Mission Impossible

Mineral Shortages and the Broken Permitting Process Put Net Zero Goals Out of Reach

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Executive Summary

In 2018, Center of the American Experiment released the report "Unearthing Prosperity: How Environmentally Responsible Mining Will Boost Minnesota's Economy." In 2020, American Experiment released "Updating Prosperity: How Mining Can Boost Minnesota's Economy." These reports were the first attempt to quantify the economic benefits of developing Minnesota's vast resources of copper, nickel, cobalt, platinum, palladium, and titanium. The update reviewed developments in several proposed mining projects in Minnesota.

Why are we revisiting mining in 2024? It's simple: mining has never been more important to the future of the U.S. than now. Federal and state governments are mandating ever-stricter requirements for wind and solar electricity generation and setting ambitious targets for vehicle electrification. Artificial intelligence (AI) data center demands on the electricity grid are causing the first rise in electricity demand in two decades. At the same time, federal regulators are actively denying permits and creating rules to slow exploration and development.

Policy roadblocks threaten the domestic mining projects that the U.S. will need to achieve its net-zero ambitions. We offer this executive summary based on the findings of this report.

Modern life requires mining: Each person in the U.S. uses more than 40,000 pounds of materials, minerals, metals, and fuels[1] annually and over three million pounds during their lifetime.

International, national and state-level policies based on the 2015 Paris Agreement are mandating changes in the composition of energy generation: The International Energy Agency's (IEA) Net Zero Emissions Scenario by 2050 (NZE) adopts the Paris Agreement's objectives to restrict global temperature rise to 1.5° C above preindustrial levels.

The federal government and many U.S. states, including Minnesota, have enacted laws to try to meet the NZE objective: The U.S. is aiming to require 50 percent of all new passenger vehicle sales be electric by 2030, and 100 percent electric by 2050. Plans also call for replacing 24/7 dispatchable coal and natural gas powerplants with less dependable wind and solar energy facilities.

Federal and state mandates to close coal and natural gas powerplants are threatening U.S. electricity grid reliability: Replacing always available power from coal and natural gas powerplants with weather-dependent and intermittent solar and wind power systems has unwisely weakened the strength and dependability of the U.S. electrical grid.

A mandated energy transition would require numerous minerals: Copper, the electricity metal, is the linchpin because it is used in all electrical applications and renewable energy technologies. Lithium, nickel, cobalt, and graphite are used to manufacture the lithium-ion batteries that power EVs and store energy. Rare earth elements are necessary for the magnets in wind turbines and EV motors. Solar panels use at least eight minerals.

The mineral intensity of electric vehicles is the largest driver of the skyrocketing demand for minerals: This is especially true for copper because EVs use a lot more copper than gasoline-powered vehicles.

Demand for minerals is also rising due to AI and data centers: New pressures from AI data centers alongside renewable technologies are increasing demands for electricity and minerals. An estimated 115 percent more copper will need to be mined between now and 2050 than has *ever been mined in human history* just to meet business as usual demands. Global vehicle electrification would require developing an additional 55 percent more mines than that baseline. The need for more mining is urgent and compelling.

No form of energy comes without tradeoffs: All renewable and fossil fuel energy sources — wind and solar, hydropower, coal, natural gas, and nuclear — create environmental impacts. The impacts associated with renewable energy must be considered as a cost of meeting energy transition goals.

1 This report uses the terms "minerals," "materials," and "metals" interchangeably.

These impacts include mining the minerals needed for wind turbines, solar panels, EV batteries, transmission lines, etc., and the enormous landscape footprints of utility-scale wind and solar projects that destroy plant and wildlife habitats on millions of acres of land.

The U.S. is vulnerable because it is import-reliant for many critical minerals: Current tensions between the U.S. and China demonstrate the folly of relying so heavily on a potential adversary for minerals critical to U.S. national security, economic prosperity, energy transition ambitions, the electric grid, and more.

Mineral shortages will make achieving Net Zero by 2050 impossible.

Mines in some countries exploit workers and cause serious environmental impacts: The Democratic Republic of the Congo, which produces 65 percent of the world's cobalt, has mines where children work in hazardous conditions. In Indonesia, a major source of the world's nickel, some mines employ few if any environmental safeguards.

Federal government policies stack the deck against U.S. mining and resource development: A recent array of rules from the Biden-Harris administration's Interior Department/ Bureau of Land Management are creating serious conflicts between multiple uses of public lands and blocking more lands from consideration for natural resource exploration and development. New Environmental Protection Agency rules require coal and natural gas power plants to either employ unproven and costly carbon-capture technologies or close, which threatens the stability of the nation's electricity grids.

Permitting delays slow down all types of important projects including the solar and wind, transmission line, and mining projects needed for the energy transition: Politicization of permitting decisions chills investment in financing and building the infrastructure and mines required for an energy transition.

Minnesota is ground-zero for permitting hurdles: The Biden-Harris administration has obstructed timely development of two world-class copper, nickel, and cobalt deposits in Minnesota that could reduce the country's reliance on foreign minerals and provide some of the key minerals needed to meet energy transition goals.

Congress needs to enact permitting reforms: Lawmakers need to pass legislation to improve the permitting process so that proposed projects that meet all environmental protection requirements can be permitted more quickly and to limit obstructionists' routine use of the judicial system to challenge agencies' permitting decisions.

Mineral shortages will make achieving Net Zero by 2050 impossible: Policymakers must take a more realistic approach to establishing energy transition timelines and goals that consider mineral intensity and how to use natural gas and nuclear baseload power generation as bridge fuels that minimize CO_2 emissions while maintaining reliable electricity grids.

Minnesota and the U.S. have an important role to play in responsible domestic mining that can shorten the time it takes to achieve Net Zero and help provide the minerals we need for many purposes: Because Minnesota and the U.S. have stringent and comprehensive environmental protection and labor standards and regulations, they can produce some of the minerals needed to meet energy transition goals and other uses from the cleanest and safest mines in the world.

Policymakers should assess ways to avoid and minimize the adverse impacts of an energy transition. This evaluation should take a hard look at whether it makes sense to continue to pursue the current scale and timeframe of the NZE energy transition, whether the transition needs to be slowed down to reduce impacts, or whether it should be pursued at all.

Introduction

The 2015 Paris Agreement, also known as the Paris Climate Accord, is a United Nations-sponsored international agreement to reduce greenhouse gas emissions. There are currently 190 signatory nations. (The U.S. signed the 2015 Paris Agreement, briefly exited the agreement in 2020, and re-signed the agreement in 2021.) This agreement seeks to limit the global temperature increase to below two degrees Celsius (3.6 Fahrenheit) above pre-industrial levels by the year 2100 and to achieve the more aggressive goal to keep temperature increases to 1.5 degrees Celsius (2.7 Fahrenheit). The Paris Agreement is also called the 21st Conference of the Parties (COP) to the U.N. Framework Convention on Climate Change, or COP 21.[1] Starting in 1995, the COP countries have meet annually at various locations. In 2024, COP 29 took place in Baku, Azerbaijan. COP 30 will meet in Belém, Brazil in November 2025.[2]

The greenhouse gas reduction goals established in the 2015 Paris Accord have produced a myriad of global, national, and state-level mandates that dictate the composition of energy sources to reduce greenhouse gas emissions, focusing largely on carbon dioxide (CO_2) emissions. These mandates have in turn created an enormous demand for new renewable energy sources and technologies that require significant quantities of many minerals, as discussed in detail in this report.

This report focuses on the achievability of the International Energy Agency's (IEA's) Net Zero Emissions Scenario by 2050 (NZE) policy objective. This scenario, which is based on the 2015 Paris Agreement, assumes that global CO_2 emissions are net-zero by 2050, and global temperature rise is restricted to 1.5° C above preindustrial levels. Some countries, such as the United Kingdom and Germany, and some U.S. states have enacted laws that adopt similar and, in some cases, more ambitious timelines to achieve net zero emissions. For instance, Minnesota passed a law in 2023 to require entirely carbon-free electricity by 2040.[3]

With a focus on Minnesota, this report examines how northern Minnesota's large undeveloped deposits of copper, nickel, and cobalt should play an important role in supporting U.S. and global goals to achieve the NZE objective. We discuss how despite the U.S.' strong and growing need for these and other minerals due to demands for renewable energy technologies and the electricity needed to power AI, the federal government is nonetheless stymieing development of domestic mineral resources. In this report, we assert that Minnesota and the U.S. have the opportunity and obligation to responsibly develop domestic resources, rather than procure them from sources overseas where there are adverse environmental impacts and lack of concern for workers' health and safety.

> **The U.S. makes a value judgment every time it decides it would rather offshore a mining project than do it domestically.**

This report is comprised of the following sections:

Section I highlights the many ways in which metals and minerals are necessary in the modern world.

Section II sets the stage by evaluating the growing demand for minerals used in renewables technologies, AI data centers, and electric vehicles in addition to business-as-usual demands. Section II also evaluates existing projections of mineral demand.

Section III demonstrates that the U.S. is currently obtaining its energy minerals from foreign countries, specifically China and Canada. While it is only possible to mine where there are economically viable deposits, the U.S.' offshoring of mining to foreign countries leads to vulnerabilities. Section III also describes the rich mineral deposits that could be mined in Minnesota to partially meet U.S. mineral demands.

Section IV reviews several reports that estimate mineral demand for cobalt, copper, lithium, graphite, nickel, rare earth elements, and other minerals that will be crucial to attempt an energy transition. Demand for copper, the key energy transition mineral, will vastly exceed supply. This section anticipates future changes in battery technology and notes that, while recycling may help ease shortages for some minerals, it won't eliminate the need for mining.

Section V reviews the thicket of Biden-Harris administration policies that have put lands off-limits to mining and other natural resource development projects. From withdrawing permits for specific projects with dubious legal justification to sweeping rulemakings that withdraw millions of acres from exploration and development and throw up roadblocks limiting access to vast swaths of public lands, the Biden-Harris administration's actions run at cross purposes with its energy transition goals.

Section VI looks at one of the ways that federal policy could assist with mining policy: streamlining the protracted and litigious permitting process. Fixing the decades-long permitting process will not only benefit mining projects but also improve construction timelines for constructing high-voltage transmission lines, wind turbines, and solar farms. Section VI describes a few reforms that might speed up permitting.

Section VII describes the opportunity and responsibility that the U.S. has to promote domestic mining. The U.S., and Minnesota in particular, have strict environmental standards for design, construction, operation, monitoring, and closure of mines that minimize their environmental impact and put a premium on mine worker health and safety. The U.S. makes a value judgment every time it decides it would rather offshore a mining project than do it domestically.

This report takes no position on the benefits or costs of pursuing the NZE energy transition goal but suggests that a cost-benefit analysis is needed to carefully consider current realities regarding mineral shortages, permitting delays, and decreasing electricity grid reliability. We acknowledge that many people support U.S. policies seeking to achieve the NZE goal. However, data on the NZE's minerals intensity and the geologic feasibility of acquiring the necessary minerals to achieve the NZE energy transition goal reveal that mineral shortages will interfere with achieving NZE by the envisioned 2050 deadline. Based on this finding, we suggest that policymakers need to adopt a longer, more realistic timeline to accomplish the NZE objective. We also discuss some of the unintended adverse consequences currently resulting from governments' policies to pursue the NZE by 2050 goal and assert that decisionmakers should find ways to avoid and minimize undesirable consequences.

Section I: Modern Life Requires Mining

The amenities of daily life are too often taken for granted. Every year, each person in the U.S. depends on 40,630 pounds of minerals, metals, and other materials.[4] Minerals are essential components of everything we use and consume, including our homes, cars, phones, and all of our electronic gadgets. During our lifetimes, each American will need 3.02 million pounds of minerals, metals, and fuels as shown in Figure 1.[5]

For illustrative purposes, consider three minerals found in abundance in the Duluth complex in northern Minnesota: copper, nickel, and cobalt.[6] These minerals are critically important for many essential applications as well as ambitious low-carbon energy transition goals.

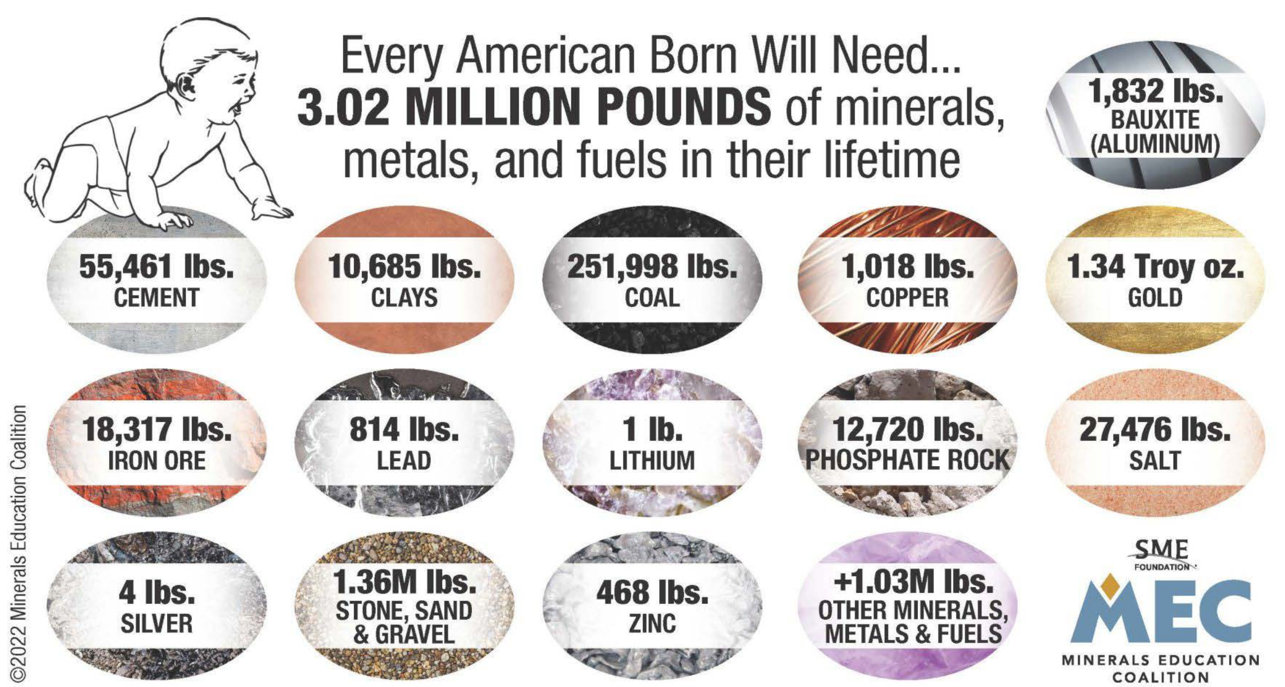
Take copper, for example. As shown in Figure 1, every American will use 1,018 pounds of copper during their lifetime. Copper is widely used in electronics and electrical applications due to its conductivity, flexibility, and durability. The average single-family home contains 439 pounds of copper in wiring, plumbing, and appliances.[7] In 2023, "copper and copper alloy products were used in building construction, 45%; electrical and electronic products, 22%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, 7%."[8] Copper is also unusually recyclable, and post-consumer scrap copper contributed 150,000 tons to the U.S. copper supply.[9]

Nickel is predominantly used as an alloy in stainless steel, and it is used extensively in contexts where hygiene is important, such as hospitals and kitchens. Nickel is essential to produce lithium-ion batteries, which have a cathode predominantly composed of nickel, which power EVs and store the intermittent energy produced by solar and wind energy.

