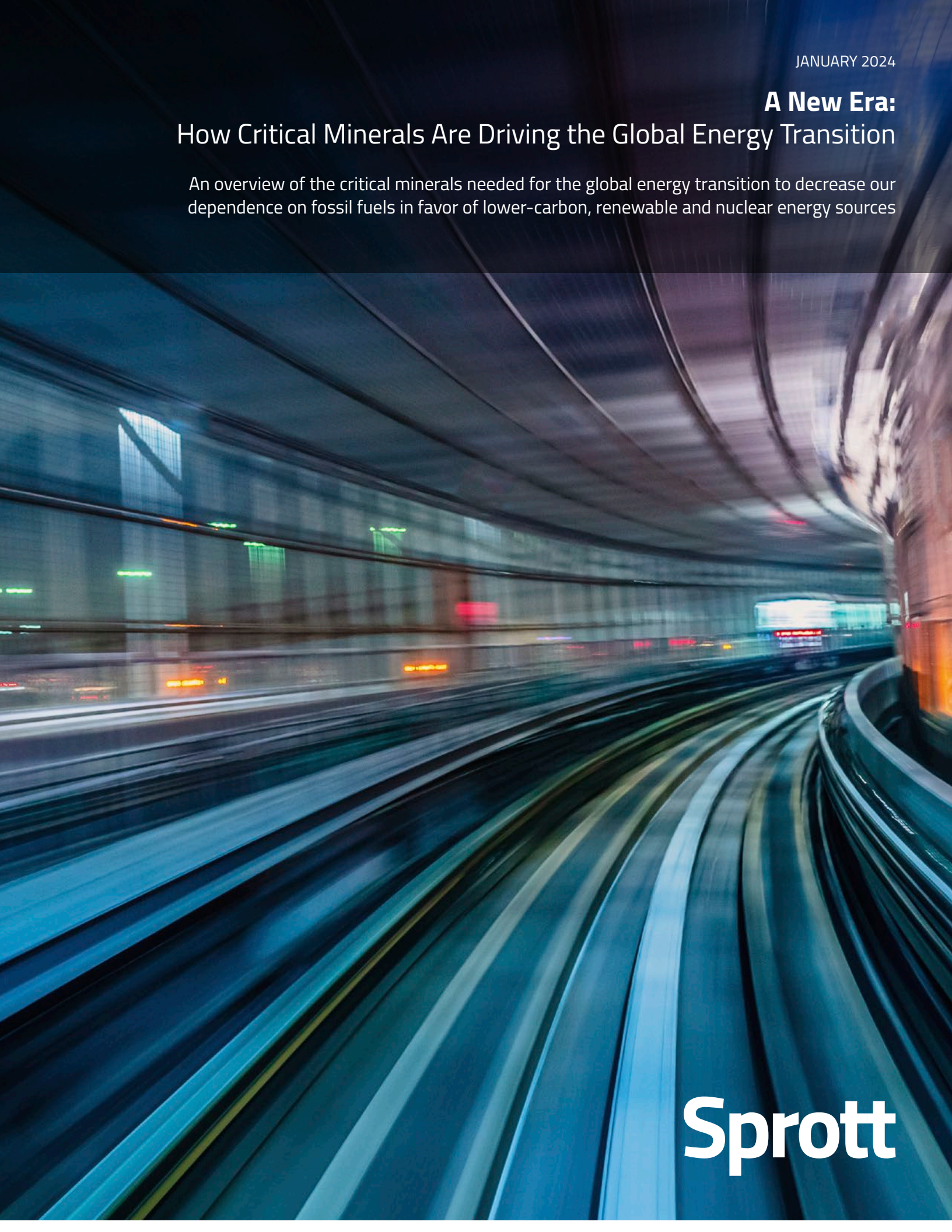
JANUARY 2024

A New Era:
How Critical Minerals Are Driving the Global Energy Transition

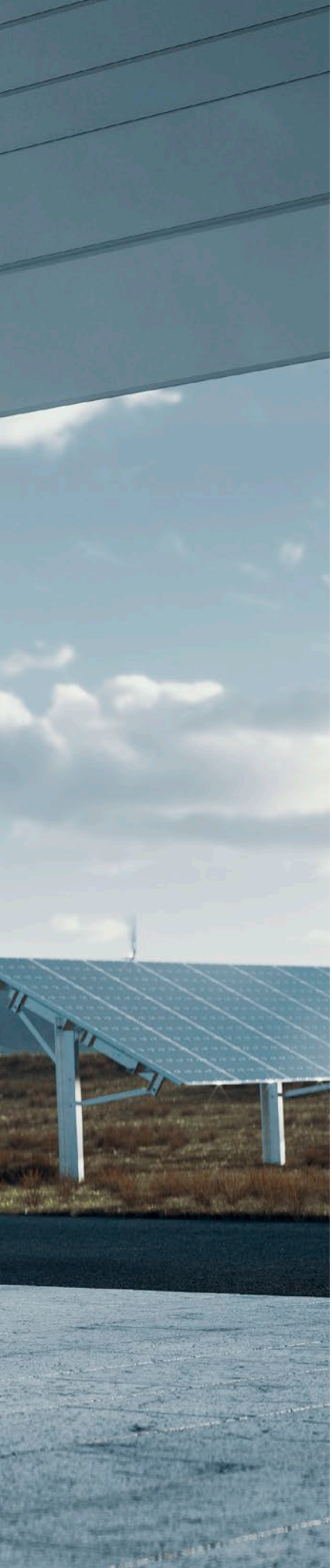
An overview of the critical minerals needed for the global energy transition to decrease our dependence on fossil fuels in favor of lower-carbon, renewable and nuclear energy sources



Sprott

"Critical minerals provide the building blocks for many modern technologies and are essential to our national security and economic prosperity. These minerals—such as rare earth elements, lithium and cobalt—can be found in products from computers to household appliances. They are also key inputs in clean energy technologies like batteries, electric vehicles, wind turbines and solar panels."

Source: *Fact Sheet: Securing a Made in America Supply Chain for Critical Minerals*, The White House, February 22, 2022, Statements and Releases.



The Energy Transition Depends on Critical Minerals

Global governments are engaged in an energy transition representing a significant structural change to combat rising greenhouse gas (GHG) emissions. The energy transition is intended to decrease our dependence on fossil fuels in favor of lower-carbon, renewable and nuclear energy sources.

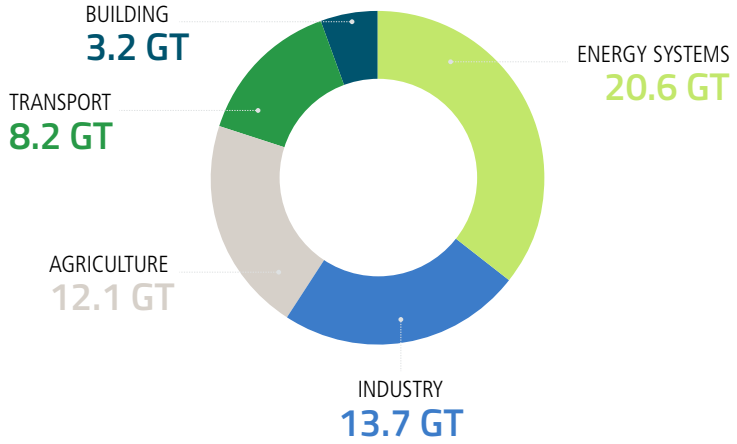
The global energy transition depends on a specific set of minerals key to green-energy generation, battery storage and energy transmission—making them critical minerals.

Critical minerals are essential for the global energy transition as we gradually phase out CO_2-intensive energy sources with cleaner sources, including nuclear, solar, wind, hydro and geothermal energy and greater use of electric vehicles (EVs). The reality is that these critical minerals will likely experience significant increases in demand, while developing new supplies will require enormous amounts of capital and time. We believe the unique supply and demand dynamics for critical minerals will underpin potential investment opportunities in the years ahead.

Combating Rising Carbon Dioxide Levels

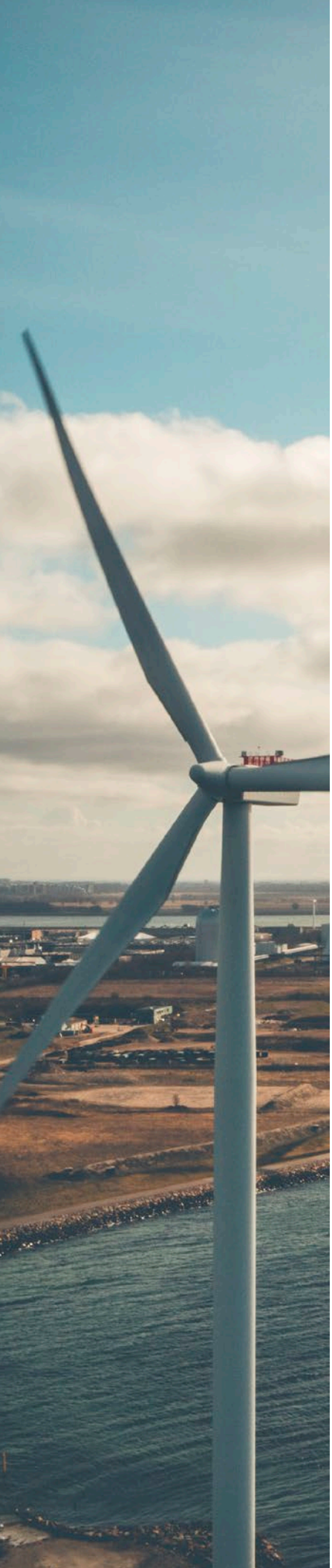
According to NASA,[1] the Earth's atmosphere contains 50% more carbon dioxide than at any point pre-1950. Greenhouse gas emissions trap more of the sun's heat, raising the planet's temperature and causing extreme weather patterns and record-high temperatures. The largest sources of CO_2 emissions are energy systems (which include burning fossil fuels for electricity and heat) followed by industry, as shown in Figure 1.

Figure 1. Global Greenhouse Gas Emissions by Sector 2022
In Gigatons, GT of CO2@ equivalent (CO2eq)



Source: World Emissions Clock by World Data Lab. Data as of 12/31/2022. Included for illustrative purposes only.

[1] Source: https://climate.nasa.gov/.

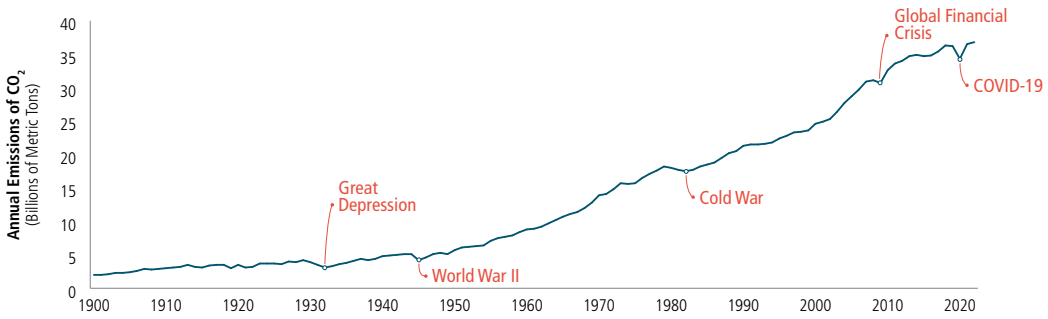


We believe we are at a tipping point that has pushed the cleaner energy movement into the mainstream. The energy transition relies on established and emerging technologies and critical minerals, many of which are in limited supply and capital intensive to mine.

