies made it easier to mine and process copper than ever before. Along with iron and steel, large blast furnaces and reverberatory furnaces could be used to process copper in greater and greater quantities.
- Copper is also relatively easy to recycle, and refined scrap metal left over from manufacturing or from previously used products accounts for up to 17% of copper production.

Source: <https://www.worldcoppersmith.com/articles/copper-in-history/> and <https://icsg.org/>.

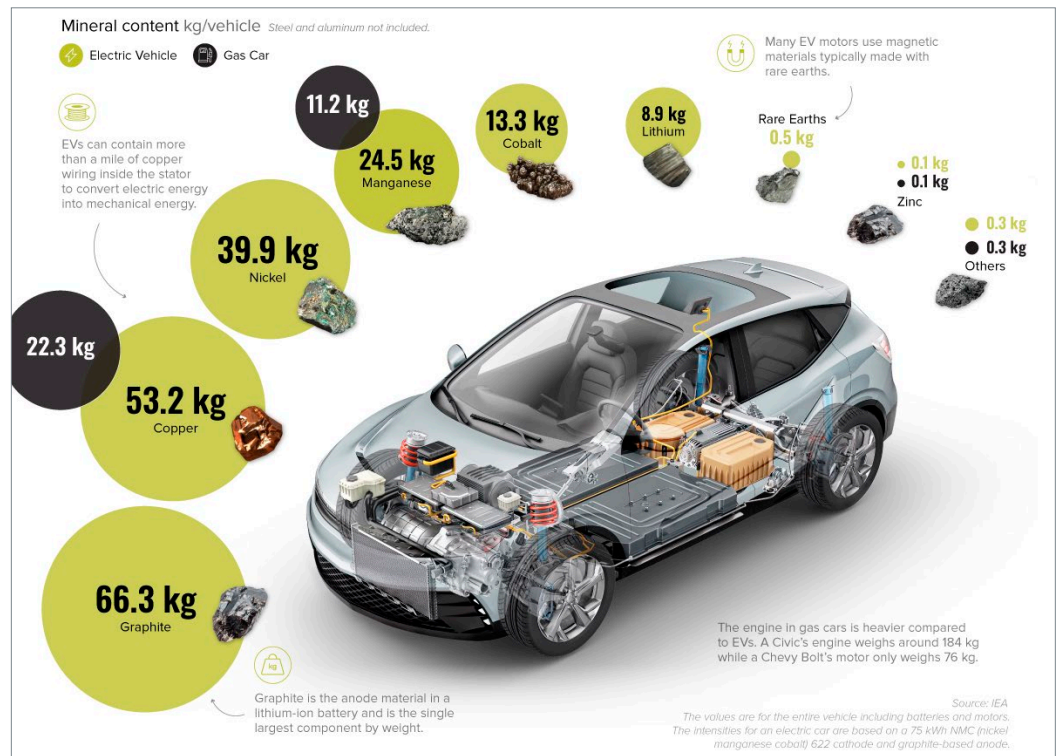
Figure 7. EVs and Renewables Require More Copper



Source: The role of critical minerals in energy transition, IEA, May 2021. Included for illustrative purposes only.

Given these developments, it’s anticipated that copper demand will be increasingly driven by EVs and renewable energy sources. Investments in renewables are poised for steady growth in the coming years. EV sales, which surpassed 10 million in 2022—a fivefold increase from 2019—are forecast to reach 14 million vehicles in 2023.¹⁰ This surge is pushing 23 countries toward the 5% adoption rate, a threshold often seen as a tipping point for a technology’s market penetration, marking the transition from early adopters to the early majority.