Cobalt, while used in smaller quantities than copper and nickel, is critical in lithium-ion battery cathodes to enhance

Figure 1

Mineral Baby Showing Each American Needs 3.02 Million Pounds of Minerals, Metals, and Fuel During Our Lifetimes



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battery energy density and lifespan. As detailed in American Experiment's 2018 report, "Unearthing Prosperity: How Environmentally Responsible Mining Will Boost Minnesota's Economy," Minnesota contains "the vast majority of the cobalt deposits of the United States, with just three of the several ore bodies in the Duluth Complex holding 47 percent of U.S. cobalt resources."[10]

In addition to cobalt, copper, and nickel, rare earth elements (REEs) are frequently used in renewables technologies. REEs are a set of 17 lustrous, soft, and nearly indistinguishable heavy metals. While they are not unusually scarce geologically (contrary to their name), deposits with sufficient mineral concentrations and the right REE composition that can be economically mined and processed are relatively scarce.

For instance, neodymium, a REE, is used in the generator and motor magnets of wind turbines as well as in the motors in EVs and hybrid vehicles. A Toyota Prius is reported to contain up to a kilogram of neodymium in its motor.[11] Neodymium, praseodymium, and terbium are also used to enhance battery efficiency.[12]

For more information about iron, gold, manganese, silver, and titanium — which have all been discovered in economically significant quantities in Minnesota — please refer to American Experiment's first report, "Unearthing Prosperity: How Environmentally Responsible Mining Will Boost Minnesota's Economy."

Section II: Demands for Minerals and Power Are Rising

Because copper, nickel, cobalt, REEs, lithium, and other minerals are critical to constructing solar panels, wind turbines, and EVs, meeting the 2050 NZE timeline will require having access to globally sufficient supplies of these minerals when they are needed. Shortages of one or more of these necessary minerals will likely delay achieving the energy transition goal well past 2050.

Until recently, policymakers have not adequately considered the possibility that there will not be enough of these minerals available when they are needed to meet their energy transition policy objectives. The documented mineral shortages discussed in this report call into question whether the NZE goal is realistically achievable in the reasonably foreseeable future (i.e., between now and 2050) — and possibly much longer into the future.

The mineral shortfall reality means that policymakers must reassess their currently aggressive goals for the buildout of renewable energy facilities and adoption of EVs in order to meet the 2050 timeframe and adjust the schedule to respond to minerals availability and also to reduce the adverse consequences of rushing to replace always available fossil fuel powerplants with intermittent wind and solar energy systems that are reducing the reliability of our electric grids. This section reviews current estimates for minerals and power demand and describes how minerals availability is projected to be inadequate to manufacture EV batteries, construct wind and solar power infrastructure, and meet the enormous increase in the electricity needed to power AI data centers, and national electrification.

The IEA estimates that total mineral demand from clean energy technologies will quadruple from 2020 levels if the world pursues the Sustainable Development Scenario (SDS).[13] The SDS assumes that global temperature rise would be limited to "below 1.8°C with a 66% probability if CO_2 emissions remain at net zero after 2070."[14]

The IEA's estimates expressly do not account for steel or aluminum, and aluminum is "assessed for electricity networks only and is not included in the aggregate demand projections."[15] EVs and battery storage account for almost half of the total materials growth expected under the SDS, growing ten times over 2020 levels. Under this SDS, electricity networks create the second highest demand for minerals, with wind, solar, and other low-carbon energy sources comprising the rest of the demand.

As discussed in Section IV, the IEA's 2024 report presents a detailed breakdown of specific mineral demands. The bottom line is that the IEA forecasts shortfalls for copper, lithium, nickel, and cobalt. The IEA also expresses concerns about the geographic concentration of minerals coming mainly from China, stating that in 2030, China will control the supply of over 90 percent of the world's battery-grade graphite and 77 percent of refined REE. The IEA concludes that new mines and more mining will be required to produce the minerals that are essential to achieving the Net Zero Emissions Scenario by 2050 (NZE) policy objective.[16]

The IEA's 2024 report projects mineral demands under NZE and two other clean energy transition scenarios in 2030 and 2050: the Stated Policies Scenario (STEPS), which is associated with a temperature rise of 2.4° C in 2100 (with a 50 percent probability); and the Announced Pledges Scenario (APS), which is associated with a temperature rise of 1.7° C in 2100 (with a 50 percent probability). As shown in Figure 2, under all three scenarios, EVs and battery storage create the largest demand for minerals, followed by mineral demands for electricity networks, solar PV, and wind. Figure 2 also shows that by far, copper leads the demand for minerals under all three scenarios. There is also a substantial demand for nickel and other (undifferentiated) minerals.[17]

The Inflation Reduction Act (IRA) has compounded U.S. demand for electrification minerals. An S&P Global report finds that:

> Post-IRA, US energy-transition demand for lithium will be 15% higher by 2035 than projected pre-IRA; 14% higher for nickel; 13% for cobalt; and 12% for copper. Compound annual growth rates for the listed critical minerals to 2035 range between 20% and 30%. US energy-transition demand for these three metals together will grow 23 times between now and then, driven mostly by electric vehicles. Meanwhile, growth for copper will double, driven by a broad range of applications.[18]

In 2021, the average size of a new wind turbine was 3 MW, which requires nine tons of copper.[19] An average offshore wind turbine at 3.6 MW contains approximately 32 tons of copper.[20] A three MW turbine also includes 335 tons of steel, 1,200 tons of concrete, three tons of aluminum, and two tons of rare earth elements.[21] Solar panels are also material-intensive, primarily using silicon, aluminum, copper, and silver, as well as glass and polymers.

As shown in Figure 3, battery electric vehicles (BEVs) are more material-intensive than regular internal combustion engine (ICE) vehicles. A BEV uses 80 kilograms of copper, whereas an ICE vehicle uses 22 kg.[22] A battery electric bus uses 253 kg.[23] Graphite, cobalt, nickel, lithium, and rare earths are only necessary for BEVs; they are not used in ICE vehicles.

The demand for electrical power is soaring due to vehicle electrification, power-hungry AI data centers and applications. The Electric Power Research Institute's (EPRI's) May 2024 report found that data centers could consume up to nine percent of U.S. electricity generation by 2030, more than double the current amount. This increase could create regional supply issues.[24] Consequently, the demand for electrification minerals like copper will increase dramatically, driven by policies that incentivize a transition to wind, solar, battery storage, and EVs and burgeoning AI data center construction and applications. The electrical power grid must expand to accommodate the interconnection of wind and solar projects, to charge a nationwide network of EVs, and to respond to the power demand from AI data centers.

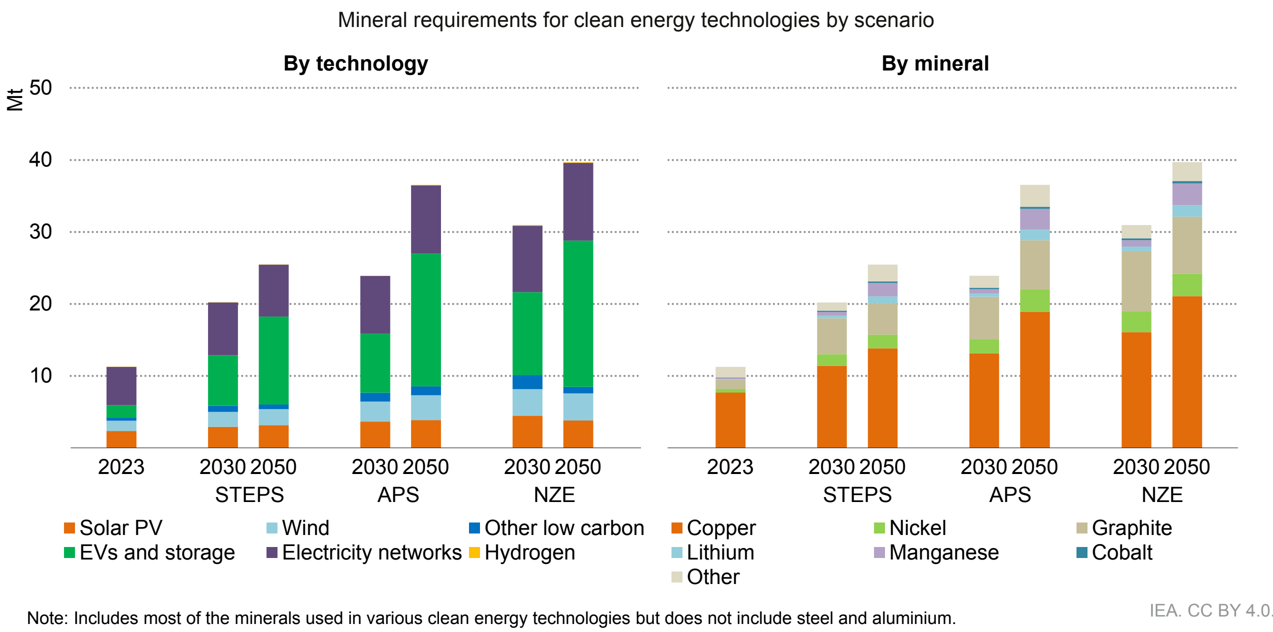
The IEA's estimates are similar, projecting that "US data centre electricity consumption is expected to grow at a rapid pace in the coming years, increasing from around 200 TWh in 2022 (~4% of US electricity demand), to almost 260 TWh in 2026 to account for 6% of total electricity demand."[25]

A McKinsey & Co. report estimates that if the U.S. "reaches the federal [zero-emissions vehicles] sales target," requiring 50 percent of "new passenger cars and light trucks" sold in 2030 to be zero-emissions, U.S. electricity demand for EV charging will reach 230 terawatts (TW) annually by 2030 (Figure 4).[26] Demand would consist of 167 TW for passenger cars, 33 TW for light commercial vehicles, 23 TW for trucks, and eight TW for buses.

As shown in Figure 4, in 2021, commercial EVs, EV trucks, and EV buses only demanded 0.4 TW of energy combined. EV use in the commercial sector will be difficult due to higher upfront costs of the vehicle and charging infrastructure. Heavier batteries lead to reduced range, which requires operators to make more frequent stops to charge and increases downtime. Commercial EVs will also need substantial additions of widespread, high-capacity chargers along major shipping routes, which will need to be connected to the grid.

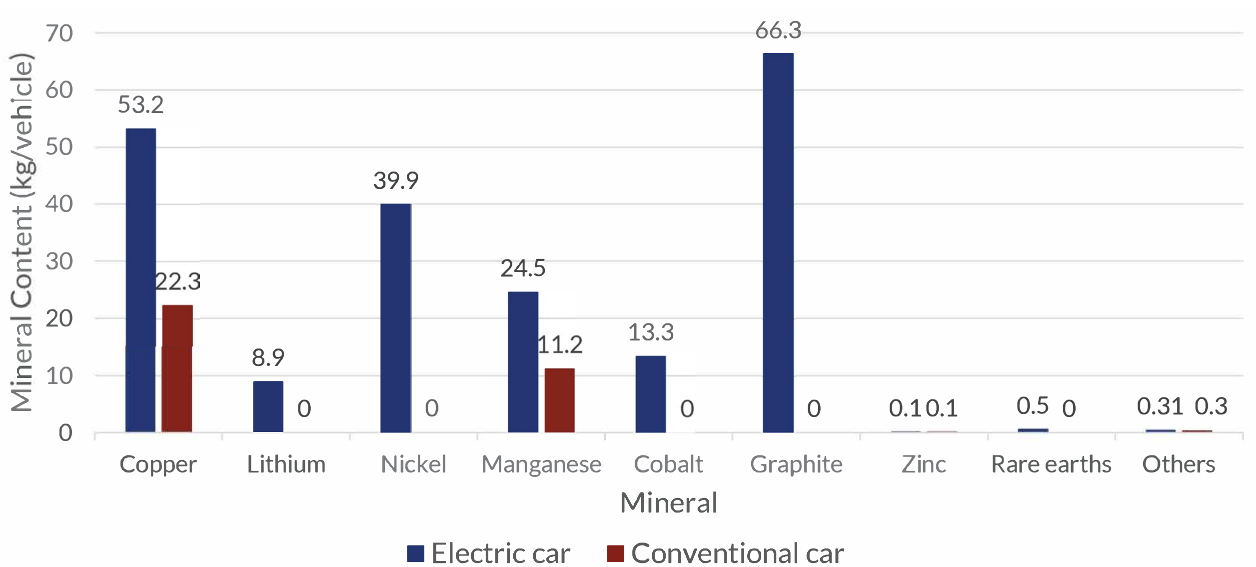
The growing power demands to charge EVs are on a collision course with the rise of data centers and generative AI.

Figure 2
IEA Projected Mineral Demand by Technology and Minerals in 2030 and 2050



Source: "Minerals Used in Electric Cars Compared to Conventional Cars – Charts – Data & Statistics." IEA. Accessed September 23, 2024. https://www.iea.org/data-and-statistics/charts/minerals-used-in-electric-cars-compared-to-conventional-cars.