The Global Commitment to the Energy Transition

Decarbonization is the process of replacing fossil-fuel-burning activities with low-carbon-emitting activities. The European Union (EU) and 193 countries have now ratified the Paris Agreement, an international treaty to slash GHG output on a schedule intended to limit global warming to 2 degrees Celsius (or preferably, to 1.5 degrees Celsius).[2] To achieve the 1.5 degree target, the world needs to reach net-zero—a state where GHG emissions are minimized and offset by an equivalent magnitude of GHG-absorbing activities—by the year 2050.

Figure 2. Yearly CO_2 Emissions Continue to Rise (1900-2022)



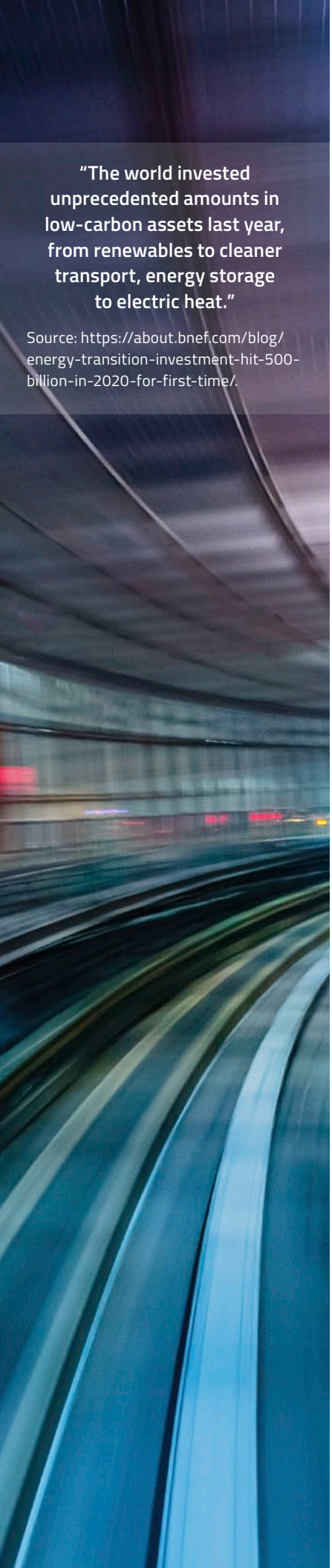
Source: IEA, Global CO2 emissions from energy combustion and industrial processes, 1900-2022. Included for illustrative purposes only.

After a brief COVID pandemic-induced retreat, GHG emissions have resumed their climb. Electricity and heat production and surface transport (i.e., vehicle driving) account for the lion's share of GHG emissions, and both continue to grow amid rising demand for electricity, traded goods and travel.

To combat rising CO_2 levels, developed countries have installed renewable-energy sources into electricity grids. Consumers are embracing EVs in higher numbers as the technology becomes more affordable and the charging infrastructure more accessible, and as the driving range of EVs expands. Although these changes have not yet reversed GHG emissions trends, researchers estimate that the contribution from cleaner energy sources to overall electricity production is accelerating.[3] Today, these alternatives are "in addition to" fossil-fuel burning sources, rather than "instead of". For example, the number of EVs on the road—the volume of which has quadrupled in the past three years, with one out of every six new vehicles now electric—is not yet large enough to offset growing surface-transport miles.

[2] Source: IPCC Special Report on Global Warming of 1.5°C, https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.

[3] Source: International Energy Agency (IEA).

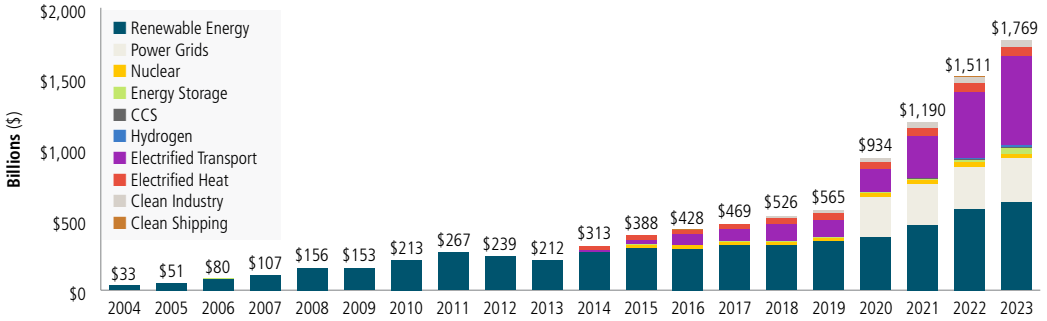


"The world invested unprecedented amounts in low-carbon assets last year, from renewables to cleaner transport, energy storage to electric heat."

Source: https://about.bnef.com/blog/energy-transition-investment-hit-500-billion-in-2020-for-first-time/.

This shift to cleaner technologies has created a dynamic energy transition investment market that is growing significantly. 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.[4]

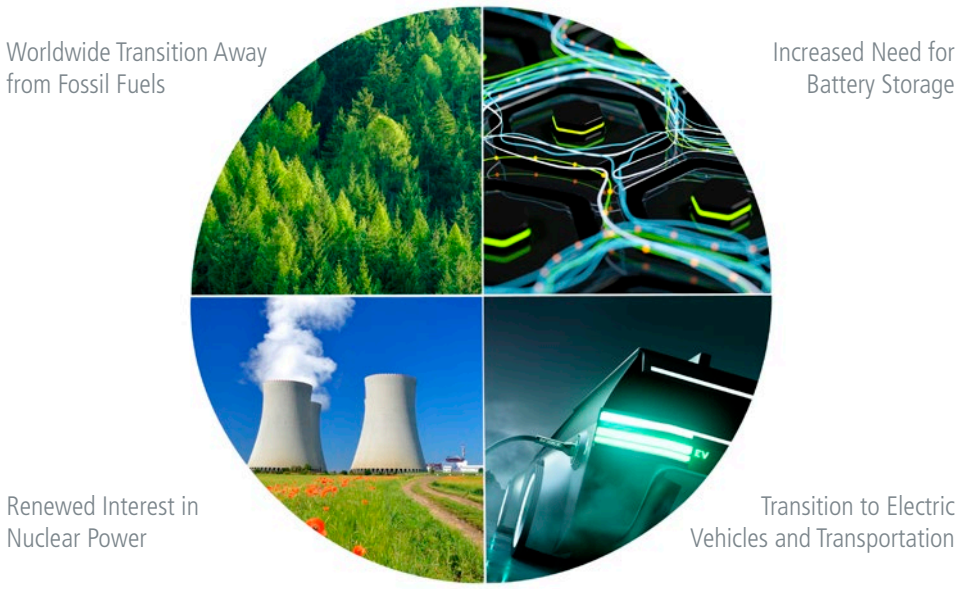
Figure 3. Surging Global Investment in Clean Energy



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

Multiple Fronts of the Energy Transition

CO_2 emissions need to fall by about 45% from 2010 levels by 2030 to reach net-zero by 2050.



Source: IPCC Special Report on Global Warming of 1.5°C, https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.

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

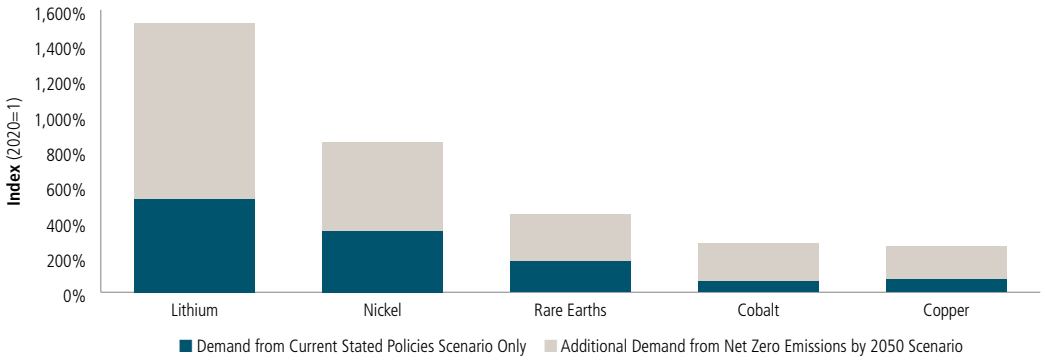
A New Focus on Energy Security

There is a growing consensus among policymakers and consumers that clean energy is not just the future—it is now. The ongoing Russia-Ukraine war has also prompted a new era of energy security, amplifying the momentum of the energy transition. Across Europe, national governments and municipalities are aggressively strategizing to end energy dependence on Russia. According to the REPowerEU Plan announced in early 2022, the European Bloc aims to help limit overall energy demand in the EU, to diversify away from Russian supplies and importantly, to accelerate investment in cleaner energy infrastructure. The European Council on Foreign Relations has tracked 110 new energy deals across the EU and its member states since the initial invasion of Ukraine in February 2022, and analysts found that about half of the deals involve some clean energy component.[5]

The clean energy movement has more momentum than ever given the confluence of disruptive climate change, falling costs for cleaner energy technology, growing consumer preferences for decarbonized options and increased threats to global energy sources.

Figure 4. The Climbing Demand for Critical Minerals

Growth Projections for Mineral Energy Transition Demand in 2040, Relative to 2022



Source: "Critical Minerals Market Review", International Energy Agency (IEA), July 2023. Neodymium demand is used as indicative for rare earth elements. The Stated Policies Scenario indicates where the energy system is heading based on a sector-by-sector analysis of today's government policies and policy announcements; the Net Zero Emissions by 2050 Scenario indicates what would be required in a trajectory consistent with meeting the Paris Agreement goals. Included for illustrative purposes only.

Critical Minerals: The Linchpins of Decarbonization

The technologies underpinning decarbonization rely more heavily on critical minerals than existing energy infrastructure and systems. These minerals are not new in end uses; internal combustion engines (ICE), fossil-fuel electricity plants and mobile phone batteries already rely on these inputs. The issue is a matter of scale. According to the International Energy Agency, an offshore wind turbine depends on nine times more minerals than a comparable gas-fired power plant, and an EV uses six times more critical minerals than an ICE vehicle.[6]

[5] Source: https://ecfr.eu/special/energy-deals-tracker/. Data as of April 24, 2023.

[6] Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary.

Did You Know?

Many critical mineral oxides and metals are used in the process of coloring glass.

Critical Minerals in Glass

Uranium Oxide

Used to make glass a fluorescent green/yellow; the secret ingredient in making Vaseline glass.

Copper Compounds

Used to make glass in shades of red, green and blue.

Nickel Oxide

Used to make violet-colored glass.

Manganese Dioxide

Used to make purple glass.