Figure 8. Minerals in Electric Vehicles vs. Gas Cars



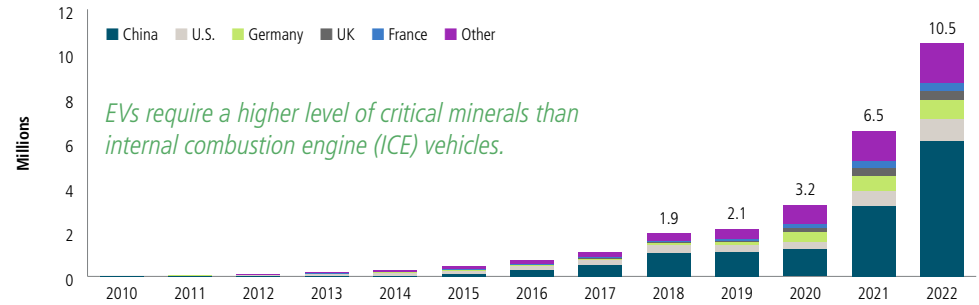
Source: <https://elements.visualcapitalist.com/evs-vs-gas-vehicles-what-are-cars-made-out-of/>. Included for illustrative purposes only.

¹⁰ Source: IEA, Electric car sales break new records with momentum expected to continue through 2023. <https://www.iea.org/reports/global-ev-outlook-2023/executive-summary>.



Figure 9. Strong Growth in Battery-Based Electric Vehicles Is Underway

Across the globe, over 10 million electric cars were sold in 2022, almost five times the sales three years ago.



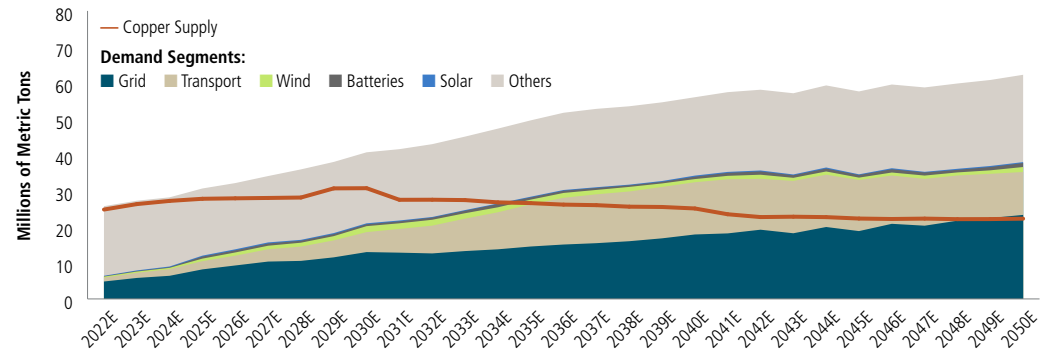
EVs require a higher level of critical minerals than internal combustion engine (ICE) vehicles.

Source: BloombergNEF, March 2023. Included for illustrative purposes only.

3 Copper Supply Faces Challenges

While copper is abundant, mining it economically and efficiently is a challenge. Chile and Peru, the top copper-producing countries, are grappling with labor strikes and protests, compounded by declining ore grades. Russia, ranked seventh in copper production, faces an expected decline due to the ongoing war in Ukraine. Despite efforts by miners to ramp up production, many analysts anticipate a widening supply imbalance.

Figure 10. Copper Supply and Demand Imbalance May Likely Grow



Source: BloombergNEF Transition Metals Outlook 2023. The line represents demand and the shaded area represents supply. Demand is based on a net-zero scenario, i.e., global net-zero emissions by 2050 to meet the goals of the Paris Agreement. Included for illustrative purposes only.

The copper mining industry is both large and mature, having begun thousands of years ago. However, high-quality copper projects are increasingly rare, and major new discoveries are dwindling. Copper ore grades have also decreased significantly; today’s average grade is around 1% or less, compared to over 5% 150 years ago.¹¹

The process from discovery to production is lengthy, averaging 16.5 years.¹² This long lead time exacerbates supply issues. For instance, Codelco, the world’s largest copper producer, has faced multiple challenges, including recently reducing its 2023 production guidance after its lowest output in approximately 25 years in 2022.¹³

¹¹ Source: S&P Global Market Intelligence, The Future of Copper. <https://www.spglobal.com/marketintelligence/en/mi/info/0722/futureofcopper.html>.