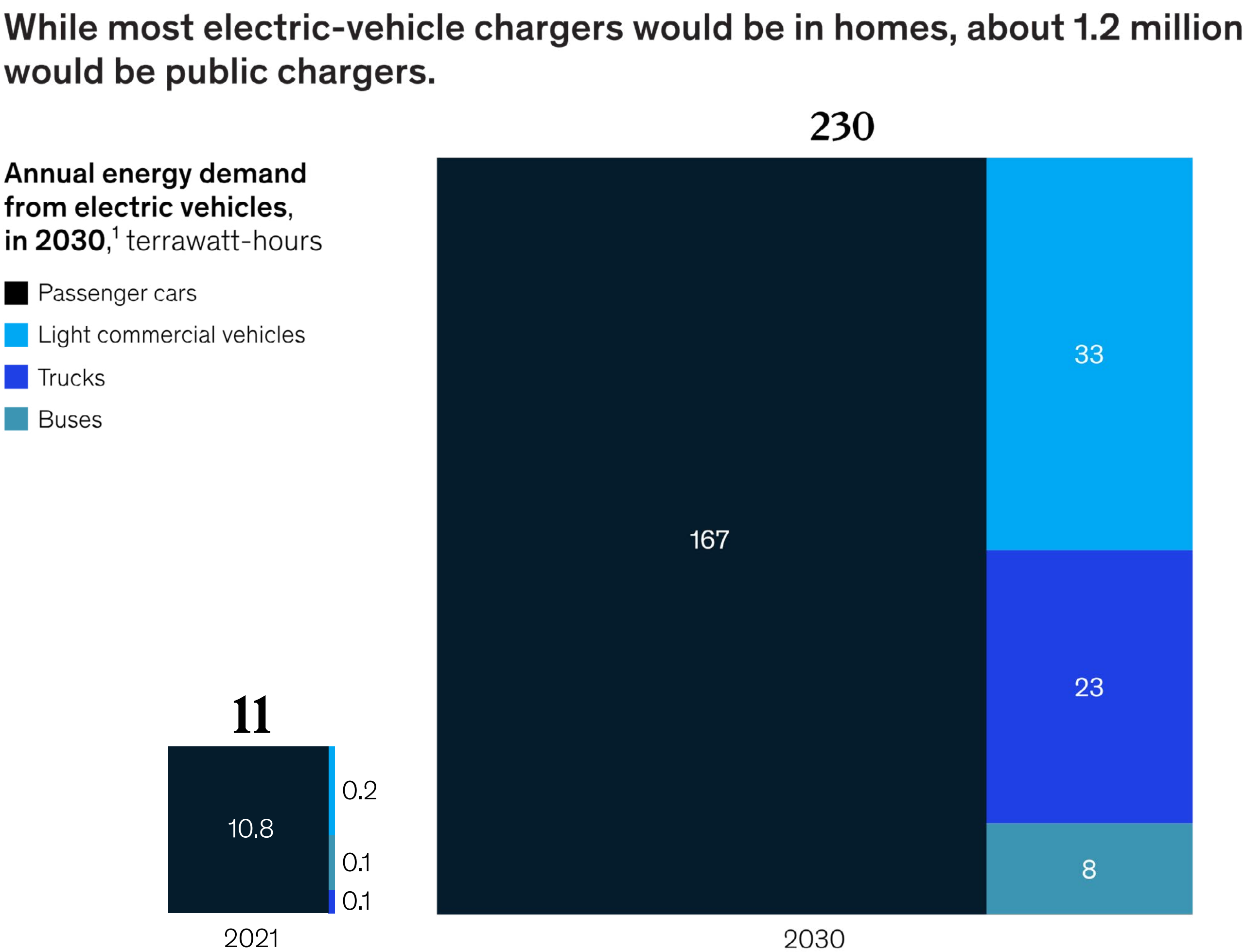
Figure 3
Mineral Content of Battery Electric Vehicles Compared to Conventional Vehicles



Source: The Role of Critical Minerals in Clean Energy Transitions, IEA. https://www.iea.org/data-and-statistics/charts/minerals-used-in-electric-cars-compared-to-conventional-cars

Figure 4

McKinsey & Co. Estimates Annual Electricity Demand from EVs Will Reach 230 terawatts by 2030, Up from 11 terawatts in 2021



Source: Kampshoff, Philipp, Adi Kumar, Shannon Peloquin, and Shivika Sahdev. "Building the Electric-Vehicle Charging Infrastructure America Needs." McKinsey & Company, April 18, 2022. https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs.

An average ChatGPT query takes 10 times the electricity as a traditional Google search.[27]

An April 2024 Wells Fargo analysis found that power demand due to generative AI is likely "to grow over eightyfold from 8 TWh in 2024 to 652 TWh by the beginning of the next decade."[28] Figure 5 shows the growth in power demand (TWh) expected by 2030, of which two-thirds will be driven by training AI models. Training a new AI model requires significantly more power than using a developed AI to make predictions (known as inference), as training involves processing vast amounts of data to develop the model. As depicted in Figure 5, although both inference and training demands are projected to rise substantially over time, training will require much more electricity than inference.

The construction of more data centers is already exacerbating copper demand because copper is used for power cables, busbars, electrical connectors, heat exchangers and heat sinks, and power distribution. Data centers need "27 tonnes per MW of applied power," according to the Copper Development Association.[29]

Citing recent reports, *The Wall Street Journal* described the growing competition for copper:

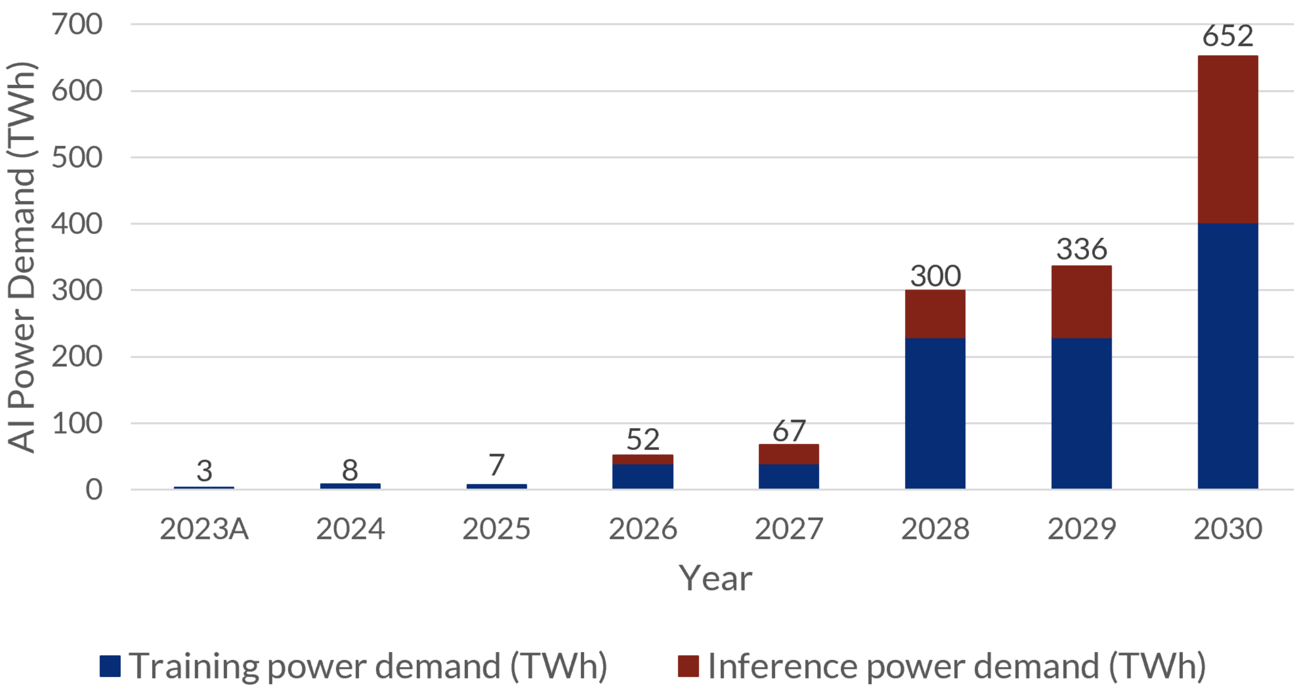
> JP Morgan forecasts the additional power consumption required by data centers could expand a predicted global copper deficit of 4 million metric tons by 2030 by another 2.6 million tons. Bank of America estimates the demand directly from data centers for copper could be around 200,000 metric tons a year between 2025 and 2028, while investment in the electricity needed to power the centers could add further demand of at least 500,000 tons annually.[30]

Copper prices are already reflecting the mineral's newfound importance. In May 2024, copper futures exceeded $5 per pound, marking a record high.[31]

Although all experts agree that more mines must be built and operated to meet the mineral demand to meet energy transition goals and schedule objectives, there is some variability in the estimates of how many new cobalt, copper, nickel, and other critical minerals mines will be necessary. For example, the IEA estimates that there would need to be 50 more lithium mines, 60 more nickel mines, and 17 more cobalt mines constructed by 2030 to meet global net carbon emissions goals.[32] A United Nations Conference on Trade and Development report projects requirements of "80 new copper mines; 70 new lithium and nickel mines, each; and 30 new cobalt mines" to achieve net-zero emissions by 2030.[33] UNCTAD estimates that the total cost of that expansion

Figure 5

Power Demand Driven by the AI Portion of Data Processing Alone is Expected to Grow by Eightyfold Over the Next Decade



Source: Wells Fargo Securities, LLC estimates. Testimony of Ben Fowke in U.S. Congress. https://www.energy.senate.gov/services/files/7F2AC3C4-87CB-4562-99F8-5BB999FC6433.

will range between $360 billion and $450 billion, with an "anticipated investment gap" between $180 billion and $270 billion. A Benchmark Minerals forecast suggests that the right number is around 384 new mines for lithium, graphite, nickel, and cobalt to meet demands by 2035.[34] After considering recycling of raw materials, the number of mines drops to 336. Benchmark's analysis accounts for average mine sizes in each mining sector.

The IEA notes that "hydropower, biomass and nuclear make only minor contributions [to mineral demand estimates] given their comparatively low mineral requirements and modest capacity additions."[35] A nuclear power plant is far less material-intensive than wind turbines and solar panels. However, the U.S. imports 95 percent of the uranium it uses in its power plants, predominantly from Canada (27 percent), Kazakhstan (25 percent), and Russia (12 percent).[36] Following Russia's invasion of Ukraine in February 2022, imports of Russian oil, natural gas, and coal were banned, but imports of uranium were not.

Section III details the U.S.' deep reliance on foreign countries for critical minerals and the dangers the status quo poses for modern life and the U.S.' ambitions for a wind-and-solar-powered future. Section IV examines the need for three electrification minerals found in Minnesota — copper, nickel, and cobalt — in more detail.

Section III: Where Does the U.S. Get the Minerals we Need?

Section III.A: The U.S. Imports Many Critical Minerals

Despite the fact that the U.S. is richly endowed with a broad array of mineral deposits, Figure 6 shows that the U.S. is highly dependent on imports of the minerals used in five key sectors that underpin every aspect of modern life: aerospace, defense, energy, telecommunications and electronics and transportation. Our national security, economic well-being, manufacturing and technology sectors, our infrastructure, our vehicles (both ICE and EVs), our transportation network and more rely on these minerals.

The dominant role that China currently plays as the main source of many of the minerals shown in Figure 6 is alarming. The U.S. has not always been so dependent on mineral imports. In the past, the U.S. was much more self-reliant for the minerals we needed. In fact, in the first half of the 20th century, the U.S. was a mining powerhouse, producing between 30 and 40 percent of global mineral production from 1910 to 1950. In 1916, the U.S. Secretary of the Interior, Franklin K. Lane, wrote: "We can build a battleship, or an automobile, a railroad or a factory, entirely from the products of American mines…."[37] Sadly, that is no longer true.

Given the current tensions between the U.S. and China, this reliance is both dangerous and unsustainable. China has recently demonstrated that it will not hesitate to restrict exports of key minerals to the U.S. and the rest of the world. For example, in July 2023, China announced it would start restricting exports of germanium and gallium, which are minerals critical to manufacturing high-tech semiconductor chips.[38] On October 19, 2023, Reuters reported that China's exports of wrought germanium products had shrunk to a mere one kilogram in August 2023, compared to 8.63 metric tons in July. During August and September of 2023, China did not export any wrought gallium products. A year earlier in September 2022, prior to the export ban, China's exported 5.57 tons of wrought gallium products.[39] As shown on Figure 6, the U.S. obtains 35 percent of our gallium from China and over half of the germanium we use from China.

China's export restrictions extend to other minerals besides germanium and gallium. China is imposing export restrictions on graphite and rare earths. Graphite is used in the anodes in lithium-ion batteries that power EVs and so many electronic devices. The U.S. imports 100 percent of the graphite we use and obtains 35 percent of it from China (see Figure 6). China produces 60 percent of the world's rare earths but processes nearly 90 percent, giving China a near monopoly over processed rare earths, especially the processing of the heavy rare earth minerals[40] that are key components of the high-performance permanent magnets used in EV motors.[41]

Most recently, in August 2024, China's commerce ministry announced new export limits on antimony due to its uses in military applications, such as "ammunition, infrared

Figure 6

Minerals are Essential to Key U.S. Industry Sectors

The 2022 U.S. list of critical minerals, percentage of the U.S. supply imported in 2022, industries in which each is used, and primary import source

		Key Industries					
Mineral	Percentage from foreign sources[a]	Aerospace	Defense	Energy	Telecommunications and electronics	Transportation (non-aerospace)	Primary Import Source (2018–2021)[b]
Arsenic	100%		●	●	●		China: 57%
Cesium	100%	●	●	●	●		N/A
Fluorspar	100%			●	●		Mexico: 66%
Gallium	100%	●	●	●	●		China: 35%
Graphite	100%	●	●	●	●	●	China: 35%
Indium	100%	●	●	●	●		Republic of Korea: 35%
Manganese	100%	●	●	●		●	Gabon: 67%
Niobium	100%	●	●	●			Brazil: 66%
Rubidium	100%	●	●	●	●		N/A
Tantalum	100%	●	●	●	●		China: 24%
Bismuth	96%		●	●	●		China: 65%
Rare Earth Elements (Cerium, Dysprosium, Erbium, Europium, Gadolinium, Holmium, Lanthanum, Lutetium, Neodymium, Praseodymium, Samarium, Scandium, Terbium, Thulium, Ytterbium, Yttrium)	>95%	●	●	●	●	●	China: 74%
Titanium	>95%	●	●	●			Japan: 89%
Antimony	83%		●	●	●	●	China: 63%
Chromium	83%	●	●	●			South Africa: 37%
Tin	77%		●		●		Peru: 25% (refined Tin)
Cobalt	76%	●	●	●	●	●	Norway: 22%
Zinc	76%		●	●			Canada: 66%
Barite	>75%			●			China: 38%
Tellurium	>75%		●	●	●		Canada: 52%
Platinum[c]	66%	●		●	●	●	South Africa: 24%
Nickel	56%	●	●	●			Canada: 45%
Aluminum	54%	●	●	●		●	Canada: 50%
Vanadium	54%	●	●	●			Canada: 31%
Germanium	>50%	●	●	●	●		China: 54%
Magnesium	>50%	●	●	●	●	●	Canada: 21%
Tungsten	>50%	●	●	●	●		China: 29%
Zirconium	<50%	●	●	●			China: 89% (Zirconium unwrought, including powder)
Palladium[c]	26%	●		●	●	●	Russia: 34%
Lithium	>25%	●	●	●	●	●	Argentina: 51%
Beryllium	<20%	●	●	●	●		Kazakhstan: 43%
Hafnium	—	●	●	●			Germany: 36%
Iridium[c]	—	●		●	●	●	—
Rhodium[c]	—	●		●	●	●	—
Ruthenium[c]	—	●		●	●	●	—

Source: U.S. Geological Survey (USGS), *Mineral Commodity Summaries 2023* (Reston, Virginia: 2023). | GAO-24-106395

[a]U.S. net import reliance expressed as a percentage of apparent U.S. consumption in 2022, a metric developed and calculated by USGS using import data from the U.S. Census Bureau and consumption data from *USGS's Mineral Commodity Summaries 2023*.

[b]Import source percentage from 2018 through 2021, calculated by USGS using import data from the U.S. Census Bureau.

[c]This mineral is a part of the platinum group and the key industries shown are for the group.

Source: U.S. Government Accountability Office. Critical Minerals: Status, Challenges, and Policy Options for Recovery from Nontraditional Sources. GAO-24-106395, p. 4. Washington, DC. July 31, 2024. https://www.gao.gov/products/gao-24-106395 missiles, nuclear weapons and night vision goggles, as well as in batteries and photovoltaic equipment."[42] Figure 6 shows that the U.S. is reliant on imports for 83 percent of the antimony we use, with 63 percent of the antimony we need coming from China.

Looking again at Figure 6, the U.S. obtains 95 percent of the processed REE we use from foreign countries. The U.S. imports 74 percent of REE from China, which has a stranglehold on processing REE into products that can be used to manufacture magnets and for other applications.