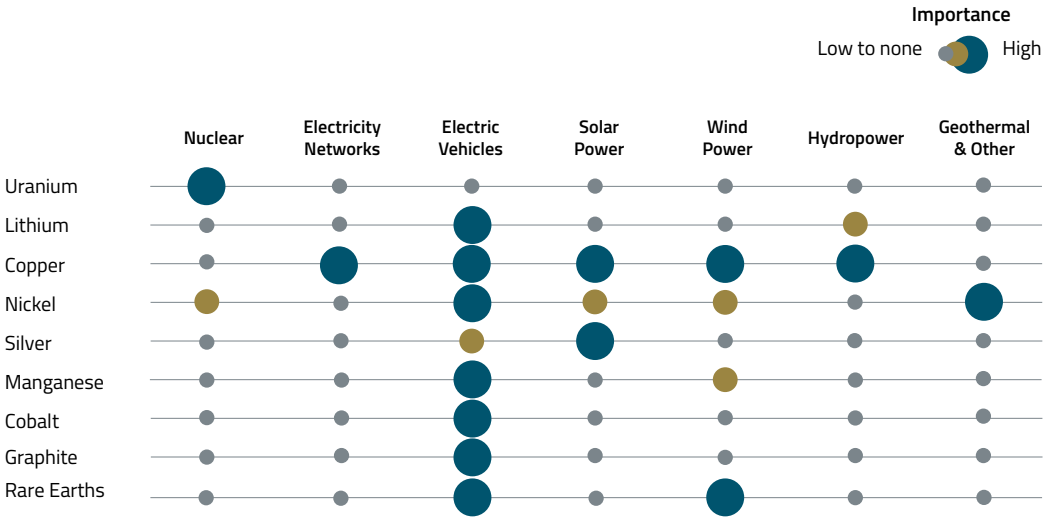
Cobalt Oxide

Used to make glass that has a blue/violet tint to it.

Source: https://www.bohaglass.co.uk/metals-used-to-create-coloured-glass-ornaments/.

Figure 5. Cleaner Technologies Rely on Critical Minerals

This list reflects Sprott's critical minerals focus, and is not inclusive of all critical minerals. For example, the USGS "2022 Final List of Critical Minerals" includes 50 minerals.[7]



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.

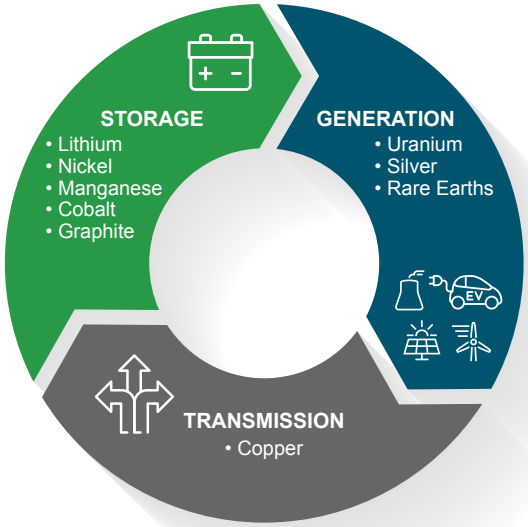
Nuclear power plants depend on uranium for fuel. Nickel alloys are also a key component for the heat transfer and cooling systems of nuclear power plants and inside the nuclear reactor vessel.[8] Solar, wind, hydropower and geothermal power production rely on copper, nickel, silver and rare earths. Electric vehicles rely on a range of critical minerals for battery components, but they also require rare earths for motor design and copper for conductivity throughout the system. Indeed, all energy-usage systems, including electricity grids managing greener-energy inputs, rely on copper to transmit electricity between power sources, batteries and power uses.

We separate the energy transition into three broad categories based on primary purpose: generation, transmission and storage. Each category relies on a set of critical minerals for which there are no real substitutes.

With the global energy transition gathering steam, demand for critical minerals is expected to increase significantly, as shown in Figure 6. This growth has the potential to benefit mining companies involved in the discovery, extraction and processing of critical minerals, and the investors who gain access to these miners.

[7] Source: https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals.
[8] Source: https://nickelinstitute.org/about-nickel-and-its-applications/nickel-alloys-in-energy-and-power/.

Critical Minerals Across Three Functions: Generation, Transmission, Storage

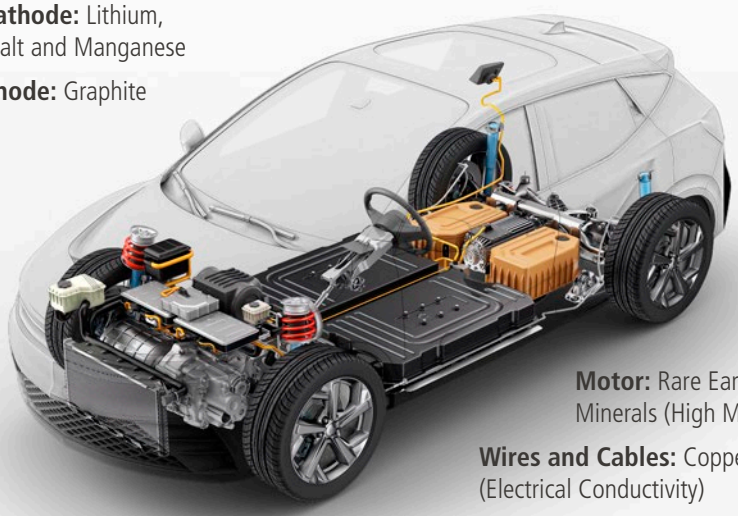


EVs Depend on All Three Functions

Electric vehicles require a range of critical minerals that span all three functions: generation, transmission and storage. Beyond rechargeable lithium-ion (Li-ion) batteries, an EV requires critical minerals to power its motor and supply electrical power throughout the vehicle.

Battery Cathode: Lithium, Nickel, Cobalt and Manganese

Battery Anode: Graphite



Motor: Rare Earths Minerals (High Magnetism)

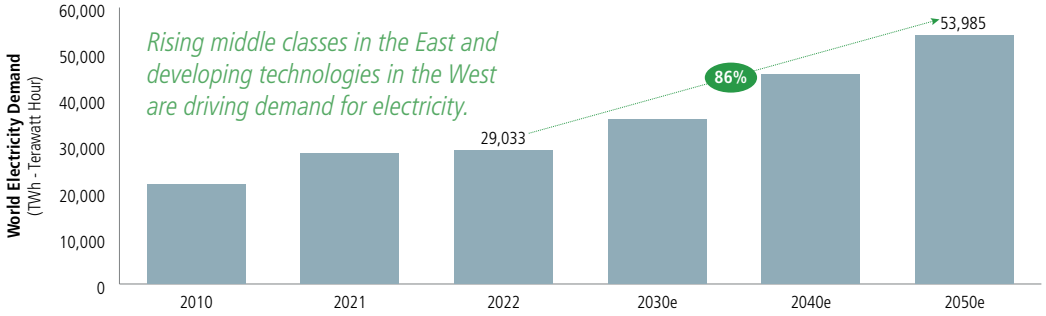
Wires and Cables: Copper (Electrical Conductivity)

Critical Minerals in Electricity Generation

GENERATION: URANIUM

Global electricity demand is expected to grow by 86% between 2022 and 2050, according to the IEA World Energy Outlook. Countries must shift their production mix to include a much higher share of greener-energy sources to lower GHG emissions from electricity production while accommodating expanding demand. Nuclear energy must be at the top of the list.

Figure 6. Electricity Demand Estimated to Increase 86% by 2050



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

Nuclear power offers the lowest GHG profile while also delivering the highest capacity, meaning that actual electricity production is close to its maximum potential output compared to other greener-energy sources. Solar, wind, geothermal and hydropower are all valuable contributors to green energy, but none can provide the steady baseload power that nuclear power plants provide.

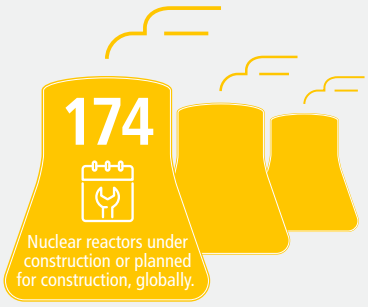
Sentiment toward nuclear power has shifted dramatically as the dual threats of climate change and geopolitical upheaval beset governments. Increased focus on decarbonization and energy security has shifted nuclear energy policies and government support, and at COP28 (the annual United Nations climate change conference) there was "the greatest outpouring of global support for nuclear power the world has seen since the thunderous reception to Eisenhower's Atoms for Peace call exactly 70 years ago", said Seth Grae, President and CEO of Lightbridge Corporation. To this end, 22 countries pledged to triple global nuclear energy capacity by 2050.

Uranium Miners Are Poised for Growth

Today, the post-Cold War uranium stockpiles are gone, many mines have been closed and new supplies aren't keeping up with demand:

- The number of nuclear reactors is set to increase by 40% in the coming years.
- As of January 2024, 174 new reactors are under construction or planned for construction.
- Existing and committed uranium mines at historic production capabilities are not forecasted to meet reactor demand to 2040.

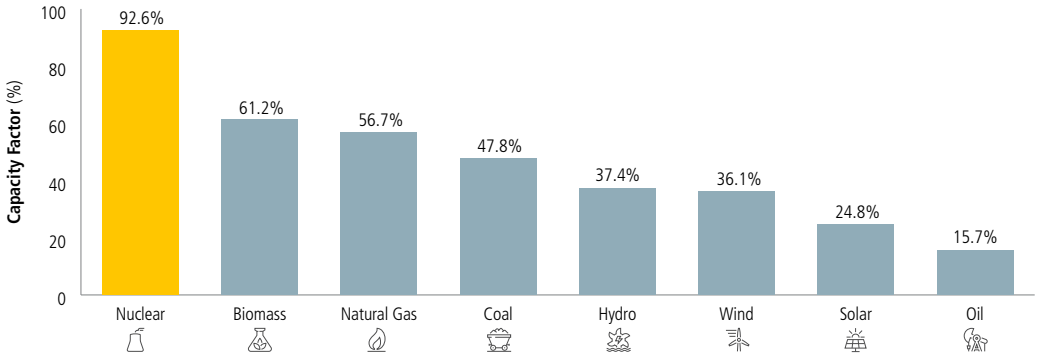
† Source: UxC, LLC. Data as of Q4 2023.



Source: World Nuclear Association as of 1/10/2024. Included for illustrative purposes only.

