Critical Metals over the next decade

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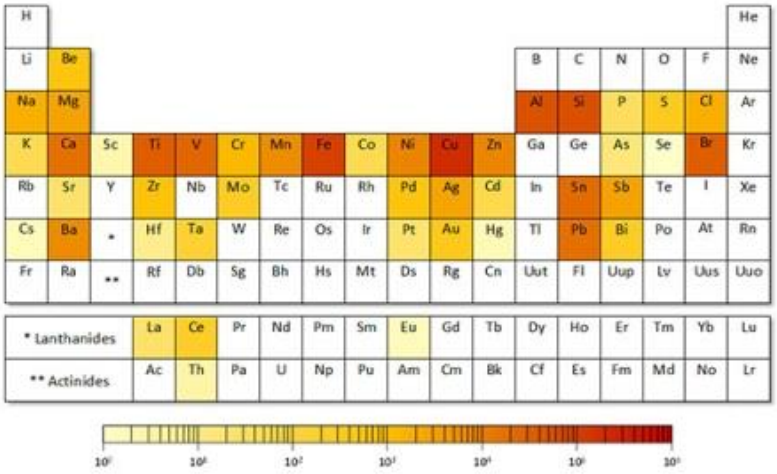
1. Understanding Metal Criticality: A Methodological Approach

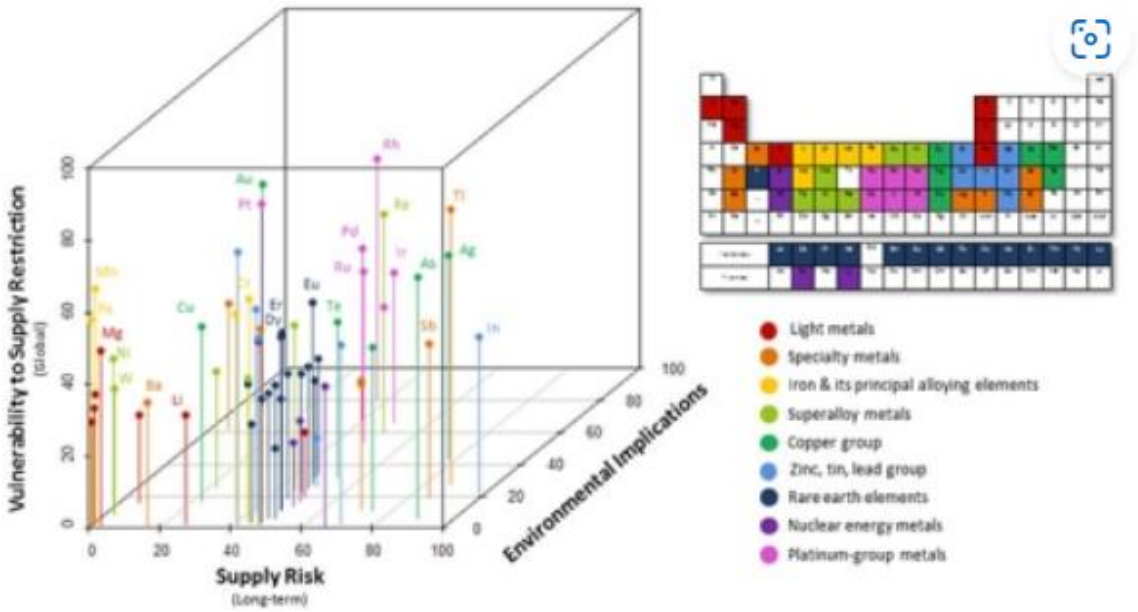
- The metals we've been using for a long time probably won't present much of a challenge. We've been using them for a long time because they're pretty abundant and they are generally widespread geographically," Graedel said. "But some metals that have become deployed for technology only in the last 10 or 20 years are available almost entirely as byproducts. You can't mine specifically for them; they often exist in small quantities and are used for specialty purposes. And they don't have any decent substitutes.
- In order to assess the state of all metals, researchers developed a methodology that characterizes criticality in three areas: supply risk, environmental implications, and vulnerability to human-imposed supply restrictions.



- This illustration of the metals used in a printed circuit board illustrates, modern technology relies on virtually all of the stable elements of the periodic table. While the concentrations of copper and iron are the highest, it does not reflect elemental importance: All the elements are required in order to maintain the functions for which the board was designed
- They found that supply limits for many metals critical in the emerging electronics sector (including gallium and selenium) are the result of supply risks. The environmental implications of mining and processing present the greatest challenges with platinum-group metals, gold, and mercury. For steel alloying elements (including

chromium and niobium) and elements used in high-temperature alloys (tungsten and molybdenum), the greatest vulnerabilities are associated with supply restrictions.