But what about Canada, the second most important source of mineral imports to the U.S. (Figure 6)? Does importing so many minerals from Canada make sense in the long run? Although serious trade tensions between the U.S. and Canada are not currently an issue, Canada cannot export all of its minerals to the U.S. because Canada must satisfy its internal demand for minerals. It is reasonable to ask if Canadian minerals will always be available to export to the U.S. This is especially true for minerals like zinc and nickel that could also be mined with the highest environmental safeguards and worker health and safety provisions from U.S. deposits. Should the U.S. rely on Canada for 66 percent of the zinc and 45 percent of the nickel we need (see Figure 6)? In evaluating this question, it is important to consider that China has majority ownership of some Canadian mining companies. The Canadian government is looking for ways to limit Chinese investment in its mining sector.[43]

Once the South 32 Project southeast of Tucson, AZ goes into production, the U.S. will be able to obtain some of the zinc we need from this domestic project.[44] Besides its essential role in galvanizing steel and producing brass, bronze, and other zinc alloys, processing of certain zinc ores can produce germanium and gallium as byproducts. Mines in Alaska, Idaho, New York, and Tennessee are producing zinc or have produced zinc in the recent past.[45] In addition to being a source of the zinc used to manufacture stainless steel, brass, bronze, and other alloys, zinc deposits that can produce germanium and gallium as byproducts take on elevated importance in light of China's restrictions on exporting these essential chip-making minerals. According to the U.S. Geological Survey's (USGS) 2024 Mineral Commodities Summary, zinc mines in Alaska and Tennessee produced byproduct germanium in 2023. However, no domestic mines recovered gallium as a byproduct of zinc production.[46]

Section III.B: Critical Minerals and Materials that Could be Mined in Minnesota

Minnesota is a mineral-rich state with many important mineral deposits. Minnesota's long and proud history of producing iron ore makes it the fourth-largest mineral-producing state in the U.S. In 2023, the value of mineral production in Minnesota exceeded $6.82 billion, mainly from iron ore mining but also from sand and gravel produced for construction and industrial applications and crushed stone.[47] Minnesota's mineral endowment includes other types of mineral deposits besides iron ore, including copper, nickel, cobalt, and platinum-palladium, also called Platinum Group Minerals (PGM). As shown in Figure 6, nickel, cobalt, and palladium are critical minerals for which the U.S. has significant import reliance. Although copper is not included in the USGS' critical minerals list, the U.S. Department of Energy (DOE) classifies it as a critical material. (Section IV.B. discusses copper's pivotal role in the energy transition.)

Examples of Minnesota mineral projects include New Range Copper Nickel LLC's NorthMet and Mesaba projects in St. Louis County; Twin Metals Minnesota LLC's Birch Lake deposit in Saint Louis County and its Maturi and Spruce Road deposits in Lake County, MN; and Talon Metals Corp.'s Tamarac Deposit in Aitkin County. These polymetallic mineral deposits contain copper, nickel, cobalt, PGM, gold, and silver.

The MN Department of Natural Resources' 2017 map entitled "Exploration for Metallic Mineral Resources in Minnesota: Copper, Nickel, and Platinum Group Metals",[48] shows that the NorthMet, Mesaba, Maturi, Birch Lake, and Spruce Road Projects are clustered near Babbitt, MN, where they occur with a 40-mile-long zone located along the edge of the Duluth Complex. The Tamarack deposit occurs in a different geologic setting related to the Midcontinent Rift.

American Experiment's 2018 report entitled "Unearthing Prosperity – How Environmentally Responsible Mining Will Boost Minnesota's Economy,"[49] describes a massive rock formation called "The Duluth Complex," which stretches from

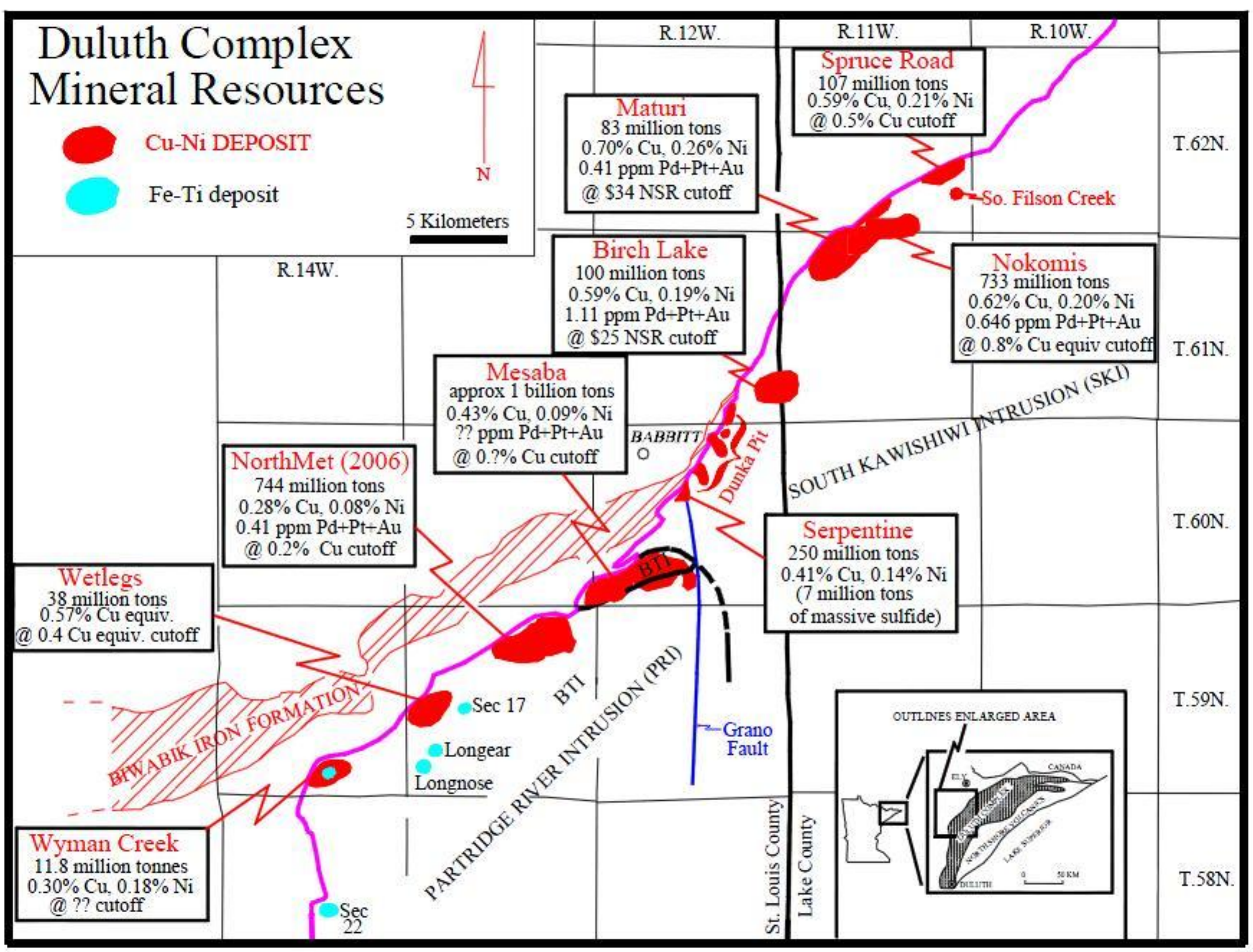
Duluth to Pigeon Point in northern Minnesota and contains some of the world's largest undeveloped deposits of copper, nickel, platinum group elements, and ilmenite (a titanium ore) as shown in Figure 7 as well as cobalt, gold, and silver.[50,51]

The relative proportion of these minerals varies from deposit to deposit. But taken together, the Duluth Complex hosts world-class copper, nickel, and PGM deposits. According to New Range Copper and Nickel LLC, the Duluth Complex is one of the world's largest undeveloped mineral deposits in the world, containing 95 percent of America's nickel, 88 percent of America's cobalt, and 33 percent of America's copper resources.[52] The company is currently describing the combined NorthMet and Mesaba mineral deposits as having the following available resources: 9.4 million tons of copper, 2.3 million tons of nickel, 195,000 tons of cobalt, 321 tons of palladium and over 12 tons of platinum and gold.[53]

Minnesota has one of the most stringent and comprehensive environmental protection regulatory programs governing proposed mining projects of any U.S. state as discussed in American Experiment's 2018 report. Despite the strength of

Figure 7

Map of the Duluth Complex Polymetallic Mineral Deposits Showing Resources Identified as of 2018



Source: Severson, M.J. and Hauck, S.A. (2003) Platinum Group Elements (PGEs) and Platinum Group Minerals (PGMs) in the Duluth Complex. Minerals Coordinating Committee and the Natural Resources Research Inst. Technical Report NRRI/TR- 2003/37.

Minnesota's mining regulations, concerns about potential environmental impacts from mining create opposition to proposed mining operations that spawn permit challenges and litigation. For example, the NorthMet Project has been delayed since June 2023, when the U.S. Army Corps of Engineers revoked the previously approved Clean Water Act Section 404 Permit for the project. In its June 6, 2023 press release responding to the permit revocation, the company stated:

> [T]he project clearly shows that through its proposed water treatment and management processes, it will remove more than 1,400 tons of sulfate per year from the St. Louis River system, the result of historic iron ore mining operations. It also will lead to a net reduction in pre-existing mercury loading to the river system. The Corps' decision is one that requires careful review, determined action, and further engagement with regulators and all key stakeholders. NewRange is reviewing all of our options as we chart a course forward for the development of the NorthMet Project in a safe and environmentally responsible manner that considers NewRange's communities of interest.[54]

The Twin Metals Project is another example of a proposed Minnesota mining project facing significant challenges.

The Twin Metals Project is another example of a proposed Minnesota mining project facing significant challenges. Development of this project was derailed in January 2022, when the Biden-Harris administration canceled Twin Metals LLC's two federal mineral leases in the Superior National Forest. This cancellation reversed the Trump administration's 2017 decision to reinstate the leases and renew them for an additional ten years after the Obama administration denied the company's lease renewal application in 2016.[55]

Twin Metals challenged the cancellation of its leases in Federal District Court for the District of Columbia, which upheld the cancellation, stating the court did not have subject matter jurisdiction.[56] In November 2023, the company appealed the lower court's decision to the D.C. Court of Appeals, stating:

> Leveraging its long-held mineral rights, Twin Metals has spent more than 13 years in northeast Minnesota conducting extensive environmental, engineering, exploration, hydrogeological and community engagement work...and is steadfastly dedicated to the communities of northeast Minnesota, which is why we are filing an appeal to challenge the dismissal of our federal mineral lease lawsuit.[57]

As if the cancellation of Twin Metal LLC's minerals leases were not enough to halt development of the Twin Metals Project, the Biden-Harris administration has also put a broad swath of land at and near the proposed project off-limits to mining. In October 2021, the Biden-Harris administration proposed a 20-year mining moratorium in the watershed of the Boundary Waters Canoe Area Wilderness. This moratorium puts over 225,000 acres (roughly 350 square miles) of land in the Superior National Forest, including the lands where the Twin Metals LLC minerals leases were located, off-limits to mining for at least 20 years.[58] This proposal became effective on January 31, 2023 when Public Land Order 7917 for Withdrawal of Federal Lands, Cook, Lake, and St. Louis Counties, MN was published in the Federal Register[59] to withdraw this area from geothermal and mineral leasing laws.

In a July 11, 2024 op-ed, James T. Callahan, General President of the International Union of Operating Engineers and Rich Nolan, President and CEO of the National Mining Association, characterize this withdrawal as unfair and premature: "The agency put the cart before the horse — halting the permitting process and subverting the detailed, project-specific review already underway by state and federal regulators."[60]

Congress has gotten involved with this withdrawal by including a provision in the House FY 2025 Interior and Environment Appropriations bill to prohibit funds for the Department of the Interior to enforce Public Land Order 7917 withdrawing lands in the Superior National Forest. If enacted, this directive would reopen these lands to minerals leasing and mineral exploration and development for a period of 30 years.

Talon Metals Corp. has submitted permitting applications for an underground mine and rail loading facility near Talon, Minnesota to the MN Department of Natural Resources. The Company describes its deposit as "the USA's only high-grade nickel source for the domestic battery supply chain that also contains copper and cobalt." Talon Metals Corp. has successfully secured grants from the federal government to advance its project including a $114.8 million from DOE to construct a nickel processing facility in North Dakota and a $20.6 million Defense Production Act Title III matching funds grant from the U.S. Department of Defense (DOD) to conduct nickel exploration in Minnesota and Michigan adjacent to Lundin Mining's Eagle Nickel Mine in Marquette County, Michigan, which is currently the only active domestic nickel mining and mineral processing operation. Talon Metals Corp. also has a strategic partnership with Tesla that features a legally binding off-take agreement under which Tesla must purchase 75,000 metric tonnes (165 million pounds) of nickel concentrate over six years. The two companies have committed to work together as partners to achieve commercial production by 2027.[61]

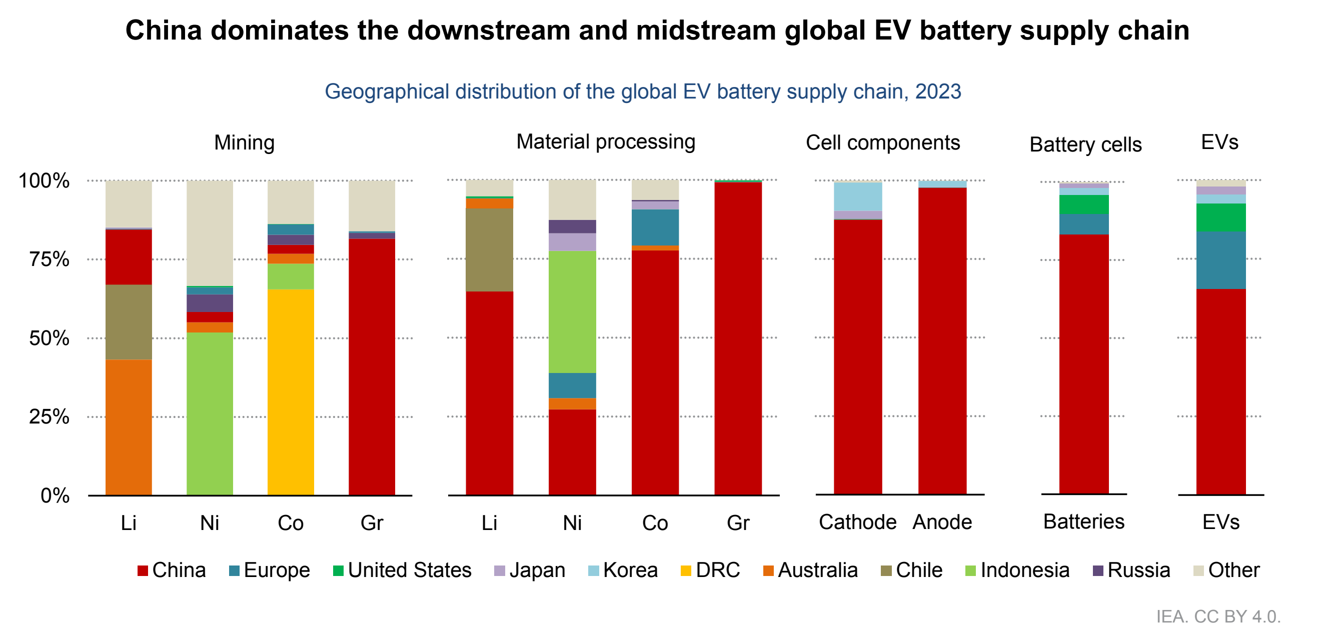
Section IV: Are There Enough Minerals to Satisfy Energy Transition Objectives and Timelines?