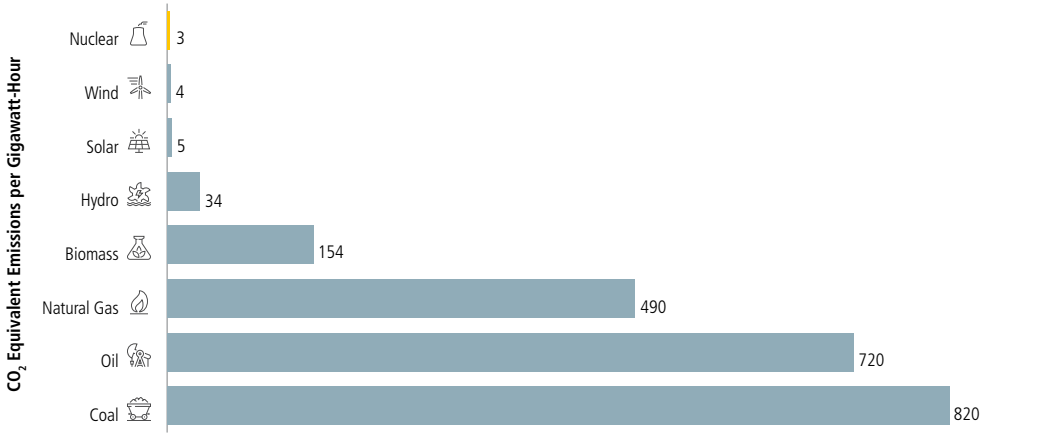
Figure 7. Nuclear Power Is a Cleaner Energy Solution

Highest Energy Capacity



Note: Capacity factor measures the total amount of energy produced during a period of time divided by the amount of energy the plant would have produced at full capacity.
Source: U.S. Energy Information Administration and energy.gov. Data as of 12/31/2022. Included for illustrative purposes only. Past performance is no guarantee of future results.

Lowest Emissions



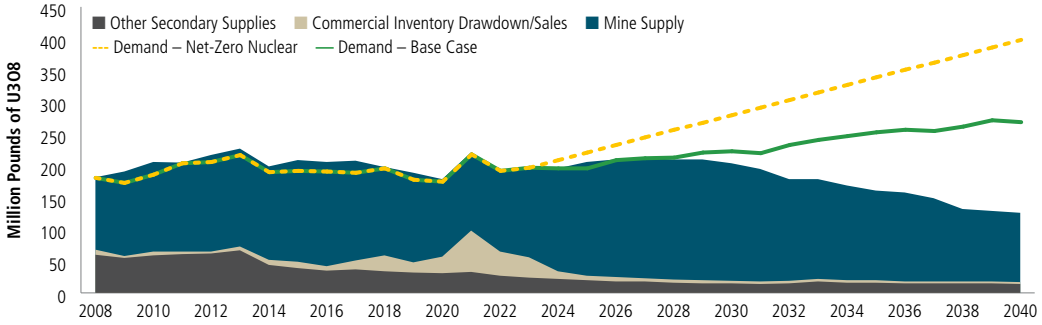
Source: https://ourworldindata.org/nuclear-energy as of 2021; measured in emissions of CO2-equivalent per gigawatt-hour of electricity over the life cycle of the power plant. Included for illustrative purposes only. Past performance is no guarantee of future results.

Nuclear power depends on one fuel for which there is no substitute: uranium. Uranium is a heavy metal that co-occurs with other elements in rocks. According to the EIA,[9] economically mineable deposits are located in the western U.S., Australia, Canada, central Asia, Africa and South America.

During the Cold War, enriched uranium was stockpiled in substantial quantities, and global uranium mining has operated at a deficit to demand for many years as power plants slowly worked through the stockpile. Now, stockpiles have been diminished. In 2002, only about half of nuclear power plant uranium came from mined supply; by 2012, 95% was coming from mined supply.[10] Yet the International Atomic Energy Agency forecasts that uranium mining will not meet reactor demand in the next decade or more.

[9] Source: https://www.eia.gov/energyexplained/nuclear/where-our-uranium-comes-from.php.
[10] Source: https://www.oecd-nea.org/jcms/pl_13870.

Figure 8. Uranium Supply and Demand Imbalance May Likely Grow



Sources: UxC, LLC and Cameco Corp. Data as of Q4 2023. Included for illustrative purposes only.

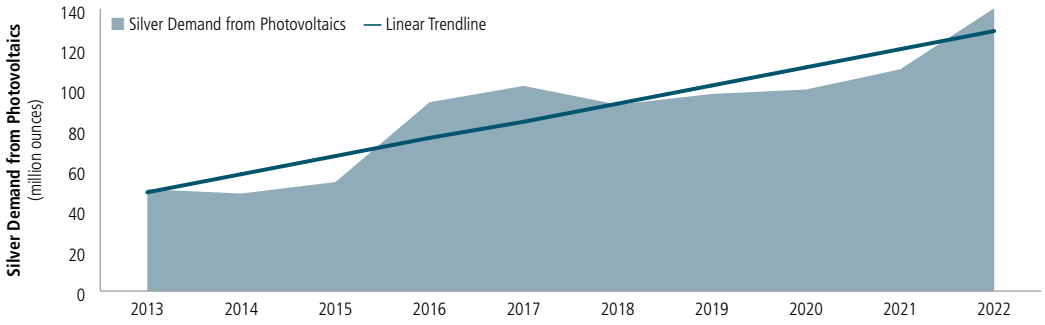
GENERATION: SILVER

Silver is unique as a critical mineral because it plays multiple roles in the economy, ranging from industrial uses to its history as an investment or store of monetary value to its use in decorative jewelry and housewares. For the energy transition, silver is essential because of its superior electrical conductivity profile—silver ranks as the most conductive metal on Earth, even more than copper.[11]

Silver plays an important role in the solar energy sector and is used to help solar panels generate electricity. As the use of solar panels grows over time, industrial demand for silver is expected to expand significantly. The World Bank estimates that green technology demand for silver will double between 2017 and 2050, from 1.4 thousand metric tons to 3.2 thousand metric tons, driven primarily by solar panels.

Figure 9.

Silver Demand from Photovoltaics

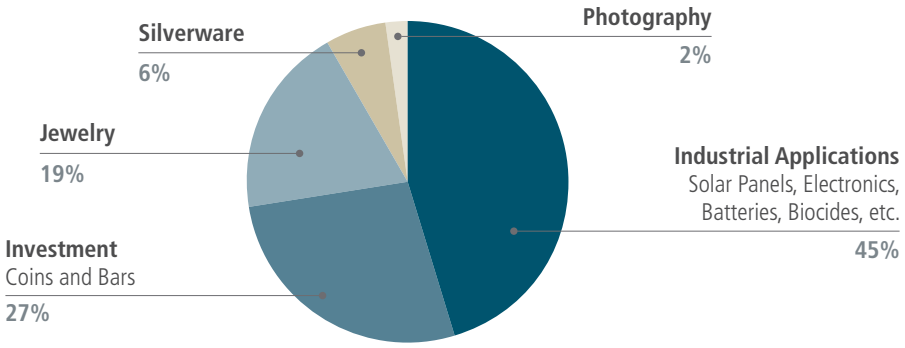


Source: GFMS Refinitiv, Metals Focus, Silver Institute, UBS. Data from the World Silver Survey 2023. Included for illustrative purposes only.

[11] Source: https://sciencenotes.org/what-is-the-most-conductive-element/.

Silver Demand by Use

Industrial Buyers Drive Approximately 50% of Silver Demand



Source: GFMS Refinitiv, Metals Focus, Silver Institute, UBS. Data from the World Silver Survey 2023. Included for illustrative purposes only.

Silver also plays a key role in auto manufacturing for both EVs and internal combustion engine vehicles. Thanks to its conductivity, silver is used extensively in autos, from electric power steering to automatic braking and control units that manage some engine functionalities. In EVs, silver plays an important role in battery design. The Silver Institute estimates that ICE vehicles use about 15-28 grams of silver, while EVs use about 25-50 grams per vehicle. By 2025, automotive use of silver is expected to catch up with solar panel use and further contribute to growing demand overall.[12]

While demand is expected to grow, silver supply has been constrained, producing supply shortfalls in 2021 and 2022.[13] Fuel inflation and labor shortages have boosted the cost of production, pressuring the profitability of mining. Seventy-two percent of silver is mined as a byproduct metal, so mining activity also depends heavily on pricing for gold, lead, zinc and copper.

GENERATION: RARE EARTHS

Rare earth elements are a collection of 17 metallic elements that are essential in many high-tech products due to their strong magnetic properties. Rare earths play an important role in electric motors, with 90% of EV models using rare earths as part of their drivetrains. They help power the wheels of an EV—electric motors use the force produced when two magnets repel one another, causing the axle to spin rapidly and creating sufficient torque to turn the wheels. Without certain rare earths, this process would be very difficult to replicate.

Rare earths are also critical to the construction of wind turbines, which rely on rare earths in significant quantity to create the same torque-generating magnet functionality.

[12] Source: Silver Institute, https://www.silverinstitute.org/silver-consumption-global-automotive-sector-approach-90-million-ounces-2025/.
[13] Source: Silver Institute, https://www.silverinstitute.org/silver-supply-demand/.

Did You Know?

Rare earths were first discovered in 1788 in Ytterby, Sweden, by a miner who found an unusual black rock. The found ore was called "rare" as it had never been seen before and "earth" as it was the 18th century geological term for rocks that could be dissolved in acid.

Interesting Rare Earth Facts

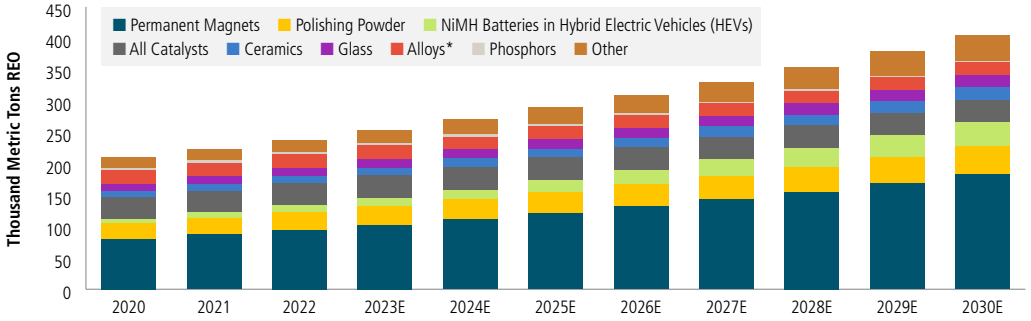
Superior Magnets – The strength of neodymium magnets makes hybrid and electric vehicles, mobile phones, televisions, computers, wind turbines, loudspeakers, aircraft controls, robots and factory automation equipment more efficient.

Color TV – Various rare earths elements were used to make red, green and yellow visible in color tube televisions, and to accentuate the vividness of the picture.

Fluorescent Crime Fighters – Rare earth compounds dysprosium, europium and terbium are fluorescent under ultraviolet light, making them incredibly useful in the anti-counterfeiting industry.

Source: https://www.brunel.net/en-au/blog/mining/five-facts-about-rare-earth-metals.