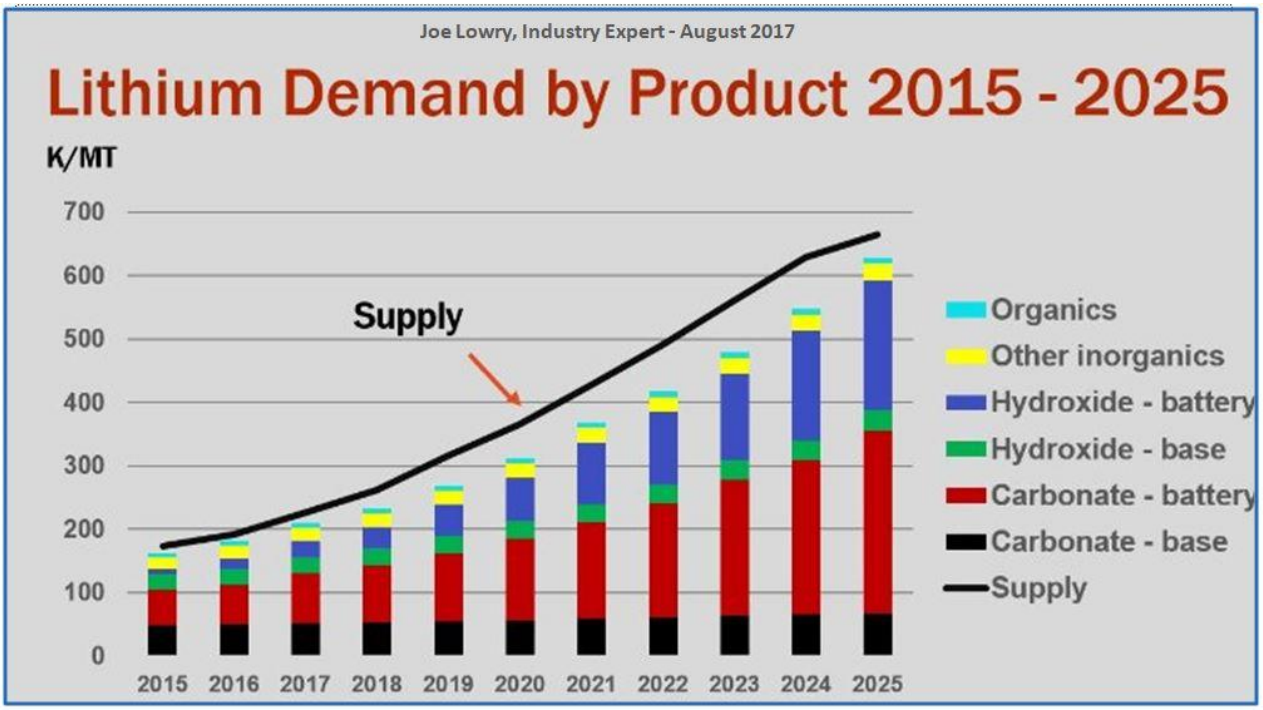
- Among the factors contributing to extreme criticality challenges are high geopolitical concentration of primary production (for example, 90 to 95 percent of the global supply of rare Earth metals comes from China); lack of available substitutes (there is no adequate substitute for indium, which is used in computer and cell phone displays); and political instability (a significant fraction of tantalum, used widely in electronics, comes from the war-ravaged Democratic Republic of the Congo).
- The researchers also analysed how recycling rates have evolved over the years and the degree to which different industries are able to utilize “non-virgin” sources of materials. Some materials, such as lead, are highly recycled because they are typically used in bulk, Graedel said. But the relatively rare materials that have become critical in some modern electronics are far more difficult to recycle because they are used in such miniscule amounts — and can be difficult to extricate from the increasingly complex and compact new technologies.



- Lithium is primarily used in the production of lithium-ion batteries, which are rechargeable and commonly used in various applications, including:
- Electric vehicles (EVs): Lithium-ion batteries are the preferred energy storage solution for EVs due to their high energy density, lightweight, and long cycle life.
- Portable electronic devices: Smartphones, laptops, tablets, and other consumer electronics rely on lithium-ion batteries for their power needs.

Renewable energy storage:

- **Lithium-ion** batteries play a crucial role in storing energy generated from renewable sources such as solar and wind power for later use.
- Additionally, lithium is used in various other industries, including ceramics and glass manufacturing, lubricants, and pharmaceuticals



Criticality and Supply:

- Lithium's criticality stems from its pivotal role in the transition to clean energy and the electrification of transportation. As countries worldwide strive to reduce greenhouse gas emissions and combat climate change, the demand for lithium-ion batteries is expected to continue rising.

The supply of lithium is limited by several factors:

- Geological availability: Lithium is primarily obtained from brine deposits, hard rock lithium mines, and lithium-rich clay deposits. Geological constraints and exploration challenges can limit the discovery and extraction of economically viable lithium reserves.
- Production capacity: While there are efforts to expand lithium production capacity, including the development of new mines and processing facilities, scaling up production to meet rapidly growing demand poses logistical and environmental challenges.
- Environmental concerns: Lithium extraction and processing can have environmental impacts, including water usage, chemical pollution, and habitat disruption. Balancing the need for increased lithium supply with environmental sustainability is a significant challenge.
- Geopolitical considerations also play a role in lithium supply dynamics, as certain countries possess significant lithium reserves, potentially leading to geopolitical tensions over access to resources.
- Overall, while lithium is currently a critical metal due to its importance in clean energy technologies, ongoing efforts are being made to address supply chain challenges and promote sustainable lithium production. However, fluctuations in demand, technological advancements, and regulatory changes can influence lithium's future criticality and supply
- dynamics.

Global Lithium Demand (2030):

- Global demand for lithium-ion batteries is expected to soar over the next decade. By 2030, the number of gigawatt-hours (GWh) required is projected to increase from about 700 GWh in 2022 to approximately 4.7 TWh (terawatt-hours) 1. Batteries for mobility applications, such as electric vehicles (EVs), will account for the vast bulk of demand in 2030—about 4,300 GWh. This trend is driven by several factors:

- Regulatory Shift: Sustainability targets and guidelines, including Europe's "Fit for 55" program, the US Inflation Reduction Act, the EU's ban on internal combustion engine (ICE) vehicles by 2035, and India's Faster Adoption and Manufacture of Hybrid and Electric Vehicles Scheme.
- Energy Transition: The broader energy transition necessitates electrification of mobility and increased adoption of clean energy technologies.