Because policymakers have set the very ambitious energy transition timeline to achieve the IEA's NZE scenario by 2050, the world needs an abundance of several key minerals now and for the next two decades to meet this goal. There are two questions about minerals availability: 1) does the geology of the world contain sufficient minerals; and 2) can we mine the known mineral deposits fast enough to provide the minerals we need when we need them?

Section IV.A: Projected Future Mineral Demand

The IEA's 2024 report, "Global Critical Minerals Outlook 2024,"[62] provides a detailed and quantitative analysis of the projected demand for and availability of the critical minerals

Figure 8
China's Hegemony Over the Entire EV Battery Supply



Notes: Li = lithium; Ni = nickel; Co = cobalt; Gr = graphite; DRC = Democratic Republic of the Congo. Geographical breakdown refers to the country where the production occurs. Mining is based on production data. Material processing is based on refining production data. Cell component production is based on cathode and anode material production capacity data. Battery cells are based on battery cell production capacity data. EVs is based on electric cars production data. For all minerals mining and refining shows total production not only that used in EVs. Graphite refining refers to spherical graphite production only.
Sources: IEA analysis based on EV Volumes; Benchmark Mineral Intelligence; BloombergNEF.

Source: "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 30. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

needed for the energy transition, focusing mainly on what it calls six "key energy transition minerals:" cobalt, copper, graphite, lithium, nickel, and rare earth elements. This report covers a 17-year period between 2023 and 2040 and assesses the mineral requirements by 2040 to be on track to achieve the NZE goal by 2050.

The IEA produced this report in response to a request stemming from the April 2023 G7 Group of Seven (G7) Ministers' Meeting on Climate, Energy and Environment in Sapporo, Japan during which the Ministers established a five-point critical minerals security plan to "...reaffirm the growing importance of critical minerals for the clean energy transition and the need to prevent economic and security risks caused by vulnerable supply chains, monopolization, [and] lack of diversification of existing suppliers of critical minerals."[63]

Some of the key findings in the IEA report include the following:

- Clean energy applications are the main driver for critical minerals demand, with EV batteries being the largest consumer of lithium and a significant consumer of nickel, cobalt and graphite.

- Solar photovoltaic (PV) and wind energy systems and the related expansion of electricity transmission networks create demand for copper and aluminum.

- Compared to 2023 mineral demands, to reach NZE by 2050:
  - Lithium demand increases by a factor of ten
  - Graphite demand almost quadruples
  - Nickel, cobalt, and rare earth elements demand doubles; and
  - Copper demand nearly doubles.

- There is a significant gap between the prospective supply of lithium and copper and the projected demand, with anticipated mine supplies of lithium and copper meeting only 50 percent and 70 percent respectively of forecast demand.

- Processed graphite and rare earth elements have the highest level of geographic concentration with over 90 percent of battery-grade graphite and 77 percent of refined rare earths coming from China, making the supply chains for these minerals vulnerable to disruption due to trade disputes, geopolitics, and extreme weather.

The IEA's 2024 report includes risk assessment profiles that assess four risk elements: supply risks; geopolitical risks; barriers to responding to supply disruptions; and exposure to environmental, social, governance, and climate risks. Lithium and graphite have the overall highest risk scores. Lithium and copper have higher exposure to supply and volume risks whereas graphite, cobalt, rare earths, and nickel face more substantial geopolitical risks. All of these minerals face high environmental risks due in part to higher carbon intensity emissions stemming from the use of coal-based electricity in processing operations for these metals in China, Indonesia, and elsewhere.[64]

Figure 8 shows that China dominates a large swath of the EV battery supply chain from upstream mining and mineral processing to midstream battery component manufacturing and downstream battery production. China also builds over 60 percent of the world's EVs. It is clear from Figure 8 that the entire world is beholden to China for most of the mining of the graphite used for the anodes in lithium-ion batteries, about 60 percent of lithium processing, 75 percent cobalt processing, and virtually 100 percent of graphite processing. China also has a near monopoly on manufacturing EV battery anodes and cathodes and produces about 80 percent of the EV lithium-ion batteries. Even if China were a friendly nation, it would be risky to rely on one country for each step of the EV battery supply chain. As noted in the IEA Report, this level of geographic concentration is problematic due to the potential for substantial supply chain disruptions due to trade restrictions, geopolitics, and weather events.

Although the U.S. does mine some lithium, nickel, and cobalt, the volumes mined are too small to show up as a separate color in Figure 8 and U.S. production is lumped in with "others" in this graph. (There are currently no graphite mines in the U.S. as reflected in the 100 percent import reliance shown on 6.) U.S. EV batteries and EV manufacturing does show up as a small component in Figure 8.

Section IV.B: Demand for Copper - the Key Energy Transition Mineral - Will Exceed Supply

The 2024 IEA report finds that "clean energy technologies drive substantial growth in copper demand."[65]

> Copper is the only critical mineral present in all of the most important clean energy technologies – EVs, solar PV, wind, and electricity networks – due to its unmatched combination of characteristics: electronic conductivity, longevity, ductility and corrosion resistance. Therefore, the security of supply of copper is paramount for the energy transition. Total copper demand is made up of a combination of refined copper demand (including both primary and secondary production, 26 Mt in 2023) plus direct use of scrap (over 6 Mt).[66]

Copper is "the electricity metal" because it is an excellent conductor of electricity. Power grids and EVs depend on copper for efficient electricity transmission. Copper is used in EV electric motors, batteries, inverters, wiring and charging stations. The reported amount of copper used in an EV ranges from about 2.4 times more than in a conventional combustion vehicle[67] to four times the amount.[68] Besides its use in EVs and in a wide array of clean energy technologies, it is also essential for many other purposes including electronics, plumbing, building construction, industry, transportation, and consumer and health products.[69] Silver is the only other metal that is a better electricity conductor than copper. However, because silver is much more expensive than copper, it is not as widely used to conduct electricity.[70]

Chile, Democratic Republic of the Congo (DRC), and Peru are the world's top copper-producing countries, accounting for 47 percent of the copper produced in 2023. By way of comparison, the U.S. produced 1,223 mt of copper in 2023, accounting for roughly five percent of global copper production. China dominates copper refining, producing about 44 percent of the world's refined copper, followed by Chile, Russia, Japan, and India.

In addition to its prominence in copper refining, China is making a concerted effort to become the world's largest copper producer. Benchmark reports that Chinese mining companies have acquired copper mining projects in the DRC and Zambia, two politically unstable countries that western mining companies have shied away from. This has given China long-term access to large copper reserves. Benchmark estimates that copper production from Chinese-backed mining operations will dominate the world's future copper supply, with Chinese companies already producing more than the top three copper mining companies (Codelco, Freeport McMoran, and BHP) combined.[71]

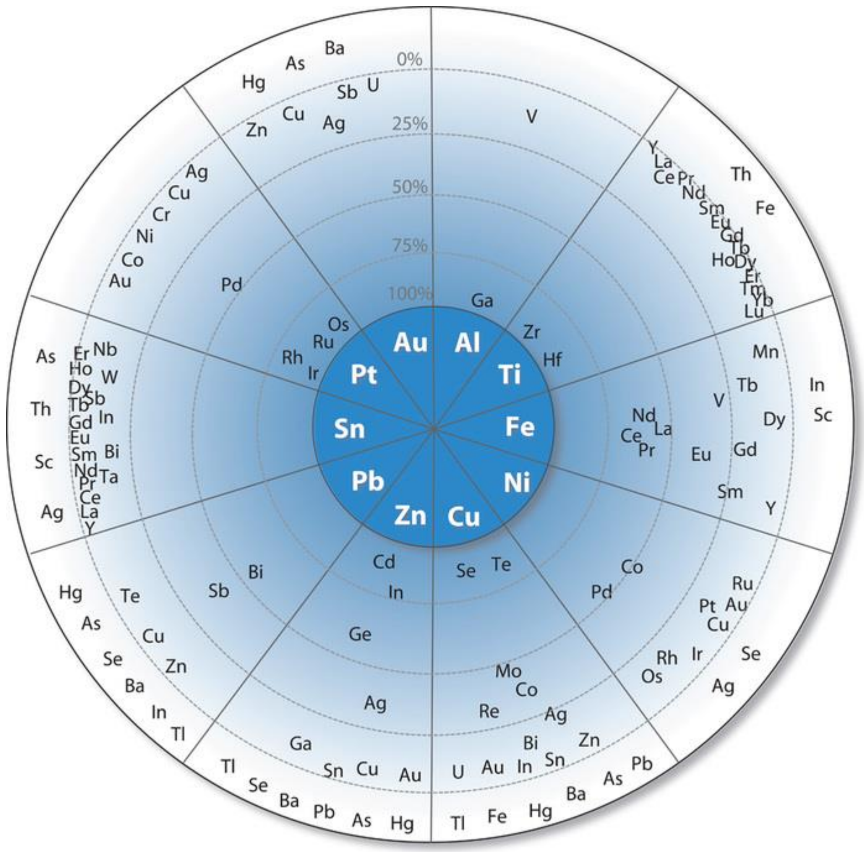
China is clearly making a strategic move to satisfy the increasing demand for copper and take advantage of the current situation in well-established copper mining countries where there is a lack of large-scale copper projects slated to be developed in the foreseeable future. Chilean copper assets, which produce one-quarter of the world's copper, are aging, have declining ore grades, and reinvestments in mine expansion are limited. Due mainly to Chinese investments, copper production is rapidly expanding in the DRC, which has recently become the second-largest global copper producer.[72]

The IEA and several other sources predict future copper shortages. For example, *Forbes* reports that "a copper shortage is threatening to stop the EV transition in its tracks, and the time and effort needed to open new mines means relief likely won't be coming anytime soon."[73]

In a study done for the International Energy Forum, Cathles and Simon show a significant copper shortfall based on the ability of the world's currently operating copper mines to satisfy demand for transitioning to 100 percent EVs, which will require copper for both EV manufacturing and expanding the electricity grid to support EV recharging. The Cathles and Simon study shows that 115 percent more copper must be mined in the next 30 years than has been mined in human history to date simply to meet business-as-usual (i.e., *without* any energy transition) demands. Some of their key findings include the following:

- The USGS' estimate of copper contained in currently undiscovered copper deposits shows that theoretically, the Earth's copper resources are adequate to meet the projected copper demand if these resources can be tapped in time to meet the demand;
- Electrifying the global vehicle fleet will require developing 55 percent more copper mines than would otherwise be needed;

Figure 9
Wheel of Metals Companionality



By-product metals are technologically essential but have problematic supply, Volume: 1, Issue: 3, DOI: (10.1126/sciadv.1400180)

Source: Nassar, N. T., T. E. Graedel, and E. M. Harper. "By-Product Metals Are Technologically Essential but Have Problematic Supply." Science Advances 1, no. 3 (April 3, 2015). https://doi.org/10.1126/sciadv.1400180.

- Satisfying the future demand for copper for transitioning to 100 percent EVs will require putting between 1.1 and 6 new copper mines into production each year for the next 32 years;

- Between 35 and 194 new copper mines must be discovered, permitted, built, and operated worldwide in this 32-year timeframe;

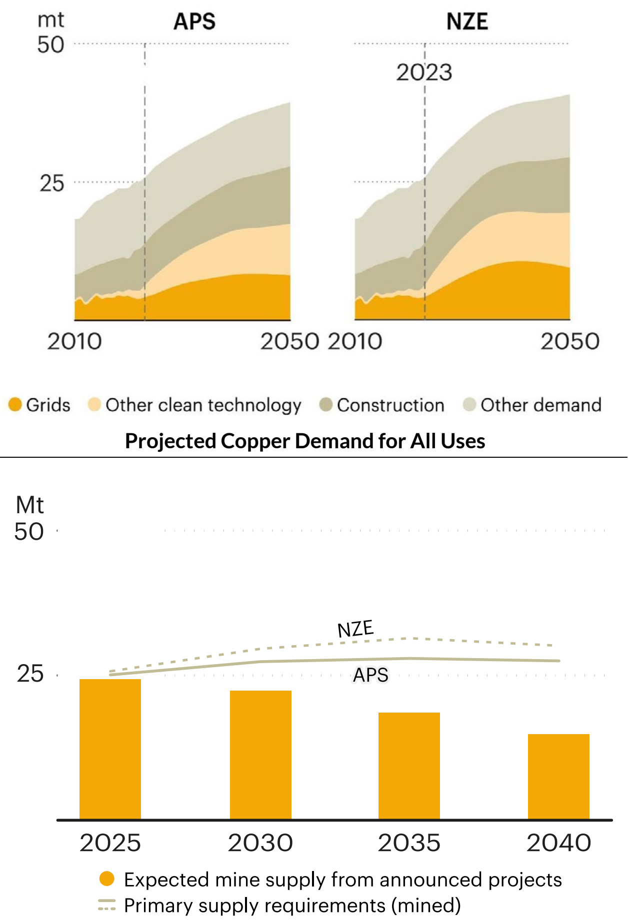
- Under today's policy settings for copper mining, it is highly unlikely that there will be sufficient new copper production to fully electrify the world's vehicle fleet by 2035;

- For the copper mines that started operating between 2019 and 2022, it took an average of 23 years to permit and build them from the time they were discovered; and

- There is an insufficient pipeline of promising copper discoveries that may be developed into future copper mines to satisfy projected copper demand.

Based on these findings Cathles and Simon conclude: "We may not be able to mine materials fast enough to meet all of humanity's desires even if there are more than enough of these materials to meet humanity's needs."[74] As discussed in Section VII, copper mining in Minnesota and other U.S. mines could play a significant role in making up this shortfall.