Figure 10. Rare-Earth Oxide (REO) Demand Estimates

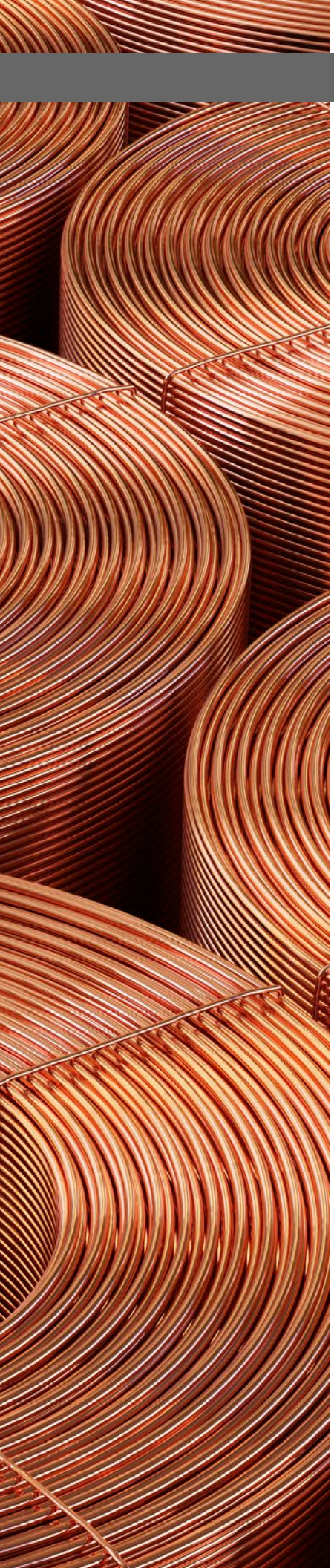


* Excludes NiMH Batteries in Hybrid Electric Vehicles (HEVs).

Source: BloombergNEF Rare-Earth Demand in Clean Energy; Ministry of Land Resources (MLR) of China as of 2020, Aclara Resources Inc., U.S. Department of Energy. Included for illustrative purposes only.

Despite its vital importance in the manufacturing of electric motors and wind turbines, the supply of rare earths is currently vulnerable. China currently produces the most rare earths, causing other countries to scramble for more reliable sources. The Biden administration has prioritized securing a domestic source of rare earth elements. This will take time to play out, but the need for onshore production is becoming more obvious as the global EV fleet expands.[14]

[14] Source: https://www.idtechex.com/en/research-article/rare-earths-in-evs-problems-solutions-and-what-is-actually-happening/25071.



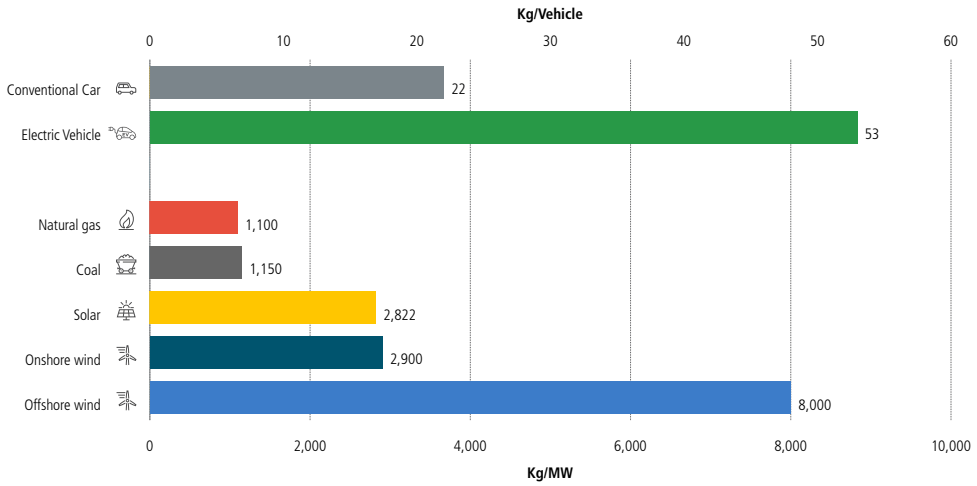
Critical Minerals in Energy Transmission

TRANSMISSION: COPPER

Copper is another key player in the big picture of clean energy. The clean energy transition relies on carbon-free electricity, both in our power grids and in our vehicles, and all of the systems that produce and store electricity depend on copper for transmission.

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 11). The capacity for solar and wind energy has been on an upward trajectory globally and is expected to continue growing. More renewable energy sources in the electric grid mean more copper demand.

Figure 11. EVs and Renewables Require More Copper



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

The shift from internal combustion engines 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 11). 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.[15]

[15] 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/

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**

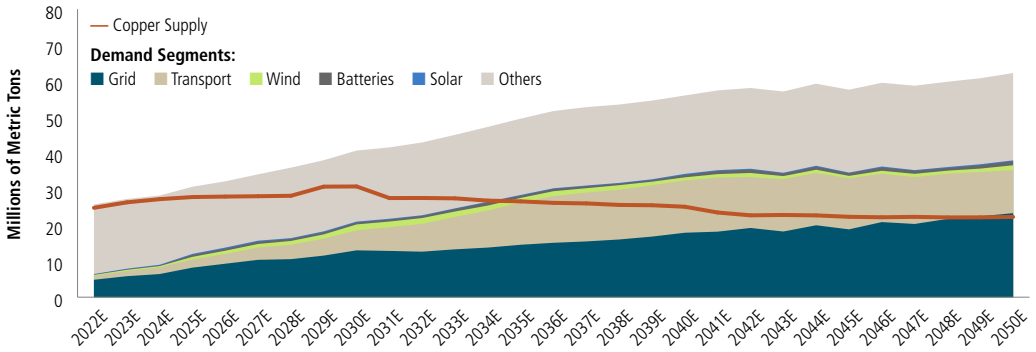
Interesting Copper Facts

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.

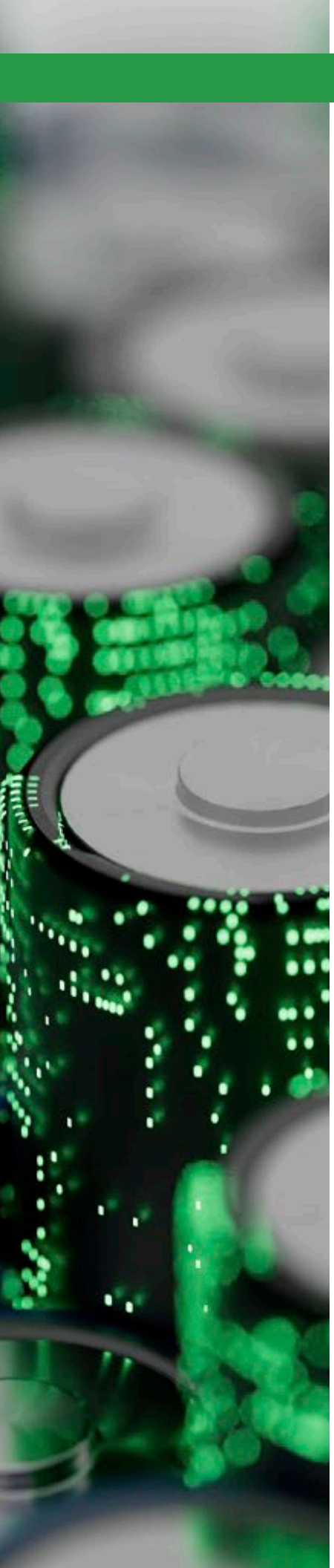
Figure 12. Copper Supply and Demand Imbalance Likely to Grow



Source: BloombergNEF Transition Metals Outlook 2023. Included for illustrative purposes only.

Copper is an abundant resource on Earth, but the challenge is mining an economically viable amount quickly enough. Chile and Peru are the world's largest producers of copper,[16] and both face challenges with labor strikes and protests. Lower ore grades are also a headwind. Russia, the seventh largest producer of copper, is expected to see production decline as the war in Ukraine continues. Still, miners are working to expand production to meet increasing demand—but many analysts see a supply imbalance continuing to grow.

[16] Source: https://www.visualcapitalist.com/visualizing-the-worlds-largest-copper-producers/.

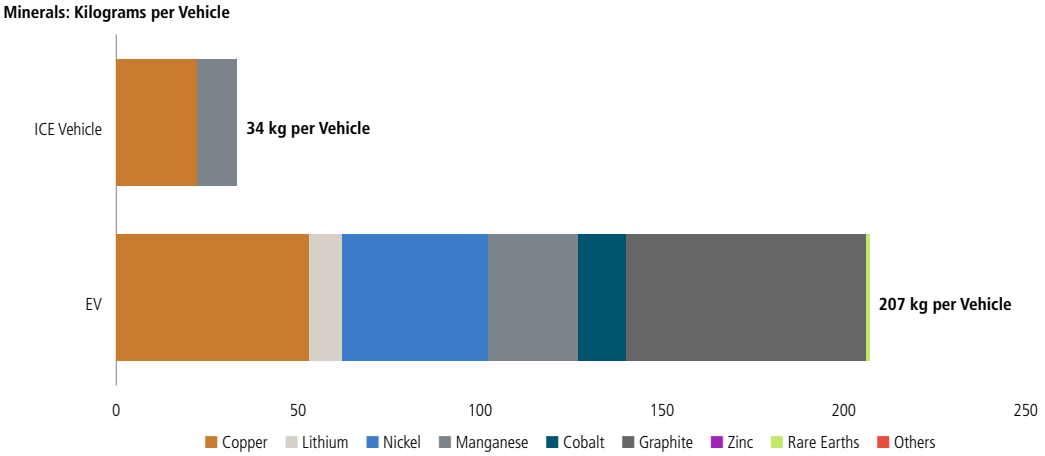


Critical Minerals in Energy Storage

Electric vehicles are becoming increasingly mainstream. In 2022, there were 26 million EVs on the road, triple the amount from three years prior. By 2030, the number of EVs in use may expand to almost 350 million globally.[17] Moreover, EVs accounted for 14% of global car sales in 2022,[17] over three times the amount in 2020. The exponential growth demonstrates the drastic change in market conditions. Lower prices, more offerings and increasingly accessible charging stations have enabled the EV market to flourish.

Of course, EVs are replacing the internal combustion engine with a battery-powered electric motor—and the engineering relies on a much higher amount of critical minerals per vehicle. The average EV contains more than 200 kilograms of critical minerals, compared to 34 kilograms per ICE vehicle—about six times more. The battery design relies on lithium, nickel, cobalt, manganese and graphite. The electrical systems require copper, and the motor requires rare earths minerals.

Figure 13. EVs Are a Driver of Critical Mineral Demand



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

STORAGE: LITHIUM

Lithium plays a pivotal part in battery construction. The movement of lithium ions back and forth between the anode and cathode of a battery generates the free electrons in the anode, producing the actual charge at the positive end of the battery.[18] That charge flows into a vehicle's motor or the electronics being powered.

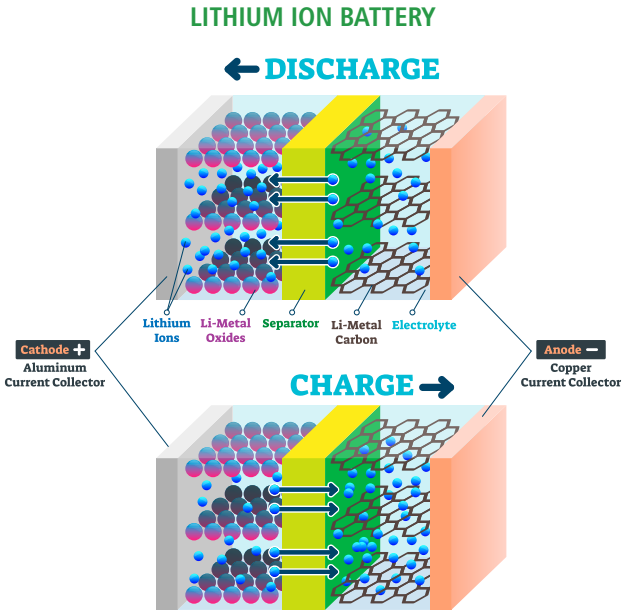
[17] Source: BloombergNEF is a leading provider of forward-thinking primary research and analysis on the trends driving the transition to a lower-carbon economy.