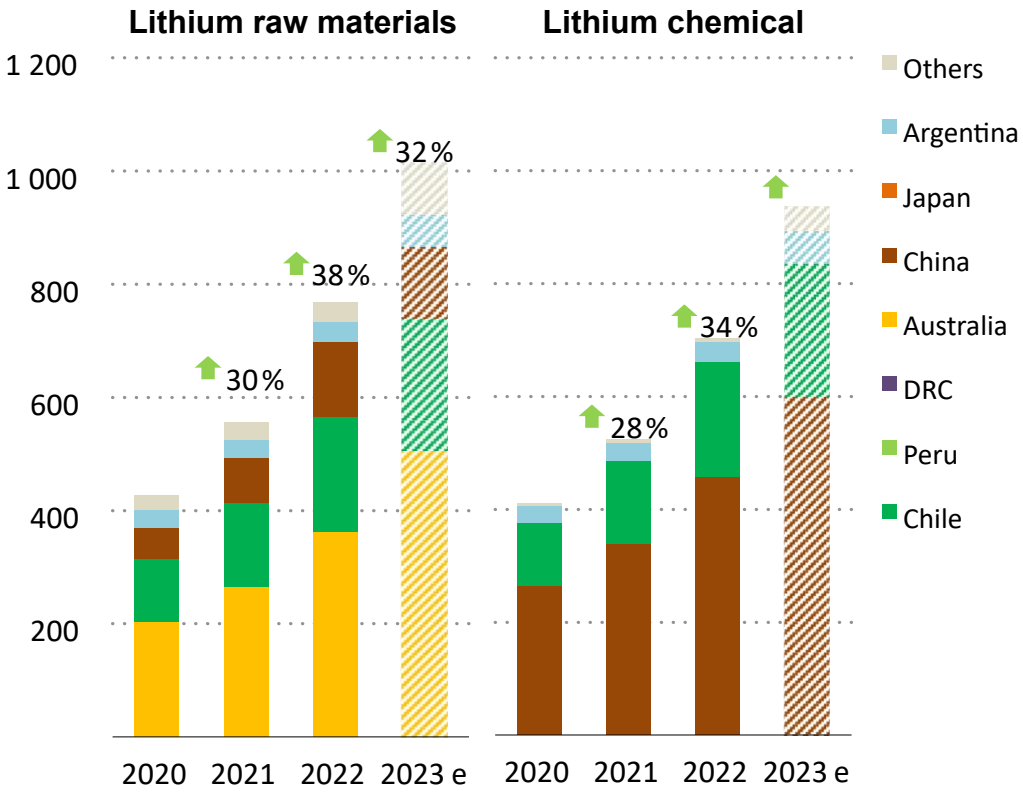
Lithium Supply (2030):

- To meet this growing demand, lithium production must quadruple between 2020 and 2030. In 2020, global lithium production stood at 345,000 tonnes, but by 2030, it is projected to reach 2 million tonnes. Additional supply will come from various sources, including investment in hard rock production in Australia, direct lithium extraction, and recycling infrastructure 2.

Challenges and Opportunities:

- **While lithium growth offers environmental and social benefits, challenges remain:**
- Securing Raw Materials: Battery manufacturers must ensure a steady supply of raw materials.
- Investment Focus: Allocating investments efficiently to the right areas.
- Decarbonization Commitment: Companies should prioritize extensive decarbonization and true sustainability.

- Lithium in just a decade the lithium industry has undergone a drastic transformation, mainly due to batteries being dominant use of lithium. Currently experiencing rapid expansion. Following a doubling of demand in 2021 compared with 2017. Lithium consumption witnessed an additional 30% growth in 2022. Production levels are also increasing at a significant pace, with an annual growth rate ranging between 25% and 35%. Lithium is attracting substantial attention from mining investors.



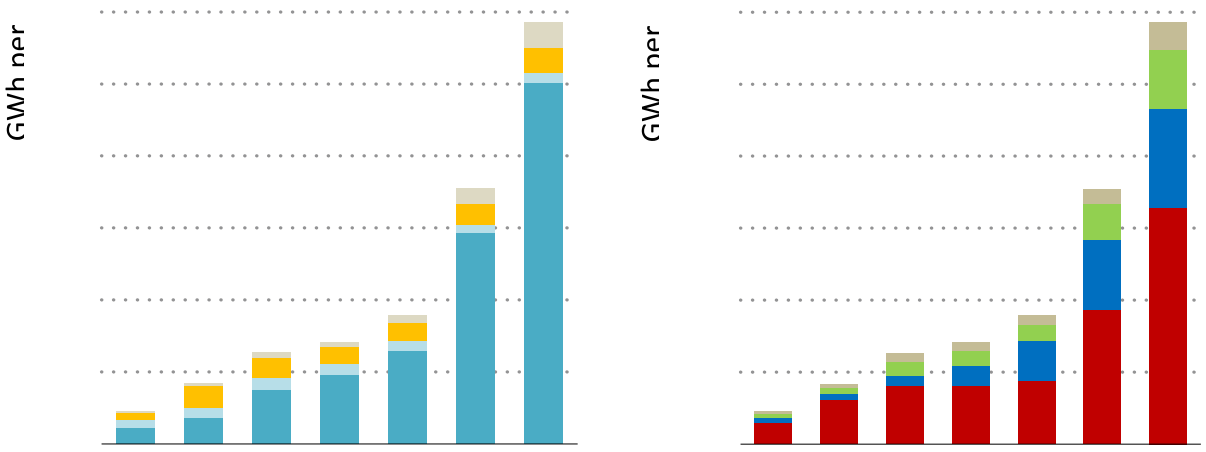
Key Points for Lithium:

- Market Transformation: Over the past decade, lithium has seen a drastic transformation, with batteries becoming the dominant use. The industry is experiencing rapid expansion, with substantial attention from investors.
- Demand and Production Growth: Lithium consumption doubled from 2017 to 2021 and saw an additional 30% growth in 2022. Production is also increasing at a significant pace, though with volatile prices.
- Supply Dynamics: China, Chile, and Australia traditionally dominated lithium mining and refining, but new projects are emerging globally, including in Canada, Argentina, Brazil, and several European and African countries.