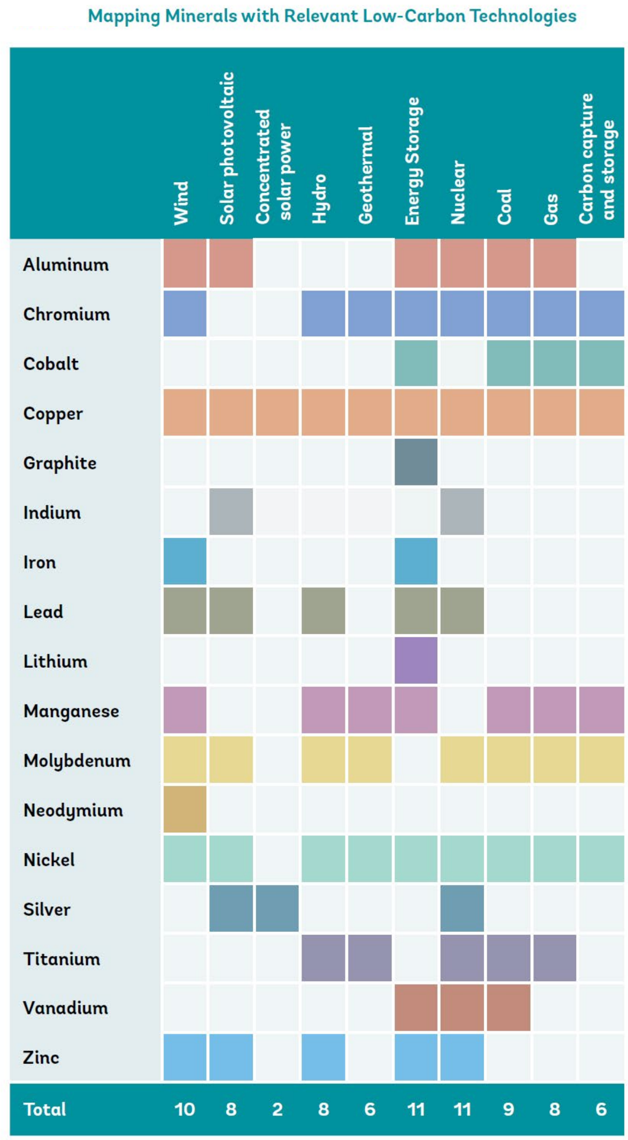
Figure 10
Projected Copper Supply, Demand, and Shortfall



Projected Copper Supply is Inadequate to Achieve all Energy Transition Goals

Source: "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 155. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

Table 1
The Mineral Intensity of Low-Carbon Energy Technologies



Source: "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 108. https://www.iea.org/reports/global-critical-minerals-outlook-2024. See also: https://www.iea.org/reports/copper and https://www.iea.org/data-and-statistics/data-tools/critical-minerals-data-explorer

A 2023 S&P Global report finds that the U.S. has 70 million metric tons of untapped copper reserves and resources that could be developed to augment copper production from existing mines.[75] Putting the 70 million metric tons of identified domestic copper reserves and resources into production would satisfy more than 20 years of U.S. copper demand for clean energy, construction, building, and other uses.

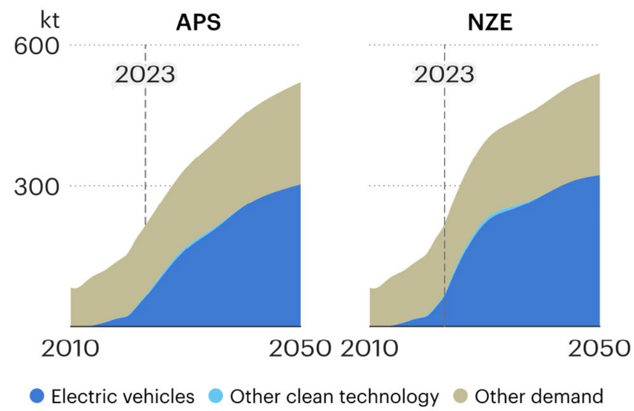
Copper mines typically produce other metals as byproducts of copper production including nickel, cobalt, molybdenum, and gold.[76] The Wheel of Metals Companionality shown in Figure 9 illustrates copper's importance as a source of other metals and also shows that the ten host metals in the darkest blue interior of the circle can be important sources of many other metals. As a recent example, in 2021, Rio Tinto constructed a new plant to recover the critical mineral tellurium at its copper smelting facilities in Utah.[77] Tellurium is used in photovoltaic solar panels, semiconductors, and as an additive to steel and copper to improve their properties.

Table 1 underscores copper's essential role in building low-carbon energy systems and achieving energy transition goals. As shown in Table 1, the May 2020 World Bank Group report, *Minerals for Climate Action*[78] identifies 17 minerals used in low-carbon energy technologies and clearly illustrates the mineral intensity of the energy transition and highlights copper as a component of all low-carbon energy systems.

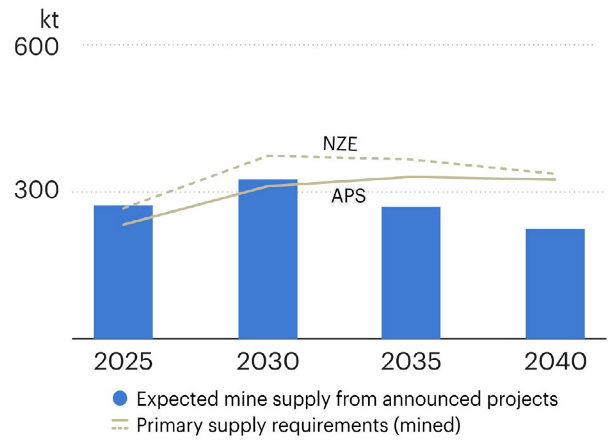
Figure 10 presents the IEA's estimates of the amount of copper that will be needed to meet the APS and the NZE in 2050. As shown in Figure 10, grid expansions and clean technologies, which the IEA Report defines as including wind, solar, EVs, grid battery storage, electricity networks, hydrogen technologies, and other low-emissions power generation, will require over 19 million tonnes (mt) of copper to achieve NZE in 2050 and another 21 mt would be required for copper used in construction and other demands for a total copper requirement of about 40 mt. The 40 mt demand for copper under both the APS and NZE scenarios is substantially higher than the 2023 copper demand of about 25 mt. Where will the additional copper come from to satisfy the 2050 NZE objective?

Figure 10 shows that after 2025, the IEA predicts that copper production will decrease from about 23 mt in 2023 to roughly 15 mt in 2040.[79] This figure also illustrates there is a copper shortfall for the NZE, APS, and STEPS scenarios. One of the reasons for this decline is that older mines are typically producing from lower ore grades zones, which translates into increased operating costs. Because it is becoming increasingly difficult to discover, finance, permit, and build new mines, the world's copper mines are aging.[80]

Figure 11
Projected Cobalt Supply, Demand, and Shortfall



Projected Cobalt Demand for All Uses

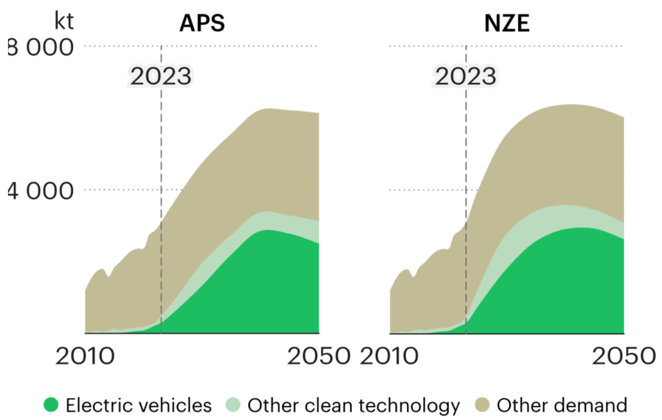


Projected Cobalt Supply is Inadequate to Achieve all Energy Transition Goals

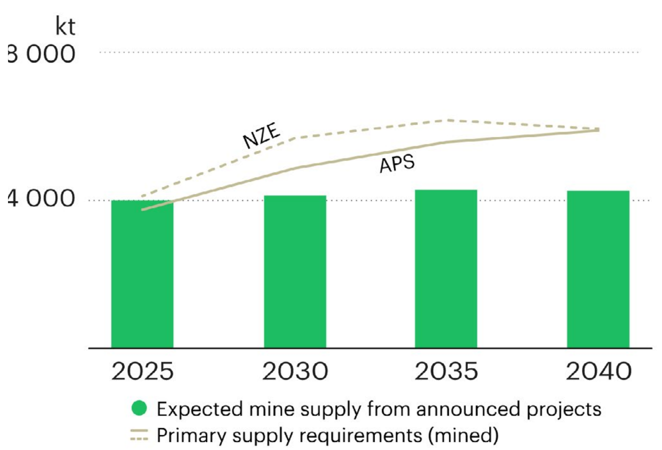
Source: "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 155. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

Cathles and Simon discuss some of the reasons for the copper shortfall. They explain that discovering mineral deposits requires vast amounts of land to be open to mineral exploration and development because finding a mineral deposit is very difficult and involves "a chain of tough probabilities." Once a copper occurrence has been discovered, the size and grade of the deposit must be determined by extensive drilling and preliminary economic and engineering assessments to determine whether the deposit can be developed into an economically viable mine. They describe a decreasing rate of discovery of copper deposits, stating that between 2001 to 2010, about 20 new copper deposits of at least 0.1 Mt were discovered per year. From 2015 to 2022, this decreased to less than 10 copper discoveries per year. This translates into a success rate of discovering an initial copper occurrence of at least 0.1 Mt to around one in 2500 for the period 2001 to 2010 and is now about one in 5000. This is the success rate to make an initial discovery.

Figure 12
Projected Nickel Supply, Demand, and Shortfall



Projected Nickel Demand for All Uses



Projected Nickel Supply is Inadequate to Achieve all Energy Transition Goals

Source: "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 155. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

The rate of success for a copper occurrence becoming an economic deposit that can be mined is between one in 100 and one in 800.[81]

Section IV.C: Shortages of Other Energy Transition Minerals are Predicted

The 2024 IEA report also predicts shortfalls for three other essential energy transition minerals: lithium, cobalt, and nickel. Lithium is seen as the mineral with the widest gap between projected supply and demand, with anticipated lithium supply meeting only 50 percent of the anticipated demand.[82] Focusing on cobalt and nickel, two metals typically associated with Minnesota's Duluth complex copper deposits, Figures 11 and 12 illustrate the forecast demand for cobalt and nickel and the projected shortfalls of both minerals. Like copper, it is unlikely there will be sufficient cobalt and nickel production to achieve the APS and the NZE CO_2 emission reduction goals.

As discussed in the IEA 2024 report, another troubling aspect of the outlook for both cobalt and nickel is the geographical concentration of the mining and processing of these minerals. The DRC mines roughly 65 percent of the world's cobalt; China dominates cobalt processing, producing over 75 percent of global processed cobalt. Just as China is positioning itself to be the world's largest copper producer, China is also aiming to become a dominant cobalt producer by investing in cobalt mines in the DRC.[83]

Indonesia mines one-half of the world's nickel and, along with China, dominates worldwide nickel refining by processing about 65 percent of global nickel. The lack of geographical diversity for cobalt and nickel mining and processing, along with similar geographical concentrations for lithium and rare earths, make these mineral supply chains especially vulnerable to disruption: "... high levels of supply concentration represent a risk for the speed of energy transitions, as it makes supply chains and routes more vulnerable to disruption, whether from extreme weather, trade disputes or geopolitics."[84] Capitalizing upon the substantial copper-nickel-cobalt resources in Minnesota would help diversify the world's supply of these minerals.

Section IV.D: Which Minerals Will be Needed in the Future?

It is reasonable to assume that battery technology will evolve in the future, which could change the chemistry of the cathodes and anodes in lithium-ion batteries and ultimately influence the types and quantities of minerals that are needed for battery manufacturing. Currently, the dominant composition of lithium-ion battery cathodes are two nickel-based chemistries: 1) nickel-manganese-cobalt-oxide, or NMC cathodes; and 2) nickel-cobalt-aluminum (NCA) cathodes.[85] Lithium-iron-phosphate (LFP) cathodes are also gaining popularity as a way to reduce the use of nickel and cobalt. However, LFP cathodes have a lower energy density than nickel-based cathodes, which means some EVs powered by LFP lithium-ion batteries have a reduced driving range. According to the IEA, LFP became a major cathode chemistry in 2023 and comprise about 40 percent of EV battery sales by capacity.[86] Regardless of cathode chemistry, most anodes in lithium-ion batteries are currently made with graphite. Silicon doping increases the energy density of graphite anodes, with roughly one-third of EV batteries using silicon-doped graphite anodes. Eventually, sodium-ion batteries may supplant lithium-ion batteries if they are become cost-competitive with lithium-ion batteries.[87]

Although the demand for nickel and cobalt for manufacturing lithium-ion battery cathodes may change with time, the many other critically important uses for these minerals will continue into the foreseeable future as shown in Figures 11 and 12. Future mining of nickel and cobalt from Minnesota mines would make a significant dent in the nation's reliance on foreign countries for these minerals. It would also substantially reduce the environmental and worker safety impacts of cobalt and nickel mining because some mines in the DRC and Indonesia employ few if any environmental or worker health and safety safeguards. In marked contrast, future copper, cobalt, and nickel mining in Minnesota would be strictly regulated and would use state-of-the-art mining and environmental protection technologies and worker safety precautions. It would be far preferrable to replace DRC-mined cobalt and Indonesian-mined nickel with responsibly mined cobalt and nickel from Minnesota. Although cobalt and nickel mines in Canada and Australia have protective environmental safeguards and worker health and safety requirements, obtaining minerals from these countries increases the CO_2 footprint due to the emissions from shipping these minerals to the U.S., making domestic mining of these minerals in Minnesota the most environmentally responsible choice.

Section IV.E: Can Recycling Eliminate the Need for Mining?

The 2024 IEA report discusses how recycling, defined as manufacturing from scrap metals and end-of-life equipment and defined as "secondary supply," can reduce the need for mining ("primary supply"), but it will not be able to eliminate the long-term need for mining. Volumes of secondary supply are predicted to increase with time as more equipment constructed with minerals reaches the end of its useful life and gets recycled. The IEA predicts that by 2040, recycled copper, lithium, nickel, and cobalt contained in EVs and clean energy equipment could reduce primary supply requirements for these minerals by 10 to 30 percent.[88]

Recycling practices are well established for certain metals like aluminum and copper but less well established for most other energy transition minerals. Recycling programs for lithium, nickel, and cobalt from EVs and storage batteries and rare earth elements from wind turbines and EV motors, are not widespread or readily available. Currently, the recycling feedstock for battery metals mainly comes from electronic waste and scrap from manufacturing processes. By the end of the decade, the first generation of EVs will reach the end of their life and will become a larger feedstock for critical minerals recycling. The IEA predicts that around 30 GWh of spent electric car batteries is expected to be globally available for recycling by the end of the decade.[89]

According to the IEA, copper is one of the few materials that can be recycled repeatedly without any loss of quality. Recycled copper and the direct use of high-grade manufacturing copper scrap is expected to substantially increase starting in 2030 when it will become an important source of copper.[90] Cathles and Simon explain the copper recycling rate as the percentage of copper that can be reclaimed for other uses when the useful life of some product has ended. There are many products with different usage lifetimes and different fractions of copper recoverable, and recovery fractions can change with time. They suggest that 70 percent is the upper recycling rate limit. One hundred percent copper recycling is not possible because copper used in very small parts in complex electronics and cannot be recycled.[91]

S&P Global's August 2024 report entitled "Copper in the U.S: Opportunities and Challenges, Copper mining, recycling and trade in the U.S"[92] states that despite the fact that copper is fully recyclable, recycling seems an unlikely solution on its own. This report cites a decline in U.S. copper secondary refined recycling input rates from about 16 percent in the mid-1990s to the current rate of about 6 percent and notes an increase in the amount of copper scrap (the feedstock for copper recycling) being exported to China, Canada, India, and Malaysia.

Although recycling is expected to make meaningful future contributions to the world's supply of the minerals needed for the energy transition, Michaux cautions that: "The vast majority of the proposed Circular Economy support systems have yet to be manufactured. As it is not possible to recycle something that has yet to be manufactured, the source for this unprecedented quantity of metals will have to be sourced from mining."[93]

Section V: The Biden-Harris Administration's Actions to Put Lands Off-Limits to Mining Conflict with its Energy Transition Goals

As Cathles and Simon note, exploring for minerals requires looking at hundreds of prospects in many places in order to find a mineral deposit that can become an economically viable mine. Their statistic that between one in 100 and one in 800 copper discoveries will ultimately be developed into a mine speaks to the difficulty in exploring for and developing a copper deposit. Other minerals have similarly daunting odds against discovery and development. In its 1999 report, "Hardrock Mining on Federal Lands," the National Research Council/National Academy of Sciences estimated that 1,000 mineral targets must be identified and evaluated to discover a single deposit that can become a mine.[94]

A corollary principle is that the odds of making a discovery are reduced if lands are not available for mineral exploration and mining. Put simply — you cannot find minerals if you cannot look for them in the first place.