[18] Source: https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work.

Interesting Lithium Facts

- Named for the Greek "lithos", which means stone.
- The lightest metal.
- Is present in most igneous rocks.
- Soft enough that it can be cut with a butter knife.
- Lowest density of any metal; if it didn't react with water, it would float.
- Burns white with crimson; used in fireworks to make red sparks.

Figure 14. Lithium Enables Rechargeable, Viable Batteries

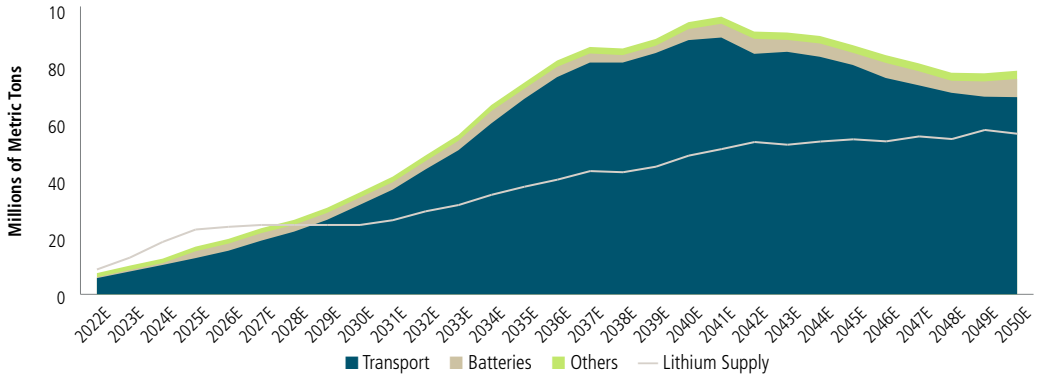


Source: istockphoto.com. Included for illustrative purposes only.

The lithium market is an area of pressing interest for a world looking to replace about 1.4 billion ICE vehicles[19] with EVs in the decades to come. Estimates put the global market for lithium at US$7 billion in the year 2022, and some project that the market will reach more than US$22 billion by 2030.[20]

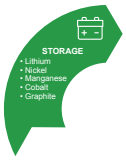
There is plenty of lithium on Earth, but extracting it from the ground fast enough poses many challenges. According to the U.S. Geological Survey, the Earth's lithium resources are estimated at 98 million metric tons, but only around a quarter of that is in reserves and is considered economically viable to mine. Demand is forecast to outpace supply in 2028 and onward.

Figure 15. Lithium Supply Unlikely to Keep Up with Demand



Source: BloombergNEF Transition Metals Outlook 2023. Included for illustrative purposes only.

[19] Source: https://www.popularmechanics.com/science/energy/a42417327/lithium-supply-batteries-electric-vehicles/.
[20] Source: ReportLinker market research by Global Industry Analysts. https://www.reportlinker.com/p05478488/Global-Lithium-Industry.html.



Nickel: More Than Stainless Steel

- The only U.S. coin that is named for its metal content.
- Often used for making wires.
- Used in gas turbines and rocket engines, as it has the capability to resist corrosion even at high temperatures.
- Used to make a variety of alloys that are further used to make armor plating, nails or pipes.
- Two-thirds of the world's nickel production is used to produce stainless steel.

Cobalt's Magnetic Personality

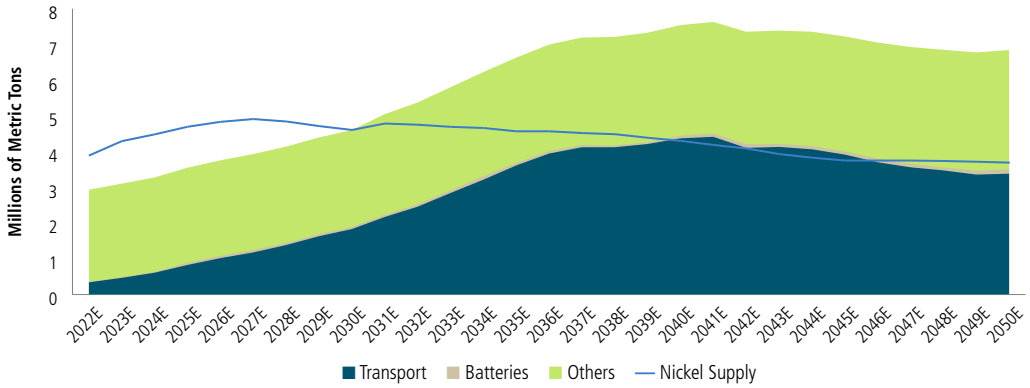
- Ferromagnetic—one of the few elements magnetized when exposed to an external magnetic field.
- Remains magnetic at extremely high temperatures, making it useful for magnets in generators and hard drives.
- Can be mixed with other metals to create superalloys, which maintain strength under stress and high temperatures; used in jet engines.

STORAGE: NICKEL

Nickel is another metal crucial to rechargeable battery design. It is the most important metal by mass in the lithium-ion battery cathodes used by EV manufacturers for long-range vehicles. Nickel may account for up to 80% of the weight in a cathode, such as in nickel cobalt aluminum (NCA) cathodes or in some nickel manganese cobalt (NMC) cathodes.

Nickel is already used widely in stainless steel and other industrial applications, including prominent roles in other energy-transition technologies. In nuclear power plants, nickel is mixed into alloy materials used in the heat transfer and cooling systems and inside the reactor vessel. Thermal solar or concentrated solar plants also depend on nickel alloys for heat-transfer purposes, while hydro and wind energy generation depend on turbines containing nickel.[21] Nickel also faces uncertainties in supply and perhaps a substantial deficit in the years to come.

Figure 16. Nickel Supply and Demand Imbalance Likely to Invert

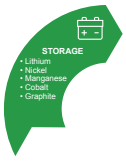


Source: BloombergNEF Transition Metals Outlook 2023. Included for illustrative purposes only.

STORAGE: COBALT

Cobalt is another mineral of critical importance to clean energy, used as a core component of cathodes in rechargeable batteries. Cobalt imparts thermal stability and high energy density to rechargeable lithium-ion batteries, which is key to the range and stability of EV batteries. It is one of the most costly components of a battery, and researchers have been hard at work trying to reduce the amount of cobalt in an EV battery—but it presently remains essential in battery design.

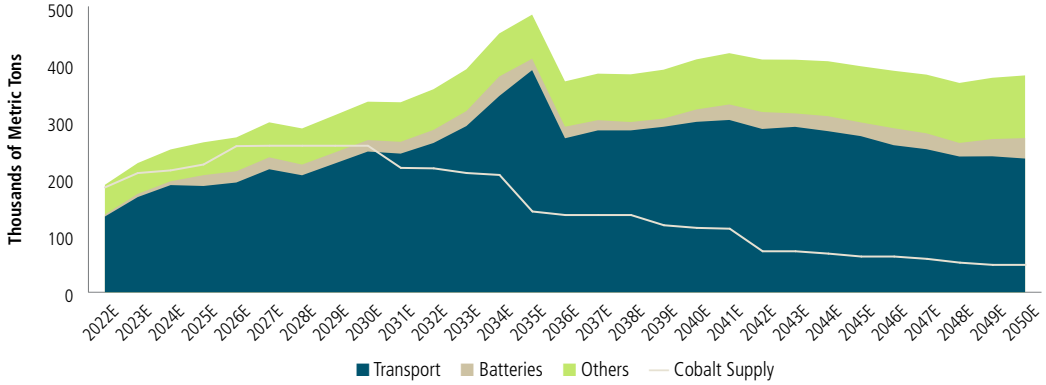
[21] Source: https://nickelinstitute.org/en/blog/2021/september/the-amazing-role-of-high-temperature-nickel-alloys-and-stainless-steels-for-concentrated-solar-power/.



Get to Know Graphite

- From the Greek word "graphein", which means to write/draw.
- Mixed with clay to make pencils since the time of Napoleon (early 1800s).
- A refractory material that is resistant to heat, pressure or chemicals; used in defense, gaskets for high-pressure seals and crucibles for molten metals.

Figure 17. Cobalt Supply and Demand Imbalance Likely to Grow



Source: BloombergNEF Transition Metals Outlook 2023. Included for illustrative purposes only.

Cobalt supply is also problematic. Analysts estimate that cobalt mining will require an annual investment of $1 billion to keep pace with the output needed for 2050 net-zero targets. Geopolitics also complicates matters, as 70% of the world's cobalt reserves[22] are located in the Democratic Republic of the Congo, a region known for instability and poor labor standards.

STORAGE: GRAPHITE

Graphite is another mineral critical to the design of lithium-ion batteries, specifically the anode—and each battery needs a lot of graphite. By weight, graphite is one of the largest components of an EV battery, accounting for 20-30%. And EV batteries are quite heavy, far heavier than ICE components, so the graphite weight is quite substantial. An average plug-in EV contains more than 115 pounds of graphite.

Energy transition demand for graphite is already climbing and is expected to grow somewhere between 750% and 2,500% by 2040,[23] relative to 2020 levels, depending on how aggressive global players are about meeting 2050 net-zero targets. EV battery technology is actively pursuing alternatives to pure graphite that would amplify the energy density of batteries. Research is currently focused on ways to incorporate silicon into anode design, as silicon can bind to more ions than graphite and thus store more energy in a battery, but silicon presents a range of design problems as well. Industry analysts are currently forecasting an anode mix that is increasingly turning to silicon, but not in a significant enough way to dampen the demand trend for graphite.

[22] Source: https://www.bloomberg.com/opinion/articles/2023-01-24/-blood-batteries-drive-us-ambitions-to-build-its-ev-supply-chain.
[23] Source: International Energy Agency, May 2021.