¹² Source: IEA, The Role of Critical Minerals in Clean Energy Transitions, May 2021. <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>.

¹³ Source: Mining.com, Codelco says 2023 copper production further hurt by heavy rains, 7/5/2023. <https://www.mining.com/web/chiles-2023-copper-production-set-to-drop-due-to-rains-says-codelco/>.



The supply and demand imbalance is set to intensify. From 1990 to 2022, 234 copper deposits were discovered, but only 18 were discovered in the last 10 years. These 18 discoveries are also considerably smaller, only containing 74.7 million metric tons or 6% of all copper in major discoveries since 1990.¹⁴ Additionally, many major copper assets discovered in the 1990s are still not in production, underscoring the lengthy development timeline.

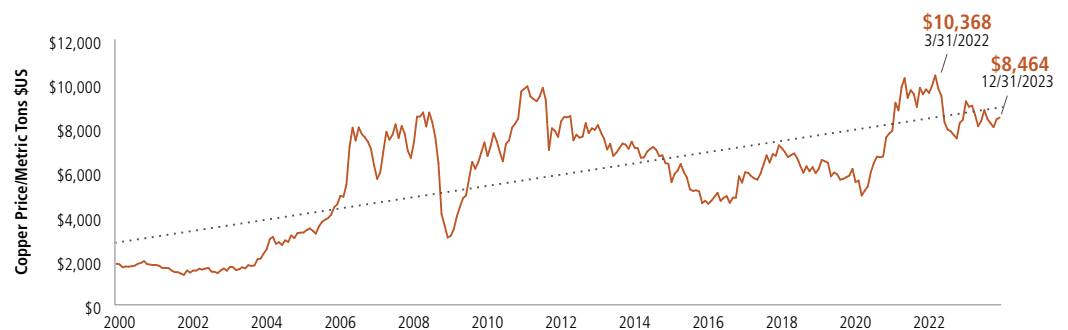
The process of permitting new mines and expanding existing ones is complex and time-consuming. Addressing the copper supply challenge will require regulatory policy considerations, technological innovations in copper extraction and refining, and a careful evaluation of other minerals upon which copper development depends.

4 Copper Price Dynamics Spurring New Production

The global demand for copper is on the rise, leading to stronger market prices and spurring the development of new projects. Despite the prediction of a long-term supply deficit, it is projected that in 2024 global mined copper production will grow by 4.1%, reaching 23.5 million metric tons.¹⁵ This increase is significantly driven by contributions from Chile, the Democratic Republic of Congo (DRC) and Russia.¹⁵

This trend follows a period of recovery after the COVID-19 pandemic, during which copper prices bounced back, even hitting a record high in spring 2022. However, in response to this increased demand, copper miners are primarily focusing their investments on extending the life span and productivity of existing, high-grade and profitable mines. This approach is favored over the exploration and development of new mining projects. Consequently, this trend of prioritizing existing mines over new ventures may take a considerable time to reverse.

Figure 11. Copper Spot Price Reached New Highs in 2022



Source: Bloomberg. Data as of 12/31/2023. Past performance is no guarantee of future results. Included for illustrative purposes only.

¹⁴ Source: S&P Global. Copper discoveries still trending down amid increasing budgets, higher prices. 8/23/2023.

¹⁵ Source: S&P Global. 12/13/2023.

Copper Through the Ages

Over the last 11,000 years, since its discovery in 9000 BC, copper has helped advance civilization in various ways.

8700 BC: Native copper was hammered into sheets, shapes and ornaments in the Stone Age.

4500-3500 BC: Copper was used for agricultural tools and weapons in the Copper Age.

2750 BC: Copper pipes and plumbing were used by ancient Egyptians.

2400-2200 BC: Egyptian medical texts documented the use of copper in wound sterilization and surgical tools.