- Challenges and Uncertainties: While the long-term outlook is promising, near-term uncertainties exist, such as declining lithium prices posing challenges to junior miners

and early-stage projects. Additionally, challenges in producing battery-grade lithium from certain sources like lepidolite are present.

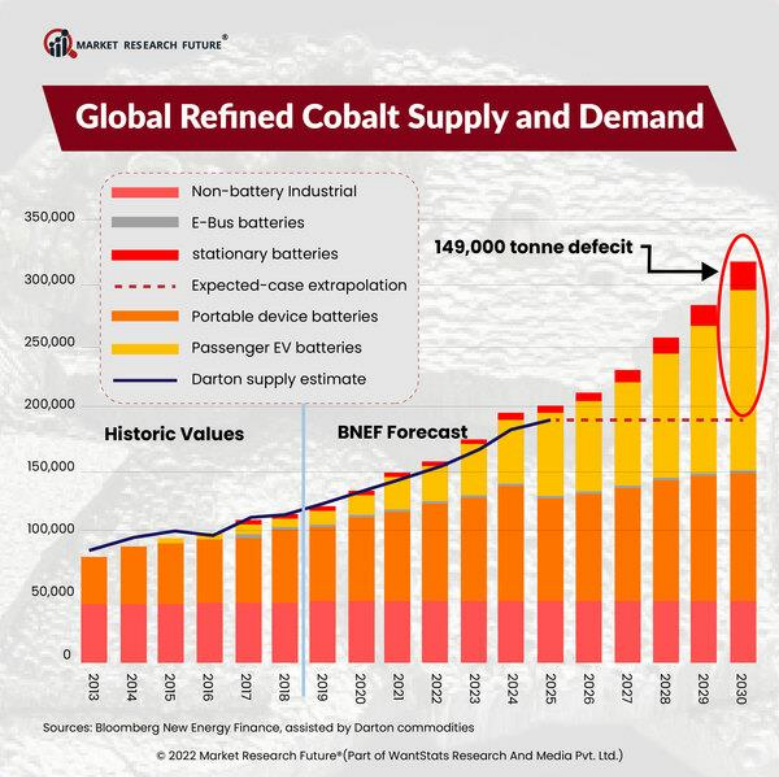
- Downstream Processing: Efforts are underway to diversify downstream processing capacities, with investments in conversion facilities closer to mines and in consumer countries, reducing reliance on traditional processing hubs like China.



Usage:

- **Cobalt** is primarily used in the production of lithium-ion batteries alongside lithium and nickel. It serves as a key component in the cathode of these batteries, contributing to their stability and energy storage capacity.
- Cobalt-based alloys are utilized in various industrial applications, including aerospace, healthcare (such as orthopaedic implants), and cutting tools due to their hardness and wear resistance.
- Additionally, cobalt compounds are used in the production of pigments for ceramics, paints, and inks, as well as in chemical catalysts and magnetic materials.

Criticality and Supply:



- Cobalt's criticality stems from its essential role in the rapidly expanding electric vehicle (EV) market and the broader transition to renewable energy. While cobalt is not as abundant as other metals, its inclusion in lithium-ion batteries improves their performance and safety.
- The majority of the world's cobalt supply comes from the Democratic Republic of Congo (DRC), where concerns exist regarding labour practices, environmental sustainability, and geopolitical stability. The extraction of cobalt in the DRC has been associated with issues such as child labour, unsafe working conditions, and environmental degradation.
- Supply chain vulnerabilities have been highlighted by the concentration of cobalt production in the DRC and concerns over ethical and sustainable sourcing. Efforts to address these challenges include initiatives to improve transparency, traceability, and responsible sourcing practices within the cobalt supply chain.
- Technological advancements, such as the development of cobalt-free or low-cobalt battery chemistries, are being explored to reduce reliance on cobalt and mitigate supply chain risks. However, cobalt remains an integral component of current lithium-

ion battery technologies, and alternative materials must undergo rigorous testing to ensure comparable performance and safety standards.