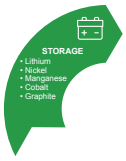
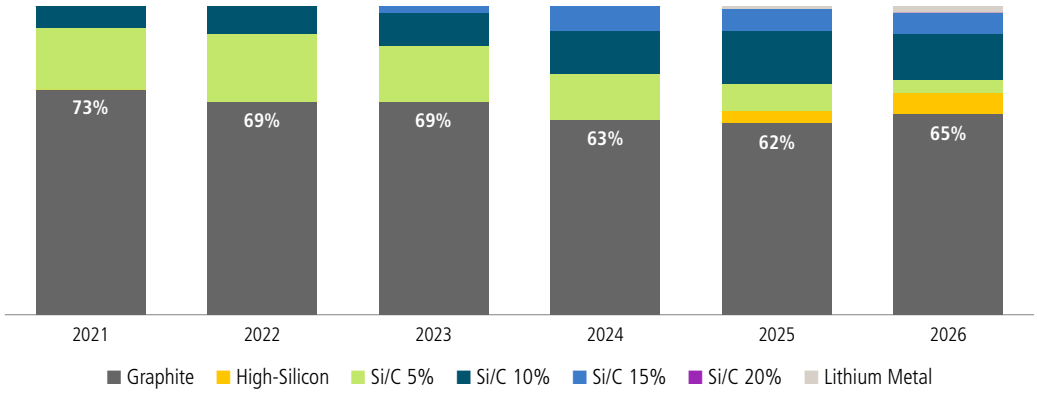


Figure 18. Graphite Dominates the Anode Chemistry Mix



Source: BloombergNEF 1H 2022 Battery Metals Outlook: Supply Turbulence Ahead. Si/C refers to silicon-graphite anodes, with the silicon percentage expressed alongside. High silicon refers to anodes using more than 50% silicon. Please note that "C" denotes Carbon in the allotrope of graphite, i.e., Si/C 5% means 5% silicon and 95% graphite. Included for illustrative purposes only.

A New Commodity Supercycle Is Underway, Driven by Critical Minerals

We believe the post-pandemic era marks the beginning of a new supercycle for commodities, especially for the critical minerals covered in this white paper. The clean energy transition is just one trend driving demand higher. Geopolitical tensions and conflict are prompting global powers to reshore their supply chains and production to ensure industrial security—an about-face after many decades of offshoring.

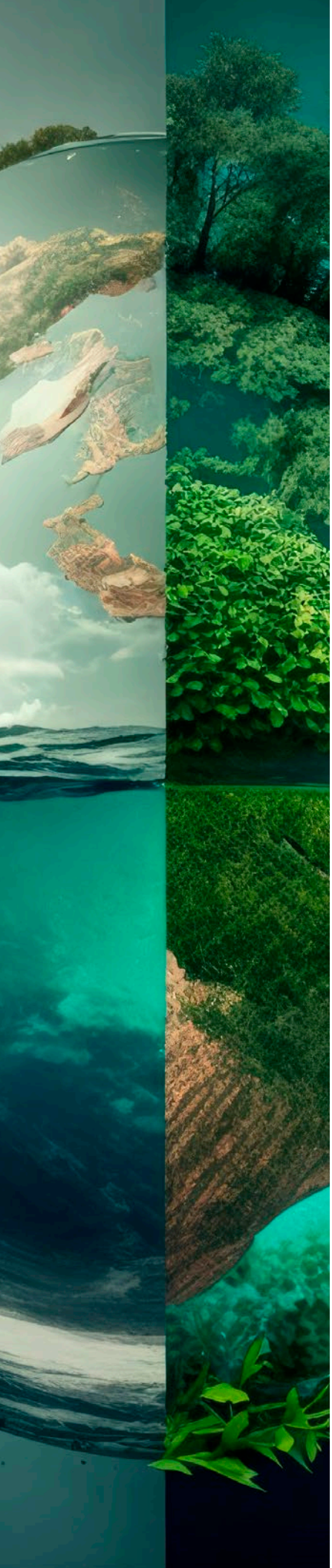
These trends are commodity- and capital-intensive, creating a demand shock for commodities. They are also inflationary in nature. We expect a steady increase in demand to drive commodities.

Meanwhile, the commodity demand shock is colliding with a supply situation that is woefully inadequate. Miners and production facilities have faced a decade of underinvestment caused by the low commodity prices that prevailed during an era of record-low interest rates and the long lead times required—often a decade or longer—to bring new production online. Sanctions on Russia, the world's largest producer of many commodities, only aggravate the situation—while also fanning the flames of rising "resource nationalism."

The commodity supercycles of the past arose from varied conditions. In the 1970s, an energy supply shock drove the distress, rooted in OPEC (Organization of the Petroleum Exporting Countries) embargoes. In the early 2000s, it was demand shock from an aggressively growing China that underpinned commodity inflation. The emerging supercycle has both supply and demand shocks, prompting heated global competition to secure commodities.

"As the world transitions to a clean energy economy, global demand for these essential products and components is set to skyrocket by 400-600% over the next several decades. Unless the U.S. expands new manufacturing, processing and installation capacity, we will be forced to continue to rely on clean energy imports—exposing the nation to supply chain vulnerabilities, while simultaneously missing out on the enormous job opportunities associated with the energy transition."

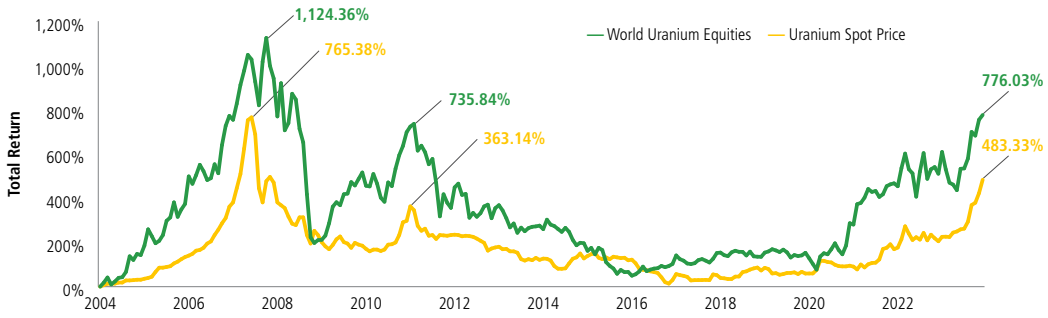
Source: U.S. Department of Energy (DOE), 6/6/2022 https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean.



Critical Mineral Miners Poised for Growth

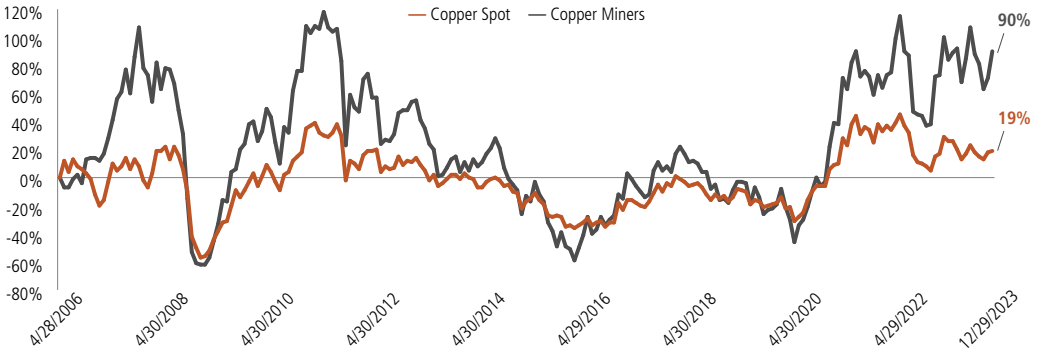
Supply and demand pressures should position miners for an era of sustained investment. From a bird's-eye view, energy is transitioning away from high-carbon sources, and miners' share of GDP (gross domestic product) production should expand in line with the share of carbon-free activity. Indeed, mining equities tend to move in line with commodity spot prices over long periods. This trend has begun to emerge post-pandemic, and we expect it to continue.

Figure 19. Mining Equities Historically Outperform During Uranium Bull Markets (2004-2023)



Source: Bloomberg and TradeTech LLC. Data from 1/1/2004 to 12/31/2023 reflecting longest available data. World Uranium Equities measured by the URAX Index, which tracks the performance of stocks globally that conduct business with uranium. URAX and Uranium Spot denominated in U.S. dollars. You cannot invest directly in an index. Included for illustrative purposes only. Past performance is no guarantee of future results.

Figure 20. Copper Equities Have Outperformed Spot During Bull



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.

What is Net-Zero?

"Put simply, net-zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance."
– United Nations Climate Action

Renewable Energy Facts

Renewable energy refers to an energy source that can be used more than once.

- The transition to renewable energy is creating jobs.
- Solar power could be the world's top power source by 2050.
- One wind turbine can power up to 1,500 homes for a year.
- Renewable energy may help you save money.

Source: https://www.inspirecleanenergy.com/blog/clean-energy-101/renewable-energy-facts.

Industrial Policy and Government Incentives

The Energy Transition Sparks a New Arms Race

The rush to secure critical minerals is analogous to the Cold War arms race, as nations compete to acquire and control vital resources essential to national security and economic competitiveness. During the Cold War, the U.S. and the Soviet Union engaged in an arms race to develop nuclear weapons and other technologies essential to maintaining military superiority and deterring potential adversaries. This competition drove significant investments in conducting research and development (R&D), stockpiling materials and developing supply chains to support military production.

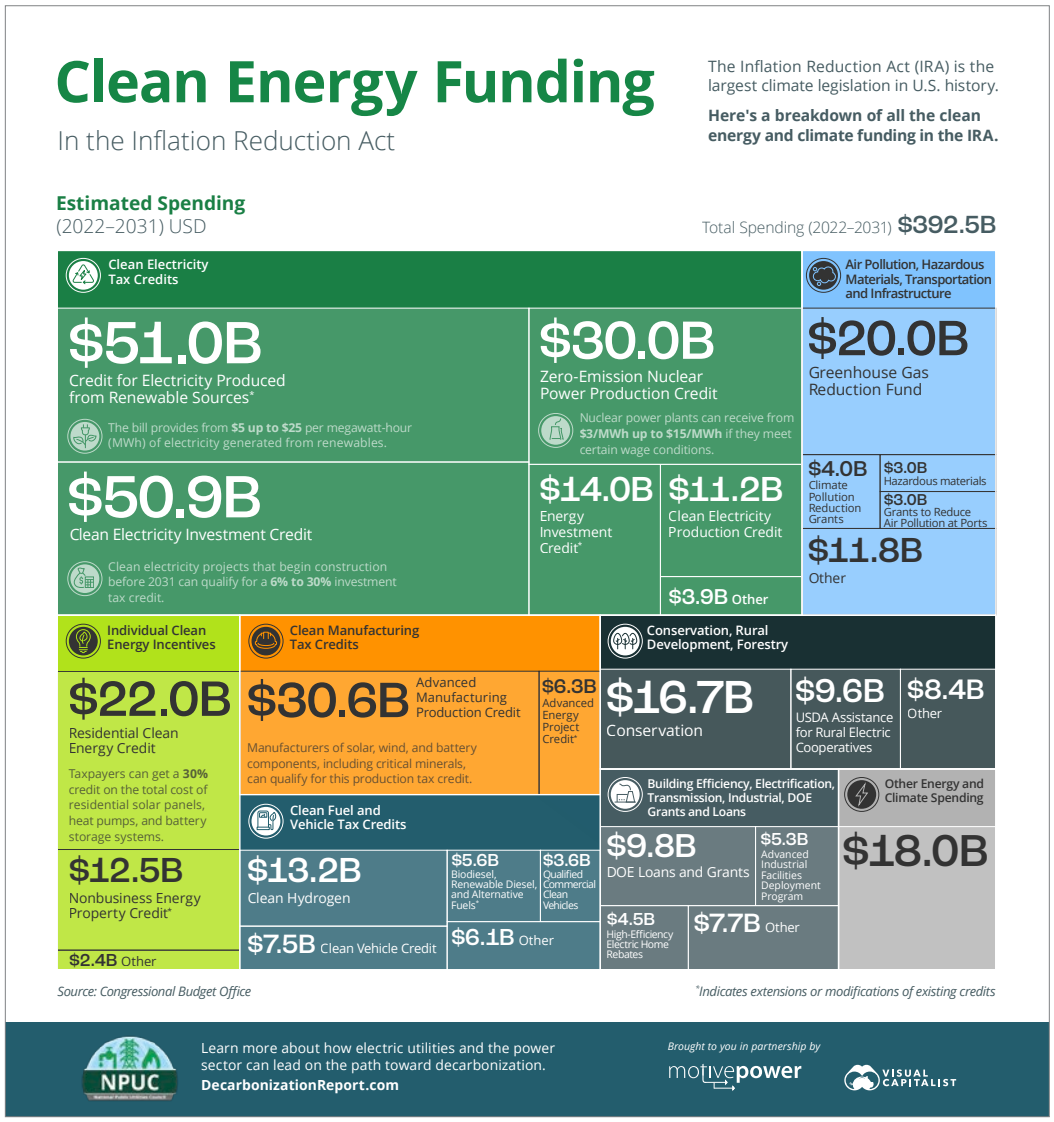
Today, nations are competing to acquire and control access to critical minerals for clean energy and electric vehicles—minerals vital to economic competitiveness and national security. Government efforts have produced policies and programs designed to secure critical mineral supplies and initiatives to promote domestic production (onshoring) and strengthen international partnerships and alliances, which is referred to as "near-" or "friend-shoring". There is also a growing focus on developing more resilient supply chains for critical minerals to reduce dependence on foreign sources and reduce the risk of supply disruptions.