700-600 BC: Rounded copper coins were used in Lydia (now Turkey). Temple roofs were also being built using copper.

1400: Greeks and Romans created musical instruments from brass—an alloy of copper and zinc.

1500-1600: Renaissance Europe used copper to make scientific instruments and roofs.

1700-1900: Wires, cables, batteries and heat exchangers used copper for its conductivity during the Electricity Age.

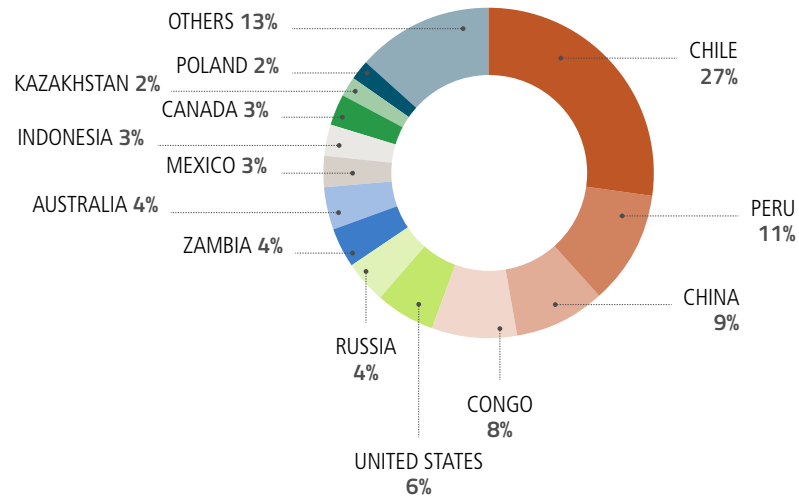
1990-2000: Telephones, floppy discs and computer chips used copper as a conductor.

2000-2010: Copper was used in motor rotors for increased efficiency. Copper demand soared as cell phones became mainstream.

2010-Present: Copper has become vital for use in EVs and clean energy technologies.

Source: Copper Development Association.

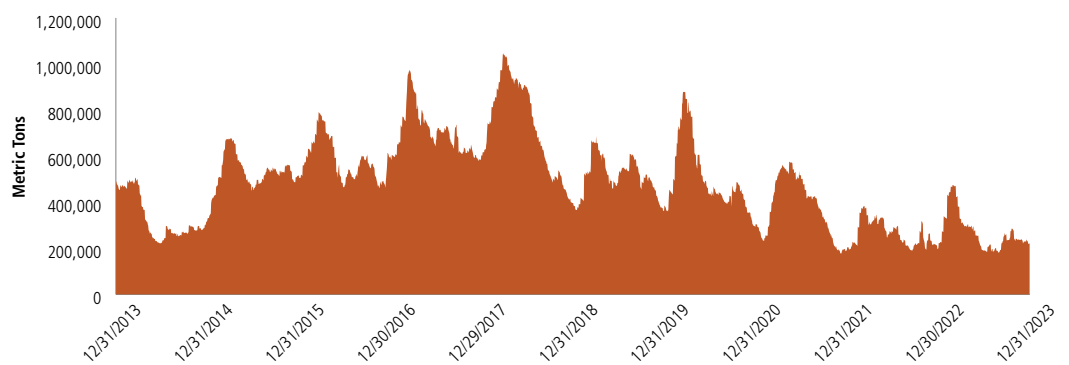
Figure 12. Top Copper-Producing Countries



Source: <https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-copper.pdf>. Included for illustrative purposes only.