Unfortunately, that is the case throughout the U.S., where roughly two-thirds of the 600 million acres of reserved public lands in the U.S. (i.e., roughly 400 million acres) have been set aside for conservation and preservation purposes and are thus functionally off-limits to mineral exploration and mining. From 1980 to 2020, the acres of conservation and preservation lands grew from 250 million to 400 million.[95] Prohibiting mineral exploration and development on the 400 million acres of off-limits lands potentially perpetuates and may even increase the nation's reliance on foreign minerals because the mineral potential within these 400 million acres can never be discovered or developed.

As discussed in Section III.B., in January 2023, the Biden-Harris administration withdrew 225,504 acres in the Superior National Forest in Minnesota and prohibited mineral exploration and development of Twin Metals' copper-nickel-cobalt-PGM mineral deposit.[96] This decision sequesters this portion of the Duluth complex, which is known to contain a world-class copper-nickel mineral deposit, for at least twenty years. By prohibiting development of the Twin Metals deposit, the Biden-Harris administration has taken overt actions that make the nation more reliant on foreign sources of these minerals that could otherwise be responsibly produced under Minnesota's stringent and comprehensive environmental protection regulations.

To put the size of the Superior National Forest 225,504-acre withdrawal into perspective, it is instructive to compare it to mining's small footprint on public lands in the 14 western states[2] that are governed by the U.S. Mining Law (30 U.S.C. 21a *et seq.*). According to a Government Accountability Office (GAO) May 2020 report, as of September 30, 2018, the U.S. Bureau of Land Management and the U.S. Forest Service had authorized 317,783 acres of mineral exploration and mining-related surface disturbance on federal lands in these western states.[97] The aggregate land mass of these western states covers nearly 1.3 billion acres; federal lands cover about 581 million acres.[98] Thus the 317,783 acres of authorized surface disturbance on the 581 million acres of federal lands is a miniscule 0.51 percent (a factor of 0.005) of the land. Similarly, the footprint of the proposed Twin Metals underground mine and mineral processing operation would also be small compared to the size of the withdrawal. The December 2019 Mine Plan of Operations shows the proposed project would impact 1,156 acres,[99] or roughly 0.05 percent of the 225,504 acres of the Superior National Forest

2 AK, AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, and WY.

Table 2
Recent Biden-Harris Administration Policies that Obstruct Mining and Conflict with its Ambitious Energy Transition Goals

Problematic Policy	Discussion
2022: Department of the Interior (DOI) cancels Twin Metals' minerals leases	Forecloses the lessees' right to go through the permitting process to determine if the proposed project can be built and operated to protect the environment.
2023: DOI withdraws 225,504 acres in the Superior National Forest from minerals leasing and mine development	Puts a world-class copper-nickel-cobalt deposit off-limits for at least 20 years despite the Nation's recognized need for these minerals in EVs and other low-carbon energy applications
2023: EPA vetoes Clean Water Act Section 404 permit for the proposed Alaskan Pebble Mine	Puts a world-class copper deposit off-limits to mining without conducting a proper evaluation of whether this project could be built and operated to protect the environment including the salmon fishery.
2023: Securities and Exchange Commission (SEC) proposes rule to adopt listing standards for Natural Asset Companies (NACs) on public lands	NACs are defined as conservation investment properties that must be managed to not cause any material adverse impact on the condition of the natural assets thus precluding most economic development of public lands.
2023: Internal Revenue Service Draft Guidance to exclude mining costs from the critical minerals tax credit in the Inflation Reduction Act (IRA).	Failure to include mining violates the intent of the Section 45X Advanced Manufacturing Production Tax Credit, which is designed to encourage domestic mining of critical minerals.
2024: BLM finalizes the Conservation and Landscape Health/ Public Lands Rule	Rule will restrict mining, transmission lines, renewable energy projects and other multiple uses on 245 million acres of BLM-administered public lands and 700 million acres of subsurface mineral lands in the western U.S.
2024: Council on Environmental Quality (CEQ) finalizes National Environmental Policy Act (NEPA) regulations[1]	Will affect all major federal actions that require authorization from one or more federal agency with broad implications for a wide array of projects including mining, renewable energy, oil and gas, geothermal, infrastructure, roads, pipelines, transmission lines and more.
2024: BLM denies Right of Way application for the Ambler Road in Alaska	Proposed road needed to access significant zinc, lead, silver, cobalt and copper deposits in the Ambler Mining District that are stranded without this road. The Secretary of the Interior is directed to permit the road in the 1980 Alaska National Interest Lands Conservation Act (ANILCA).
2024: BLM recommends prohibiting mining and oil and gas development of Alaska federal lands subject to the Alaska Native Claims Settlement Act	Keeps 28 million acres off-limits to oil, gas, and mining, rejecting a series of 2020 and 2021 proposals to consider some lands for oil and gas development.
2024: BLM issues Final EIS for the Western Solar Plan	August 2024 Final EIS makes over 31 million acres in 11 western states available for solar energy projects, creating potential conflicts with mineral development and other multiple uses.
2024: BLM issues Greater Sage-Grouse Draft EIS and Resource Management Plan Amendment (RMPA)	March 2024 Draft EIS/RMPA includes alternatives that would put between 10 million and 69 million acres off-limits to mining, oil and gas, renewable energy, transmission lines and other multiple uses in ten western states.

3 NEPA is the statute that requires federal agencies to prepare an Environmental Impact Statement, an Environmental Assessment, or another type of NEPA analysis to evaluate the environmental consequences of proposed actions requiring a federal permit, lease, or other type of authorization.

land withdrawal.

Given our urgent need for domestic sources of copper, nickel and cobalt, it makes no sense to categorically prohibit mining in this area of the Superior National Forest where the Duluth complex contains a substantial and important deposit of these minerals without first thoroughly evaluating whether these minerals could be extracted in a way that would fully protect the highly valued environmental resources in the area, including water quality in the Boundary Waters Canoe Wilderness Area. But that is exactly what the Biden-Harris administration did when it canceled the Twin Metals minerals leases, withdrawing this area of the Superior National Forest from mineral leasing and future mining and short-circuiting the environmental analysis process to examine whether the Twin Metals proposed underground mining project would protect the environment.

Unfortunately, the Biden-Harris administration's withdrawal of the Superior National Forest is not an isolated decision to put federal lands off limits to mineral exploration and mining. Since taking office, this administration has embraced several other policies to restrict and even prohibit mining, while at the same time espousing policies that give lip service to encouraging domestic mining to strengthen mineral supply chains and reduce the nation's dependency on foreign minerals. The glaring incongruity between President Biden's February 24, 2021, *Executive Order on Supply Chains*[100] (Executive Order 14017) and subsequent rulemakings and permit denials that will ultimately discourage domestic mining, further weaken mineral supply chains, and increase our reliance on foreign adversaries for critical minerals establishes an unfortunate pattern of hypocrisy by saying one thing and then doing just the opposite.

Section 3 of Executive Order 14017 required executive branch agencies to prepare a 100-Day Supply Chain Review. With respect to minerals, this executive order including the following directive:

> (iii) The Secretary of Defense (as the National Defense Stockpile Manager), in consultation with the heads of appropriate agencies, shall submit a report identifying risks in the supply chain for critical minerals and other identified strategic materials, including rare earth elements (as determined by the Secretary of Defense), and policy recommendations to address these risks. The report shall also describe and update work done pursuant to Executive Order 13953 of September 30, 2020 (Addressing the Threat to the Domestic Supply Chain From Reliance on Critical Minerals From Foreign Adversaries and Supporting the Domestic Mining and Processing Industries). The report shall include the items described in section 4(c) of this order.

Table 2 lists some of the Biden-Harris administration's policies that restrict or preclude mining that will make mineral supply chains more vulnerable to disruption and render the U.S. more beholden to China, Russia, and other adversaries for the minerals we need.

> **Given our urgent need for domestic sources of copper, nickel and cobalt, it makes no sense to categorically prohibit mining in this area of the Superior National Forest.**

Many of the actions listed in Table 2 are examples of an agency inappropriately using a rule to functionally change a law to achieve outcomes that are contrary to Congress' intent in enacting the underlying statute. This violates the Constitution's separation of powers that gives Congress the exclusive authority to promulgate laws.

Consequently, these rules and policies are unlawful. For example, the BLM's Public Lands Rule, the Western Solar Plan, and the proposed Greater Sage-Grouse RMPA violate the Federal Land Policy & Management Act of 1976 (FLPMA), which directs the Secretary of the Interior to manage public lands for multiple uses. The Public Land Rule creates a new type of BLM lease for *non-use* of public lands. Both the solar energy and sage grouse policies elevate single uses of the land (e.g., solar energy and sage grouse habitat conservation) over all other land uses. The proposed Greater Sage-Grouse RMPA also includes provisions to exclude mining, renewable energy, oil and gas, energy infrastructure, and other uses on millions of acres. Taken together, these BLM policies will significantly reduce the amount of public land available for multiple uses including mineral exploration and mining, which will interfere with the goals to increase domestic production of critical minerals to strengthen U.S. mineral supply chains and reduce the country's reliance on foreign minerals.

Similarly, the SEC's proposal to create NACs on public lands violates the multiple use mandate in FLPMA. The IRS' proposed guidance to exclude mining costs from eligibility for the Section 45X IRA ten percent tax credit is inconsistent with Congress' intent to use the tax code to stimulate domestic production of the critical minerals needed to manufacture EV batteries and other EV components.

The CEQ's new NEPA regulations are the most troublesome new policy because they will complicate and delay *any* type of project that requires authorization from a federal agency *anywhere* in the U.S. These regulations unlawfully transform the National Environmental *Policy* Act, which Congress enacted in 1969, into the National Environmental *Protection* Act. When Congress enacted NEPA, it mandated that federal agencies prepare environmental documents that inform the public of the likely environmental impacts associated with proposed projects. Since 1969, Congress has enacted numerous environmental statutes mandating regulatory programs to protect the nation's air, surface water, groundwater, endangered species, and cultural resources and other environmental laws governing waste disposal, hazardous wastes, toxic chemicals and more.

Fifty-five years later, the CEQ has inappropriately used rulemaking to blend these environmental protection laws into NEPA. The new NEPA regulations change NEPA from a procedural analysis of environmental impacts into regulations that require agencies to identify and select alternatives that achieve an environmentally preferable outcome — one that may be inconsistent with the agency's purpose and need pursuant to its statutory obligations to issue permits that authorize certain levels of environmental impacts in order for a project to occur. Moreover, this new rule is inconsistent with the NEPA amendments that Congress enacted in the Fiscal Responsibility Act of 2023, which are designed to streamline the NEPA process. As discussed in more detail in Section VI, the new NEPA regulations will cause permitting delays and spawn litigation that will thwart the energy transition.

Section VI: The Protracted and Litigious Permitting Process is Thwarting Energy Transition Goals

At S&P Global's March 2023 CERAWeek conference, U.S. Secretary of Energy Jennifer Granholm described permitting delays as "crazy," stating that it shouldn't take over a decade to get a permit for a transmission project on federal lands.[101] Secretary Granholm is right; the protracted permitting process is crazy. But it is worse than crazy because decades-long permitting is creating untenable delays that are harming the U.S. economy, national security, grid reliability, and thwarting its energy transition objectives.

Permitting delays for proposed mining projects create serious problems for project applicants and the communities waiting for the promise of high-paying mining jobs and exacerbate the country's reliance on foreign minerals. But permitting delays adversely affect much more than mining because fossil fuel, nuclear, hydropower and renewable energy development, infrastructure projects to build roads, powerlines, and pipelines, and proposed manufacturing facilities typically face permitting delays. Citing a Lawrence Berkeley National Laboratory study, *The Wall Street Journal* reports that the time it takes for a renewable energy power project to get from proposal to construction has more than doubled since the early 2000s.[102]

From the perspective of achieving the nation's energy transition goals, permitting delays associated with building the high-voltage transmission line network needed to connect new renewable energy projects to the electrical grid is perhaps the most serious obstacle. In October 2023, Secretary Granholm stated: "To realize the full benefit of the nation's goal of 100% clean electricity by 2035, we need to more than double our grid capacity."[103]

The National Academies of Sciences Engineering and Medicine's recent report entitled "Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions (2024)" states:

> Perhaps the single greatest risk to a successful energy transition during the 2020s is the risk that the nation fails to site, modernize, and build out the electrical grid...The need for adding new transmission capacity and pathways during the 2020s is unprecedented... Studies show that without significant new transmission capacity, renewables deployment would be delayed, just as electrification of transport and heating are starting to increase demands for power. The net result could be increased generation by fossil electricity plants and increased national fossil emissions during the 2020s, which would make the entire effort appear to be a failure, even assuming that investments in energy efficiencies occur in conjunction with electrification.[104]

Mr. Martin Durbin, Senior Vice President of Policy, and President of the Global Energy Institute at the U.S. Chamber of Commerce, testified at the April 24, 2023 hearing before the Senate Environment and Public Works Committee that over one million miles of transmission lines need to be built in order to achieve NZE by 2050.[105] At this same hearing, Ms. Christina Hayes, Executive Director of Americans for a Clean Energy Grid, told lawmakers that in the early 2010s, about 1,700 line-miles of high-voltage transmission lines were permitted each year in the U.S., dropping to a current rate of around 700 line-miles per year.[106] At this rate it will take 1,400 years to permit one million miles of transmission lines, dramatically illustrating that policymakers have embraced grossly unrealistic goals and timelines in which to achieve any semblance of an energy transition.

New transmission lines aren't the only projects facing permitting delays. Permitting roadblocks stand in the way of implementing the trillions of dollars intended for climate change and energy transition projects that Congress has appropriated in several recently enacted laws, including the Bipartisan Infrastructure Law, the Inflation Reduction Act, and the Chips and Science Act.

If we don't fix the broken permitting process, the transition from fossil fuels to renewable energy will take centuries to complete. These economic investments that the federal government is making to attain national electrification by 2035 and NZE by 2050 need to be tempered by the harsh realities that mineral shortages and permitting delays mean it will be impossible to achieve these goals in the next several decades, or perhaps at all.

The Fraser Institute's recent report, "Halfway Between Kyoto on 2050 – Zero Carbon is a Highly Unlikely Outcome," reaches a similar conclusion, stating: "To eliminate carbon emissions by 2050, governments face unprecedented technical, economic and political challenges, making rapid and inexpensive transition impossible."[107] This report's author, Vaclav Smil, offers the following sobering observation:

At this rate it will take 1,400 years to permit one million miles of transmission lines, dramatically illustrating that policymakers have embraced grossly unrealistic goals and timelines in which to achieve any semblance of an energy transition.