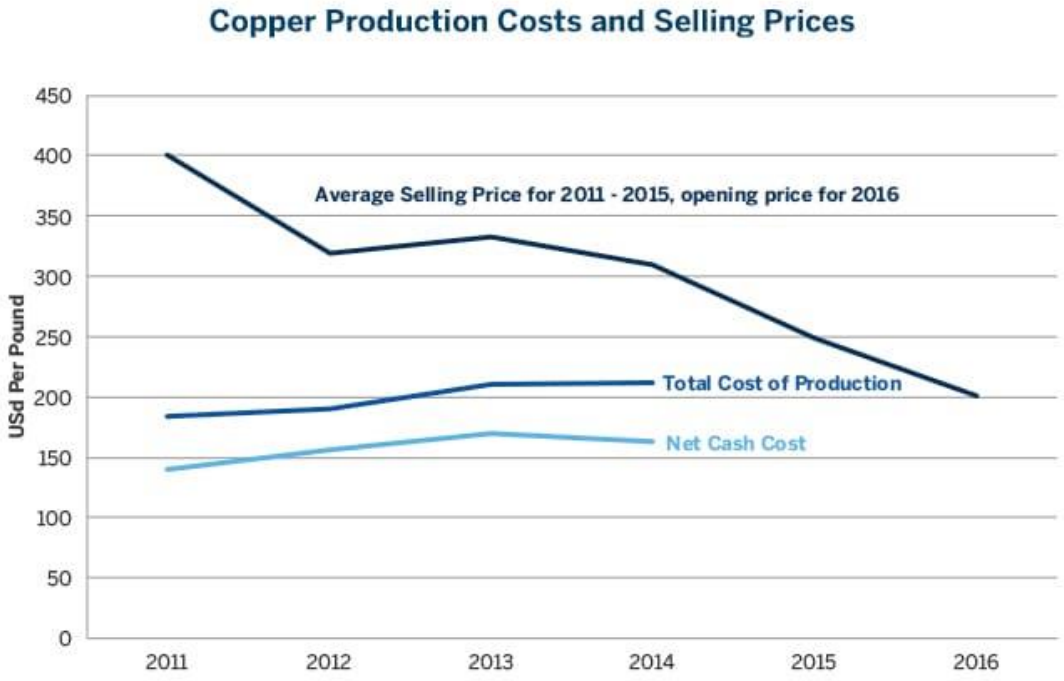
- In summary, cobalt's criticality arises from its crucial role in lithium-ion batteries, particularly in the context of electric vehicles and renewable energy storage. Supply chain challenges, including ethical and sustainable sourcing concerns, underscore the need for responsible practices and diversification of battery materials to ensure a reliable and sustainable supply of cobalt for future technologies.

Key Points for Nickel:

- Price Volatility and Trading Challenges: Nickel prices have faced volatility due to supply concentration and geopolitical tensions. The illiquidity in trading led to the suspension of Asian trading hours by the London Metal Exchange (LME) in March 2022. The LME has proposed measures to enhance market stability, but the recovery of trading liquidity among Asian participants remains uncertain.
- Supply Growth: The industry witnessed a record increase in supply in 2022, with Indonesia leading the surge in both mined and refined nickel production. Indonesia has overtaken China as the largest refined nickel producer, with much of the new capacities financed by Chinese companies.
- Processing Advances in Indonesia: Indonesia's joint ventures with Chinese companies in high-pressure acid leach (HPAL) plants are enabling the conversion of laterite resources into Class 1 nickel products. The ramp-up of nickel processing in Indonesia is expected to continue, but concerns over waste disposal and environmental challenges persist.
- Global Project Developments: Several new nickel development projects are underway outside Indonesia, notably in Australia and Canada, but they are unlikely to challenge Indonesia's dominant position in nickel supplies.

Key Points for Cobalt:

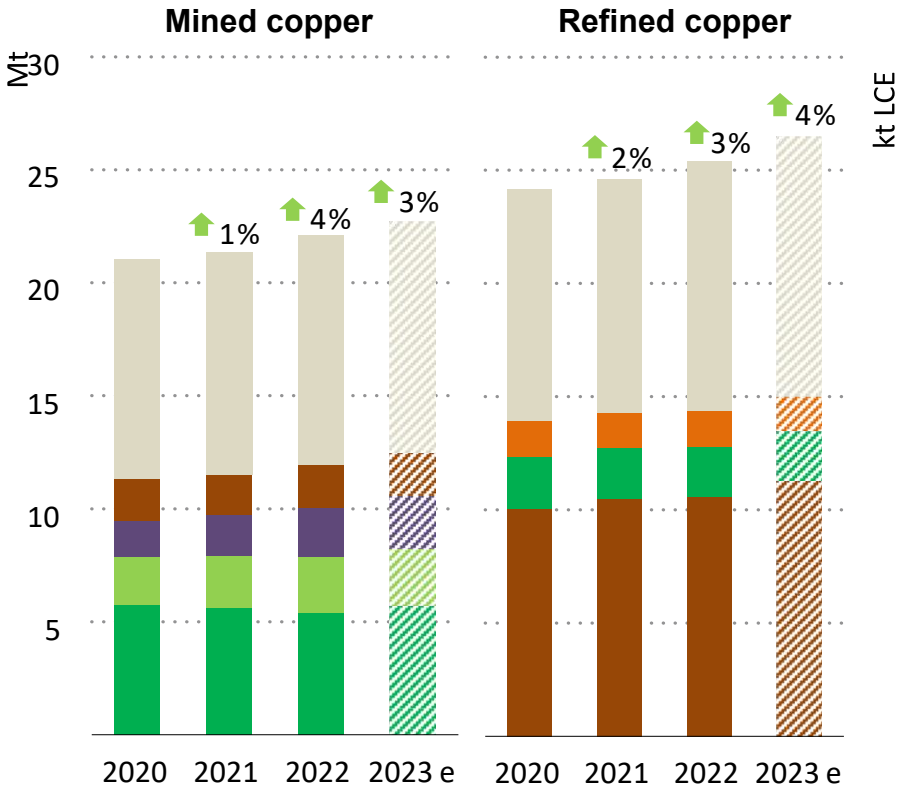
- Price Trends: Cobalt prices peaked in March 2022 but underwent a consistent downward trend throughout the year, remaining around USD 50,000 per tonne. The muted economic outlook and reduced demand from consumer electronics and EV battery producers contributed to the decline.
- Supply Surge: Supply surged in 2022 as numerous mines, including Mutanda in the Democratic Republic of the Congo, resumed production. Mined cobalt supply grew by 20%, resulting in a substantial surplus in the market by year-end.
- Producer Dominance: The Democratic Republic of the Congo maintained its position as the leading cobalt producer, with over 70% of global production in 2022. Indonesia emerged as the second-largest supplier, tripling its cobalt production with new HPAL projects.
- Price Outlook: Cobalt prices are expected to remain suppressed in 2023 due to oversupply, with the Democratic Republic of the Congo projected to increase production further and Indonesia adding more volumes as a by-product of its growing nickel industry.