The current state of copper exchange inventories, covering approximately three days of global demand, presents a risk of sudden price spikes if there are large drawdowns by buyers to secure supplies. Capital for the exploration and development of copper mines peaked at \$26.13 billion in 2013. Since then, it has almost halved and remained low, with only \$14.42 billion spent in 2022. Despite a slight 0.1% decrease in development capital expenditure for copper projects in 2022, a more significant drop of 18.7% is projected for 2023.¹⁶

Figure 13. Copper Inventories Are at Historic Lows



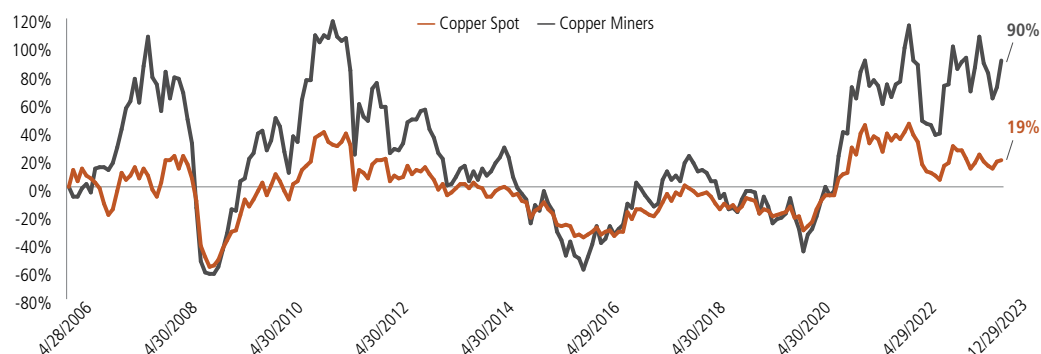
Source: Bloomberg. Data as of 12/31/2023. Includes inventories on the LME, SHFE and COMEX. Included for illustrative purposes only. Past performance is no guarantee of future results.

¹⁶ Source: S&P Global Market Intelligence.

5 Copper Miners May Offer Opportunities

The anticipated supply-demand dynamic suggests a strong performance for copper in a bull market. The previous commodity supercycle, driven by China's industrialization and urbanization, is giving way to a new cycle focused on the global energy transition.

Figure 14: Copper Equities Have Outperformed Spot During Bull Markets



Source: Bloomberg. Data as of 12/31/2023. The copper spot price is measured by the LME Copper Cash (\$), Bloomberg ticker LMCADY. Copper Miners is measured by the Solactive Global Copper Miners Index, Bloomberg ticker SOLGLOCO Index. You cannot invest directly in an index. Past performance is no guarantee of future results. Included for illustrative purposes only.

Copper prices and miners are likely to benefit from the growing supply-demand gap. Some miners, in particular, are thriving due to the optimistic long-term outlook for copper demand. Copper's strategic importance has driven significant M&A activity in 2022-2023, with major mining companies like BHP and Rio Tinto acquiring copper miners at substantial premiums. Automakers, concerned about securing future supplies of critical minerals like copper, are also investing directly in mining companies.

Investments in copper miners are likely to rise, given the supply-demand dynamics and the potential for copper equities to outperform the underlying spot price. The anticipated increase in copper price is necessary to incentivize new production to meet rising demand.