A Closer Look at U.S. Initiatives

The U.S. has a long history of securing critical minerals through government action. In 1946, the U.S. established the Defense National Stockpile Center (DNSC) to maintain strategic and critical minerals stockpiles such as tungsten and titanium during the Cold War. The Defense Production Act of 1950 provides funding and other incentives to private industry to develop and produce strategic materials. The U.S. recognized the importance of these metals for national defense and established programs to secure a reliable supply and manage stockpiles.

The U.S. Inflation Reduction Act of 2022 Provides $392.5 Billion for Energy Transition

Most recently, the Inflation Reduction Act (IRA), signed into law in August 2022, provides $392.5 billion[24] to spur the financing and development of initiatives for the energy transition.



Source: https://decarbonization.visualcapitalist.com/breaking-down-clean-energy-funding-in-the-inflation-reduction-act/.

The Inflation Reduction Act is bolstered by the Biden administration's June 2022 invocation of the Defense Production Act of 1950[25] to accelerate domestic manufacturing of clean energy. Via the IRA more than $500 million will be dispensable to clean energy initiatives through the Defense Production Act, allowing the administration to impose executive authority to advance its decarbonization agenda.

[24] Source: https://www.mining.com/web/breaking-down-clean-energy-funding-in-the-inflation-reduction-act/.

[25] Source: National Public Utilities Council and Visual Capitalist. Data as of 2/21/2023. Breaking Down Clean Energy Funding in the Inflation Reduction Act, https://decarbonization.visualcapitalist.com/breaking-down-clean-energy-funding-in-the-inflation-reduction-act/.

What Are Critical Minerals Used For?

Critical minerals are integral to the way we live and to economic growth and national security. They have unique magnetic, heat-resistant and phosphorescent properties unlike any other elements.

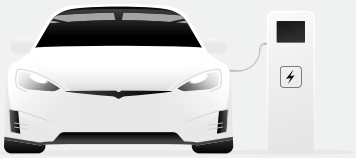
Where to Find Critical Minerals

Cell Phones and Electronics

Batteries

Solar Panels and Wind Turbines

Hybrid and Electronic Vehicles



Defense and Security Applications

Figure 21 shows IRA clean energy spending separated into seven broad categories. The largest allocation (41% of the $392.5 billion) is earmarked for Clean Electricity Tax Credits. Within this category, nuclear is set to get a $30 billion boost through the Zero-Emission Nuclear Power Production Credit, which offers from $3 up to $15 per MWh of electricity generated from nuclear reactors, applicable for all reactors in service in 2024 and continuing through 2032.

Figure 21. Energy Transition Funding in the Inflation Reduction Act

Category	Estimated Spending (2022-2031, millions)	% of Total
Clean Electricity Tax Credits	$160,940	41%
Air Pollution, Hazardous Materials, Transportation and Infrastructure	$41,870	11%
Individual Clean Energy Incentives	$36,878	9%
Clean Manufacturing Tax Credits	$36,877	9%
Clean Fuel and Vehicle Tax Credits	$35,995	9%
Conservation, Rural Development, Forestry	$34,681	9%
Building Efficiency, Electrification, Transmission, Industrial, Department of Energy Grants and Loans	$27,270	7%
Other Energy and Climate Spending	$18,000	5%
Total	**$392,511**	**100%**

Source: National Public Utilities Council and Visual Capitalist. Data as of 2/21/2023. Breaking Down Clean Energy Funding in the Inflation Reduction Act, https://decarbonization.visualcapitalist.com/breaking-down-clean-energy-funding-in-the-inflation-reduction-act/.

Energy Transition Is in Its Early Stages

The U.S. programs, along with other international efforts active in the critical minerals space, are focused on funding and developing resources and securing supply chains. The arms race in energy transition is moving rapidly and often stochastically as geopolitical events evolve. We believe there is also ample evidence that supply shortages and high demand will provide unique opportunities for investors:

- **Supply Limits:** Commodities (especially critical minerals) are becoming scarcer and therefore more valuable. The market is well past peak cheap commodities. We foresee concurrent demand and supply shocks and the emergence of a commodity supercycle.
- **Industrial Sovereignty:** Industrial policy is moving toward industrial sovereignty, with national security as a focal point. Governments are using policy, legislation, capital investment, grants, loans and other means to crowd in private sector investment, derisking it to create more predictable returns and long-term incentives.
- **An Inflationary Process:** The race to secure critical minerals is highly inflationary because building entirely new energy infrastructure—from obtaining raw materials to processing and refining them to distributing them via resilient supply chains—is extremely capital intensive.

- **Capital Intensive:** A massive amount of upfront capital will be needed before the benefits of the energy transition may be realized. Capital must be sourced and deployed, creating demand-pull on the entire energy transition sector and industrial base.
- **Reshoring Capacity:** Capital availability may likely outpace the capacity to spend. After three decades of offshoring and over a decade of chronic underinvestment in commodity resources, capacity (including commodity supply and stockpiles, skilled trades, equipment, engineering and construction) is starting from a decades-low base relative to the overall economy.

Many Challenges but an Upward Trajectory

While overall market conditions in critical minerals remain volatile, the long-term fundamental drivers are strong. Governments and corporations continue to ramp up large-scale investments in critical minerals like lithium, uranium, copper and nickel, with the goal of onshoring the primary components of energy transition infrastructure and securing a resilient and sustainable supply chain. This considerable task—the reversal of the movement over the past three decades to increase globalization and offshoring to low-cost producers and supply sources—is in its early stages today. But despite its nascency, this powerful trend may likely provide many opportunities for investors.

National Priorities Support the Energy Transition

Across the world, many countries have taken dramatic steps to ensure that the energy transition is a top priority, including:

U.S. – Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth – June 2021: Includes batteries, critical minerals and materials.

Minerals Security Partnership – June 2022: Australia, Canada, Finland, France, Germany, Japan, the Republic of Korea, Sweden, the United Kingdom, the United States and the European Commission are committed to building robust, responsible critical mineral supply chains to support economic prosperity and climate objectives.

Inflation Reduction Act – August 2022: $393 billion of incentives for clean energy.

Canada-EU Strategic Partnership on Raw Materials – October 2022: The Canada-EU Strategic Partnership on Raw Materials is the primary mechanism for engaging the European Commission and European Union member states on Canada's critical mineral and battery value chains.

EU's Critical Raw Materials Act – March 2023: Secure the critical minerals and raw materials needed for batteries for electric vehicles and renewable energy installations.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Investment Risks

Generally, natural resources investments are more volatile on a daily basis and have higher headline risk than other sectors as they tend to be more sensitive to economic data, political and regulatory events as well as underlying commodity prices. Natural resource investments are influenced by the price of underlying commodities like oil, gas, metals, coal, etc.; several of which trade on various exchanges and have price fluctuations based on short-term dynamics partly driven by demand/supply and also by investment flows. Natural resource investments tend to react more sensitively to global events and economic data than other sectors, whether it is a natural disaster like an earthquake, political upheaval in the Middle East or release of employment data in the U.S. Low priced securities can be very risky and may result in the loss of part or all of your investment. **Past performance is no guarantee of future returns.** Sprott, entities that it controls, family, friends, employees, associates, and others may hold positions in the securities it recommends to clients, and may sell the same at any time.

Micro-cap stocks involve substantially greater risks of loss and price fluctuations because their earnings and revenues tend to be less predictable. These companies may be newly formed or in the early stages of development, with limited product lines, markets or financial resources and may lack management depth.

The Funds will be concentrated in the gold and silver mining industry. As a result, the Funds will be sensitive to changes in, and its performance will depend to a greater extent on, the overall condition of the gold and silver mining industry. Also, gold and silver mining companies are highly dependent on the price of gold and silver bullion. These prices may fluctuate substantially over short periods of time so the Fund's Share price may be more volatile than other types of investments.

Funds that emphasize investments in small/mid-cap companies will generally experience greater price volatility.

Funds investing in foreign and emerging markets will also generally experience greater price volatility.

There are risks involved with investing in ETFs, including the loss of money.

Diversification does not eliminate the risk of experiencing investment losses.

The market for gold/precious metals is relatively limited; the sources of gold/precious metals are concentrated in countries that have the potential for instability; and the market for gold/precious metals is unregulated. The Fund may also invest in foreign securities, which are subject to special risks including: differences in accounting methods; the value of foreign currencies may decline relative to the U.S. dollar; a foreign government may expropriate the Fund's assets; and political, social or economic instability in a foreign country in which the Fund invests may cause the value of the Fund's investments to decline. The Fund is non-diversified, meaning it may concentrate its assets in fewer individual holdings than a diversified fund. Therefore, the Fund is more exposed to individual stock volatility than a diversified fund.

Product Risks

Sprott manages a variety of investment products. Important information about such products, including investment objectives and strategies, purchase options, management fees and expenses are contained in the offering documents. Please read the offering documents carefully before investing in any of the products.

An investor should consider the investment objectives, risks, charges and expenses carefully before investing. Investments in any of the Sprott products are not guaranteed, their values change frequently and past performance is no indication of future results. Furthermore, there is no assurance that any of the Sprott products will meet their investment objectives and their net asset value, yield and investment return will fluctuate from time to time with market conditions. There is no guarantee that the full amount of your original investment will be returned to you.

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