Source: GFMS Copper Survey 2013 and 2015, Bloomberg Professional (HG1), CME Group Economic Research Calculations

Usage:

- **Copper** is one of the oldest metals known to humanity and has been used for thousands of years due to its excellent electrical conductivity, malleability, and corrosion resistance.
- One of the primary applications of copper is in electrical wiring and conductors. It is used in power generation, transmission, and distribution systems, as well as in the manufacturing of electrical motors, transformers, and appliances.
- Copper is also extensively used in the construction industry for plumbing, heating, ventilation, and air conditioning (HVAC) systems. It is valued for its durability and ability to withstand corrosion.
- In addition to its electrical and construction applications, copper is utilized in various other sectors, including electronics, telecommunications, transportation (such as automotive radiators and brake tubing), and industrial machinery.



Criticality and Supply:

- Copper is considered a critical metal due to its fundamental role in modern infrastructure and technology. Its widespread use in essential industries such as construction, transportation, and telecommunications underscore its criticality to economic development and growth.
- While copper is relatively abundant in the Earth's crust, concerns exist regarding future supply and demand dynamics:
- Supply constraints: Despite its abundance, the availability of high-grade copper deposits is limited, leading to challenges in maintaining production levels to meet growing demand.
- Geological and geopolitical factors: Copper mining operations are subject to geological constraints, political instability in certain producing regions, and environmental regulations that can impact production and supply.
- Recycling: Recycling plays a crucial role in the copper supply chain, with a significant portion of global copper demand being met through recycled material. Efforts to improve recycling rates and technology are essential for mitigating supply risks and reducing environmental impacts.
- Demand drivers: Increasing urbanization, infrastructure development, electrification (particularly in emerging economies), and the transition to renewable energy sources are expected to drive future demand for copper.

Global Copper Outlook (2024):

- Supply: Global copper producers have benefited from robust demand in China during the first half of 2023. However, unless Beijing stimulates more assertively, mined supply could return strongly until 2025, potentially tipping the market into a modest, multiyear surplus.
- Demand: Factors such as electric vehicles and renewables are expected to sustain consumption at or slightly above long-term trends. Yet, in the near term, copper prices could fall below $8,000 per ton, with marginal cost support kicking in at $7,4001.

World Copper Deficit (2035):

- The global copper market faces a potential deficit by 2035. Energy transition-related applications are expected to boost overall copper demand to about 50 million metric tons (MT) from the current 25 million MT. Expanding capacity will be crucial to meet this demand2.

U.S. Copper Demand (2070):

- A study adapted the stock dynamics approach to forecast U.S. copper in-use stock, consumption, and end-of-life flows from 2016 to 2070. Socio-technological development trajectories play a significant role in shaping copper demand3.

Copper Demand by Sector (2020-2040):

- The International Energy Agency predicts copper demand across various sectors. The transition to renewables and electrification will continue to impact copper consumption4.

Key Points for Copper:

- Price Trends: Since the second half of 2022, copper prices have generally trended downwards, with occasional boosts from supply disruptions and expectations of Chinese demand.
- Production Growth: Copper production has been picking up, with new mines such as Quellaveco in Peru and expansions like Kamoa Kakula in the Democratic Republic of the Congo contributing significantly. The Udokan project in Russia is also scheduled to begin operations, aiming to supply Asian markets.
- Market Balance: Despite production growth, modest demand, particularly from China, may lead to a surplus in the copper market in 2023 and 2024. However, challenges like declining ore grade in Chile and supply disruptions in Peru could affect this balance.
- Long-Term Outlook: Beyond 2024, challenges in existing operations and a lack of new large-scale projects indicate a potential market deficit if demand increases due to Chinese economic recovery and energy transition acceleration, impacting prices.

Nickle:

Key Points for Nickel:

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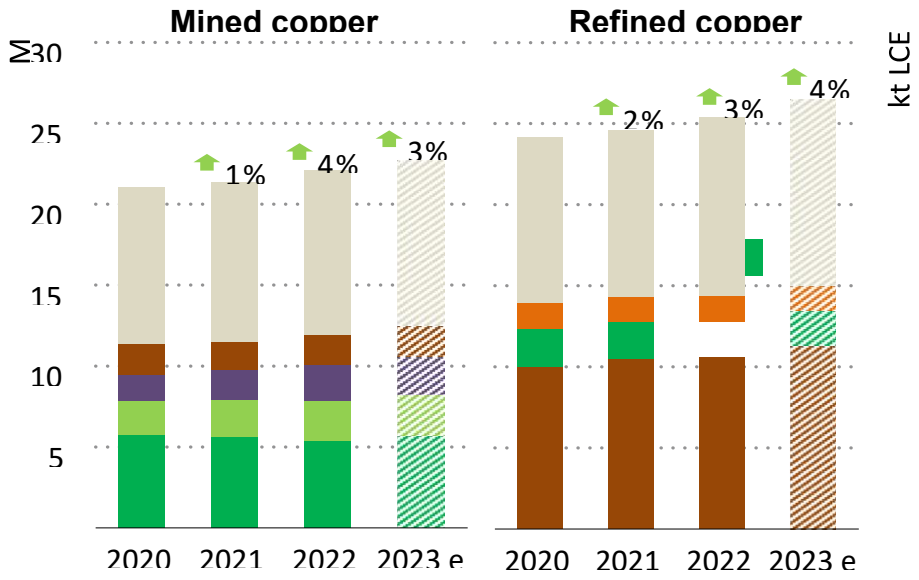