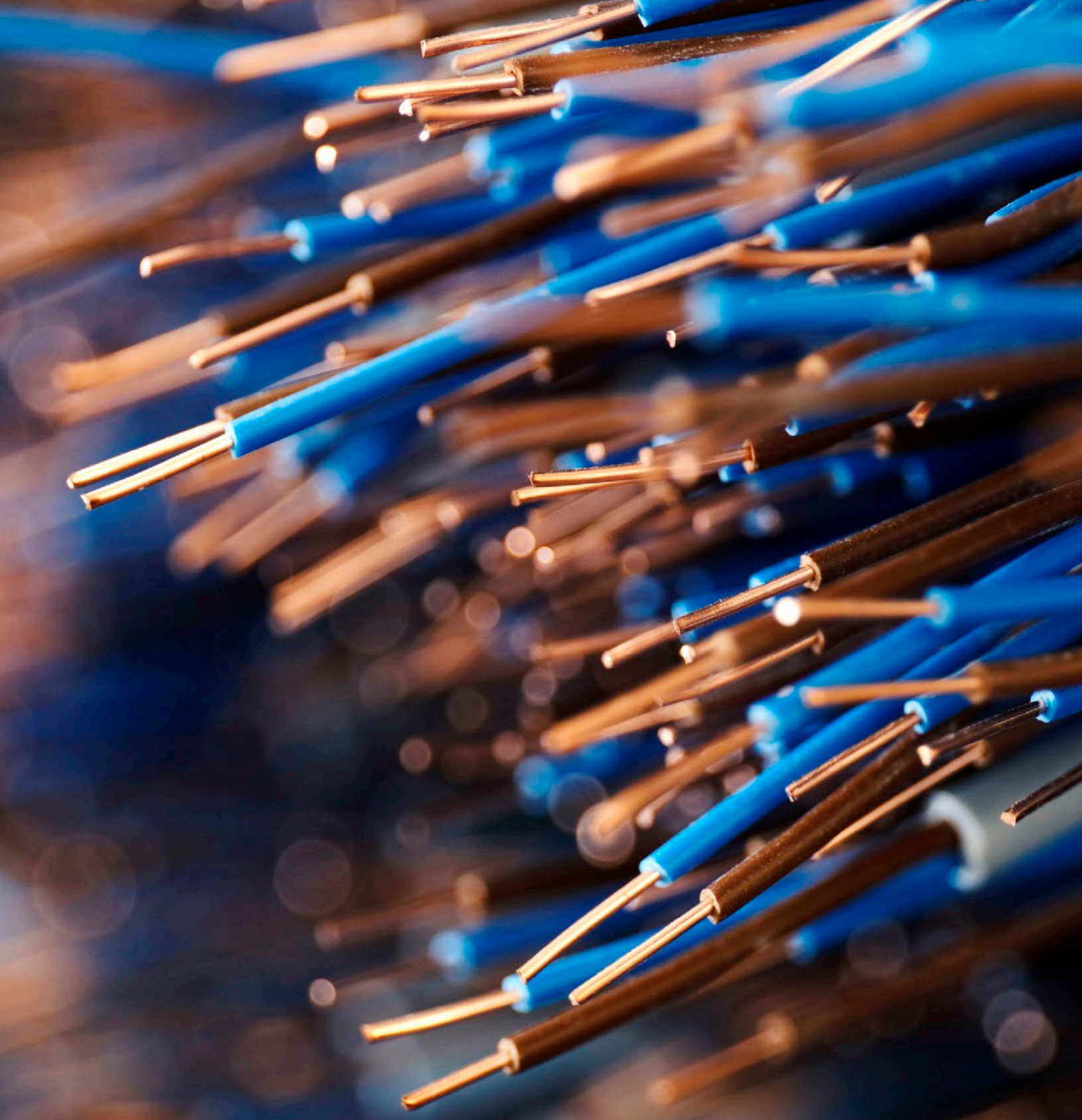
The massive 7,100-pound *Charging Bull* is a bronze sculpture located in downtown New York City.



Investing in the Next Era of Copper

Copper's role as a critical mineral in the U.S. has led to its inclusion in over \$30 billion of funding from the Inflation Reduction Act. This support is already materializing, exemplified by the U.S. Department of Energy's \$2 billion loan to Redwood Materials for battery recycling and anode copper foil production.

M&A activity in the copper sector has recently overtaken that in gold, with several companies receiving premiums of over 20%. This reflects the strength and positive outlook of the copper mining industry. As a long-valued asset, copper is entering a new era with the global energy transition. The demand for copper in energy grids, electric vehicles and clean energy technologies, combined with diminishing ore grades and limited inventories, underscores its growing importance and potential for price support. Copper miners are likely well positioned to benefit from these developments.



"The story of copper and its principal alloys, bronze and brass, is virtually a chronicle of human endeavor since man emerged from the Stone Age. The ubiquity of the copper metals and their contribution to every civilization since Sumeria and Pre-Dynastic Egypt gives them a unique position in the history of technology."

– B. Webster Smith, *60 Centuries of Copper*



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