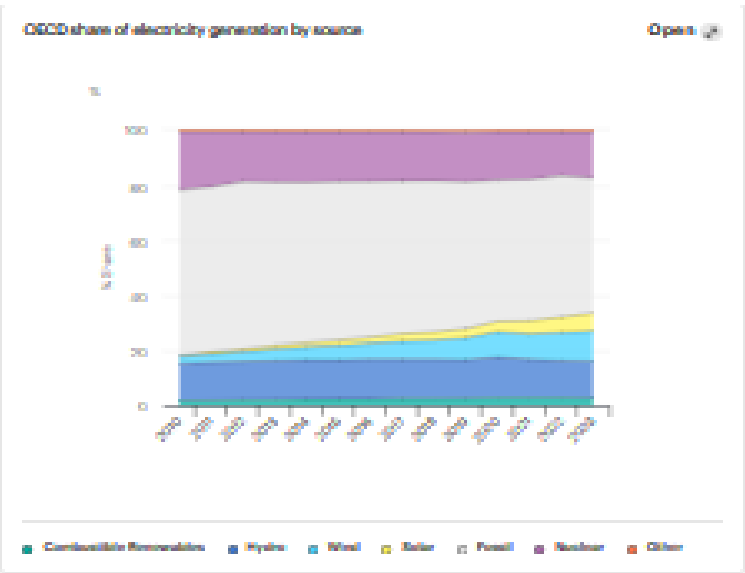

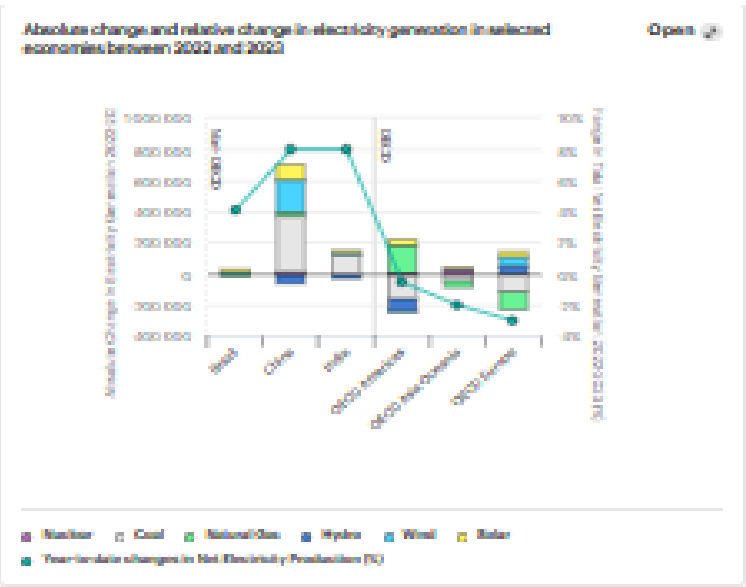

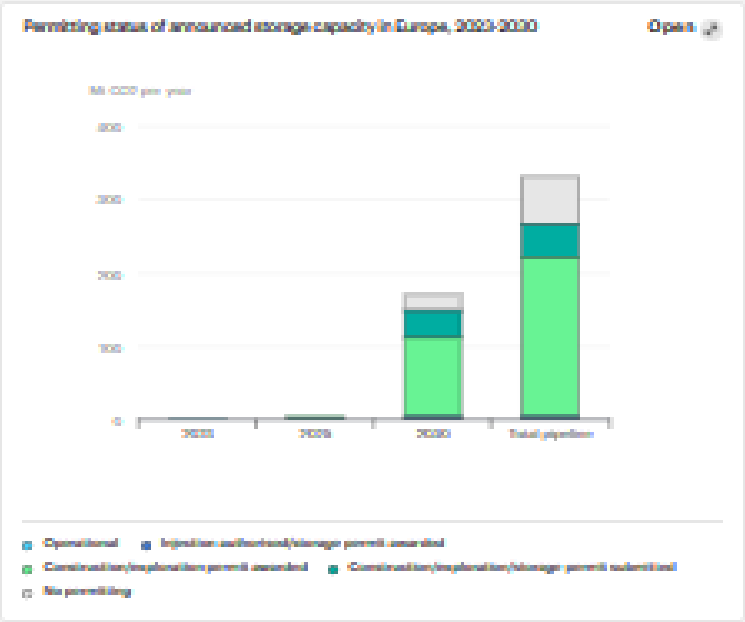

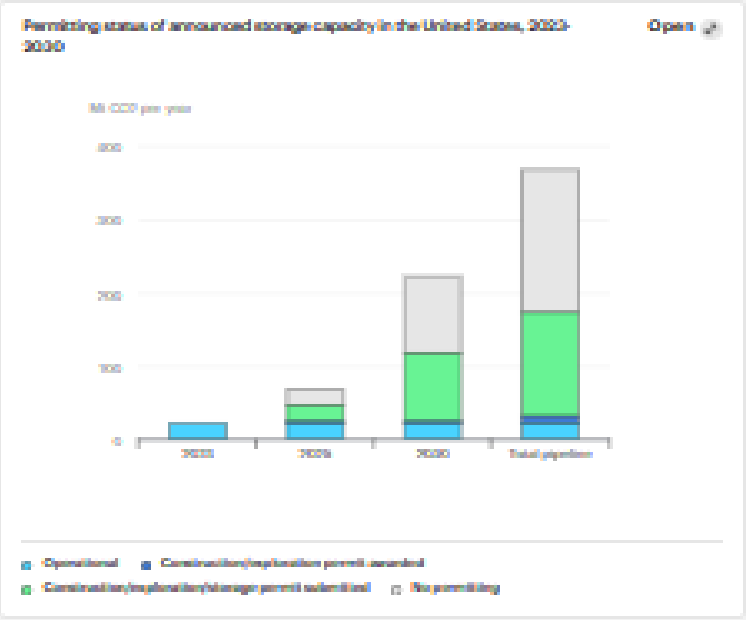

New Copper Deposit Discovery:

- The discovery of a vast copper deposit in Zambia by KoBold Metals suggests that there are significant resources available, which could potentially contribute to increased global copper supply. This discovery may lead to increased competition in the copper market but could also benefit companies involved in copper mining by expanding their access to resources.

Demand for Copper:

- The demand for copper is expected to rise due to efforts to decarbonize transportation systems and shift to renewable energy sources. Copper is essential for various applications, including power transmission lines, electric vehicles, and wind turbines. As countries invest more in renewable energy infrastructure, the demand for copper is likely to increase, potentially benefiting copper mining companies.

Infrastructure Development:

- The US government's backing of infrastructure projects in Africa, such as the Lobito railway, indicates a strategic interest in securing access to critical minerals like copper. Improved infrastructure could facilitate the transportation of copper ore from mining sites to ports for export, potentially reducing logistical challenges for copper mining companies operating in the region.

Investment and Exploration:

- The involvement of prominent investors like Bill Gates and Jeff Bezos in the mining industry underscores the importance of copper in the transition to a low-carbon economy. Companies like KoBold Metals are deploying advanced technologies, including artificial intelligence, to identify and explore new mineral deposits. Increased investment in exploration could lead to the discovery of additional copper reserves, benefiting the industry as a whole.

- Overall, while the discovery of new copper deposits and the expected growth in demand for copper are positive factors for the industry, it's important to consider various other factors such as geopolitical developments, regulatory changes, and market dynamics that could impact the growth trajectory of copper mining companies like Antofagasta. Additionally, the success of KoBold Metals' project in Zambia and its

potential impact on global copper supply will be crucial factors to monitor in assessing the growth prospects of the industry.

Investor Services Ltd. and the metals market, particularly focusing on silver, copper, and uranium:

Silver Investment Potential:

- Silver is considered an attractive investment due to its historical role as a precious metal, its industrial applications, particularly in solar energy, and its relatively lower valuation compared to gold. Interactive Investor's head of investment, Victoria Scholar, suggests that silver may be undervalued compared to gold, presenting an opportunity for investors.

Copper Demand and Investment:

- Copper's importance in the global push towards net-zero emissions, particularly in electricity grids, electric vehicles, and renewable energy technologies, has led to an anticipated increase in demand. Scholar notes that copper prices have shown signs of reversing a downtrend, indicating potential for growth. While direct exposure to copper is available through ETFs like WisdomTree's Copper ETF, investing in copper miners might offer better returns historically.

Uranium as an Investment:

- Uranium has seen strong performance, potentially driven by increased demand for nuclear energy as countries pledge commitments to renewable and nuclear energy at COP28. Investment options include funds like the Sprott Physical Uranium Trust fund and uranium miners like Cameco.

Consideration for Rare Metals Demand:

- The demand for rare metals, including those used in renewable energy and technological applications, is expected to increase significantly. Investments in these metals could be influenced by global commitments to decarbonization and the transition to renewable energy sources.
- Overall, Interactive Investor Services Ltd. and investors alike may find opportunities in diversifying their portfolios to include metals like silver, copper, and uranium, considering their potential for growth driven by industrial demand and global trends towards sustainability and decarbonization. However, careful consideration of market dynamics, investment strategies, and risk factors is essential in making informed investment decisions.

Rio Tinto PLC and its recent developments:

- Approval of Major Mining Project: Rio Tinto's board has approved the world's largest mining project in West Africa, involving a $20 billion investment in the Republic of Guinea. The project aims to produce iron ore and includes the construction of mines, a rail line, and a deep-water port.
- Chinese Partnership: Rio Tinto is partnering with several companies, including five from China, for this project. Chinese state-owned companies such as Chinalco and Baowu, the world's largest aluminium and steel producers respectively, are involved. The final investment approval from Beijing is pending, but Rio Tinto's CEO expresses confidence in the approval process.
- Project Details: The project entails the construction of a 552km rail line to transport iron ore from new mines in the Simandou mountains to a new port on Guinea's Atlantic coast. The CEO highlights progress made in preparing tunnels along the rail corridor and ordering materials for the project.

- Financial Performance: Rio Tinto reported underlying earnings before interest, tax, depreciation, and amortization (EBITDA) of $23.9 billion for 2023, in line with market expectations but down 9% from 2022. Despite lower commodity prices, the company has returned $7.1 billion to shareholders, representing 60% of its underlying profit.
- Other Projects: In addition to the West African project, Rio Tinto is ramping up production at the Oyu Tolgoi underground copper mine in Mongolia. The company also aims to develop the Jadar lithium project in Serbia, although it faced setbacks due to environmental protests.
- Outlook: The CEO remains optimistic about the demand outlook for commodities like copper, aluminium, and iron ore. He highlights China's strong demand for steelmaking materials and the increasing demand for copper and aluminium driven by renewable energy and electric vehicles.