> Since the world began to focus on the need to end the combustion of fossil fuels, we have not made the slightest progress in the goal of absolute global decarbonization: emission declines in many affluent countries were far smaller than the increased consumption of coal and hydrocarbons in the rest of the world, a trend that has also reflected the continuing deindustrialization in Europe and North America and the rising shares of carbon-intensive industrial production originating in Asia. As a result, by 2023 the absolute reliance on fossil carbon rose by 54 percent worldwide since the Kyoto commitment. Moreover, a significant part of emission declines in many affluent countries has been due to their deindustrialization, to transferring some of their carbon-intensive industries abroad, above all to China.[108]

Several House and Senate lawmakers in the 118th U.S. Congress have introduced bills seeking to streamline permitting.

The House Natural Resources Committee held a hearing in September 2024 to discuss Chairman Bruce Westerman's (R-AR) discussion draft to amend NEPA to remove the roadblocks it is currently creating. In July 2024, Senators Joe Manchin (D-WV), Chairman of the Senate Energy and Natural Resources Committee, and John Barrasso (R-WY), the Ranking Member of this committee, introduced the *Energy Permitting Reform Act of 2024* (S. 4753). As of this writing, the bill was passed out of the Senate Energy and Natural Resources Committee with wide bipartisan (15-4) support and is advancing to the full Senate floor. Some of the bill's key provisions include the following:

- Accelerates onshore leasing and permitting decisions for oil and gas, geothermal, renewable energy, coal, and hardrock mining projects on public lands;
- Establishes offshore wind and oil and gas lease sale requirements;
- Facilitates interstate electric transmission line permitting to improve grid reliability while protecting consumers, benefitting communities, and requiring cost allocation among those who benefit, and ensuring; and
- Ends the administration's ban on new liquified natural gas (LNG) exports;
- Confirms longstanding rights under the U.S. Mining Law authorizing the use of public lands for the activities and facilities needed to support nearby mining operations; and
- Levels the litigation playing field by establishing a 150-day statute of limitations from the date of the final agency action on a project; requiring courts to expedite review of legal challenges; and setting a 180-day deadline for federal agencies to act on remanded authorizations.

Section VII: Minnesota and the U.S. Have a Responsibility to Increase Their Roles in Mining the Energy Metals that Our Nation and Our World Need

The U.S. in general, and Minnesota in particular, have stringent and comprehensive laws and regulations governing mining that require mining projects to be designed, built, operated, closed and reclaimed in compliance with high standards designed to minimize environmental impacts and protect worker health and safety. The same cannot be said for some foreign countries that are key exporters of essential minerals.

In the U.S., mining projects are subject to complex and time-consuming state and federal permitting processes that require extensive engineering and environmental studies and on-the-ground baseline surveys. Regulators use these studies and surveys to prepare detailed environmental impact analyses and develop an Environmental Impact Statement (EIS) under the federal NEPA and pursuant to equivalent state laws in some states. Some projects require both federal and state regulators to prepare EIS documents. Depending on the location, type, and size of the proposed mining operation, performing the engineering and environmental studies and baseline data needed to support the permitting process for a proposed mine takes many years and costs many millions of dollars. As an example of this commitment of time and resources, NewRange announced in August 2024 that, although the current NorthMet mine plan meets all permitting requirements, the company is undertaking additional environmental and engineering studies at the proposed NorthMet Mine to "assess whether new mining technology and sustainability developments can further enhance environmental safeguards and mining performance."[109]

Minnesota regulators have special expertise in evaluating the geochemistry of Duluth Complex mineral deposits and how mined materials will interact with the environment over time. In fact, regulators with Minnesota's Department of Natural Resources (MDNR) have studied the Duluth Complex for over 40 years, making them world-recognized experts in evaluating the acid generating potential of mineral deposits.

In Minnesota, two state agencies, the MDNR's Division of Lands and Minerals and the Minnesota Pollution Control Agency (MPCA), have principal environmental regulatory jurisdiction over Minnesota mining projects. The MDNR's regulatory program is specific to mining whereas the MPCA's program applies broadly to many types of industrial projects. Minnesota's mining regulations require proposed mining operations to be planned, operated, reclaimed and closed to protect the environment, prevent impacts from acid mine generation, and provide financial assurance. In order to review a Permit to Mine, MDNR must prepare an EIS to comply with the Minnesota Environmental Policy Act (MEPA).

Once a mine has been fully permitted, the mining company must provide financial assurance to state and federal regulators prior to starting construction to guarantee that the mine and all related facilities will be properly closed and reclaimed if mining operations are unexpectedly or prematurely terminated, or if mine closure is required for any reason at any time during the life of the project.

Depending on the size and type of the mine, hundreds of millions of dollars or more of financial assurance may be required. For example, MDNR determined that PolyMet (the previous owner of the NorthMet Mine) would have to provide a $75 million bond to begin constructing the NorthMet Mine, and $588 million in financial assurance in order to start mining (neither of which has happened yet due to permitting challenges). The required amount of financial assurance would escalate as mining progresses. At Mine Year 11, MDNR estimated that Polymet would have to provide $1.039 billion in financial assurance to guarantee reclamation and to provide for long-term water treatment costs.[110]

As discussed in Section III.B., the permitting histories for the proposed NorthMet and Twin Metals projects show that the Minnesota mine permitting process takes years and all too frequently is derailed by litigation and interference from the federal government. Minnesota's stringent mining laws and regulations and its detailed permitting process are described in greater detail in American Experiment's 2018 "Unearthing Prosperity" report.

The statutory and regulatory requirements to protect the environment and worker health and safety at U.S. mines stands in stark contrast to the lack of similar standards in some important mineral-producing countries. For example, in the DRC, which produced 65 percent of the world's cobalt in 2023,[111] it is relatively commonplace for children work in hazardous conditions to extract cobalt, usually in "artisanal" mines using basic tools and their bare hands. The IEA estimates that over a million children work in mines and quarries.[112]

In deciding where to get the copper, nickel, cobalt, and other minerals needed to meet current mandates for an energy transition, the U.S. sits at a crossroads. We know we have significant deposits of many of these minerals here in the U.S. — like the world-class copper-nickel-cobalt resources in northern Minnesota. However, companies face serious roadblocks that delay the development of these and other important mineral resources throughout the country.

The Minnesota mine permitting process takes years and all too frequently is derailed by litigation and interference from the federal government.

Figure 6 shows that the U.S. already relies on foreign countries, including adversaries like China, for many of the minerals needed to meet energy transition goals as well as all other aspects of modern society. Do we continue down this path and become even more dependent on foreign countries for our minerals — or do we put more focus on responsible development of domestic mineral resources? Do we accept the lower standards in some mining countries in a desperate scramble to acquire the minerals required to achieve the looming deadlines in widely accepted energy transition objectives that are premised on the massive buildout of wind and solar power systems, construction of millions of miles of new high-voltage powerlines to connect these facilities to the grid, and manufacturing enough EVs and batteries to electrify the global transportation sector?

It appears that the Biden-Harris administration is encouraging us to lower our commitment to protecting the environment and start obtaining more of our minerals from countries where mines have lax or no environmental protection or worker health and safety standards. Speaking at the Milken Institute Global Conference in Los Angeles an official of the Biden-Harris administration, Amos Hochstein, recently stated that in order to lessen our dependency on Chinese minerals, the U.S. and its allies must encourage mining projects in countries that have mineral resources but may have poor labor and environmental standards and less stable political systems:

> We can all live in the capitals and cities around the world and say 'I don't want to do business there.' But what you are really saying is we're not going to have an energy transition. Because the energy transition is not going to happen if it can only be produced where I live, under my standards.[113]

That's exactly what China has done with its strategic investments in copper and cobalt mining assets in risky and politically unstable countries like the DRC and Zambia.[114] Is Mr. Hochstein's advice a day late and a dollar short? Has China already scooped up all of the mining investment opportunities in these countries?

Perhaps a more fundamental question that needs to be asked is whether an energy transition should be mandated at all if it comes at the cost of environmental destruction and blatant disregard for worker health and safety. The U.S. should not accept "out of sight, out of mind" as a solution — especially since we can produce many of the required minerals from U.S. mines that are the cleanest and safest mines in the world.

In addition to environmental protection and worker safety concerns, the U.S. must also focus on strengthening our national security and reducing the vulnerability of our mineral supply chains by securing more of the minerals we need from domestic mines. The federal government has a Constitutional obligation to provide for the national defense, which our current mineral reliance on China for the many critical minerals needed for military applications, the economy, and the electric grid puts at risk (See Figure 6).

The question of where we get the minerals we need cannot have the binary answer of "not here/get them from somewhere else." As citizens of the world, we must accept some responsibility for producing what we need. Minnesota and other U.S. mineral deposits could play a meaningful role in responding to the country's and the world's demand for the copper, nickel, cobalt, and the other minerals needed to achieve U.S. energy transition goals. Because future production of these minerals from Minnesota and U.S. mines would be done with state-of-the-art environmental safeguards and the utmost commitment to worker health and safety, Minnesota and the rest of the U.S. could become a world leader in providing critically important minerals while setting a very high bar for mines in other countries to follow.

Section VIII: Conclusions: Net Zero by 2050 is Impossible Without More Minerals and Fixing the Broken Permitting Process

As the U.S. implements policies to require 50 percent of new vehicles sales to be EVs by 2030,[115] 67 percent by 2032,[116] and to achieve NZE by 2050,[117] policymakers should be thinking carefully about the minerals needed to manufacture EVs and the lithium-ion batteries that power them, construct wind turbines, solar panels, storage batteries, and transmission lines — and where to get these minerals. The current policies that have made the U.S. reliant on China for 11 of the minerals shown in Figure 6 are dangerously unsustainable and will prevent the country from achieving its stated energy transition goals.

As discussed in Section VI., the world is facing soaring mineral demands and resulting shortages. Figures 10, 11, and 12 show that the demands for copper, cobalt, and nickel are projected to skyrocket due to grid and clean energy requirements on top of conventional uses like construction and manufacturing, with mineral demands exceeding supplies starting in around 2030. The same is true for other minerals like lithium, graphite, and REE that are needed to pursue energy transition objectives. Burgeoning electrical power requirements for AI and data centers will further increase the demand for minerals and precipitate likely shortages.

No form of energy is free of environmental impact — whether it comes from fossil fuels or renewable energy sources. If U.S. policy continues to disincentivize the use of coal, natural gas, and oil to generate electricity and incentivize wind and solar power to replace fossil fuels, it is deciding that new mining will be necessary, with its attendant impacts on the environment. In choosing to construct a massive number of wind turbines, solar panels, storage batteries, and EVs, the U.S. will be using products manufactured with large amounts of minerals. To conscientiously implement this decision, the U.S. must take responsibility for where and how these minerals will be mined.

Policymakers must also acknowledge the adverse grid reliability and landscape impacts associated with replacing fossil fuel power plants with enormous utility-scale wind and energy projects and ask whether these significant impacts are justifiable. Policies that rush to replace coal- and natural gas-fired power plants, which produce 24/7, always dispatchable, baseload power, with intermittent wind and solar energy have destabilized our electricity grids and substantially reduced our energy security. EPA's recently finalized regulations requiring coal and natural gas power plants to adopt commercially unproven and unaffordable carbon-capture and sequestration technologies will further erode the reliability of our electricity grids.

Some communities are objecting to gigantic utility-scale wind and solar energy projects that have a massive footprint on the landscape, turning many millions of acres of formerly arable or otherwise productive lands into biologically barren places. This is especially true for solar projects where vast solar panel arrays essentially sterilize the lands on which they are placed, creating an environment that is hostile to plants and wildlife. According to the DOE's Solar Energies Technology Office, solar energy is likely to conflict with agricultural land use because the same attributes that make land appropriate for solar energy (plentiful sun and flat land) are also attractive for agriculture.[118]

The 2021 American Experiment report "Not in Our Backyard: Rural America is fighting back against large-scale renewable energy projects," presents research showing that meeting the country's 2021 electrical energy demands with wind power would have required building wind farms on about 900,000 square kilometers (over 220 million acres), which is between 12 and 10 percent of the nation's lands. To put this footprint into perspective, 900,000 square kilometers is roughly double the size of California or the combined areas of Texas and Kansas. Although an equivalent amount of power from solar energy would not require as much land, it would nonetheless consume about 90,000 square kilometers, which is about the size of the State of Maine.[119]

Unfortunately, the U.S.' current policies are sending a clear message to the world: "Give us your minerals because we do not want to mine them in our backyard or take any responsibility for protecting the environment and keeping mine workers safe." This value judgement ignores the environmental and labor impacts at foreign mines that are out of sight and out of mind, and is irresponsible, arrogant, and immoral. We are making a conscious decision to offshore mining to countries that we know have little regard for the environment and worker health and safety.

The U.S.' strict environmental regulations are an asset for domestic resource projects, which means we can strengthen national security by developing a robust supply of domestic minerals and at the same time have a clean environment. Yet the Biden-Harris administration has created tangled contradictions in its climate policies that make it harder (and in some places impossible) to mine domestically while at the same time acknowledging the need for more critical minerals. The Public Lands Rule, Western Solar Plan, and the proposed Sage-Grouse RMPA all threaten to close off public lands to exploration and development. New NEPA regulations threaten to complicate and delay *any* type of project that requires authorization from a federal agency *anywhere* in the U.S.

Permitting a domestic mining project sets a high bar. State and federal regulators evaluate each application and all of the supporting engineering, environmental, and technical studies in meticulous detail to determine if the project can be built, operated, and closed in compliance with all applicable standards. Only if regulators verify that all of these conditions can be met, and mining companies provide multi-million dollar financial guarantees, can a project proceed.

But this process is much harder than it needs to be. The dysfunctional permitting process portends a bleak future of energy shortages, high energy costs, and supply chain disruptions because it is holding the development of important projects hostage and depriving the public of the many benefits that new roads, bridges, pipelines, transmission lines and mines would create. These permitting delays are dangerous because they make the U.S. dependent on foreign countries for the fuels, critical minerals, raw materials, and manufactured goods essential to our energy future, national security, technology, and economic wellbeing.

Minnesota's permitting histories for the NorthMet and Twin Metals projects are a poster child for a protracted and litigious permitting system that to date has thwarted development of important mineral resources. Permitting for the NorthMet mine began in 2004 with the projection that construction could begin as early as 2015.[120] Twin Metals was proposed more recently in 2019. The Biden-Harris administration derailed the permitting process for both projects when it revoked the Clean Water Act Section 404 permit for the NorthMet Project and canceled the federal mineral leases for the Twin Metals project and also withdrew lands from mineral development in the Superior National Forest where the project is located. For investors to consider undertaking a project that costs hundreds of millions of dollars and takes decades, they must have confidence that the rug won't be pulled out from under them by a politicized permitting process.

Congress needs to enact legislation like the proposed bipartisan Energy Permitting Reform Act of 2024 to transform the permitting process into a more straightforward path to get to "yes," so that projects that meet all regulatory requirements can be permitted on a reasonable and predictable schedule. This does not mean rubber-stamping project approvals or diminishing environmental protection. Permitting should become a threshold that must be crossed over rather than an all too often insurmountable obstacle. During the permitting process, companies, regulators, and stakeholders should focus on working collaboratively to find a project's "sweet spot" that identifies the best ways to minimize project impacts, protect the environment, create jobs, benefit communities, and strengthen local economies. These are not mutually exclusive goals. Lawmakers must also make litigation the exception rather than the rule and limit obstructionists' ability to use the federal court system to add years of delay and uncertainty to the permitting process.

Advancements in battery technology, recycling, and material efficiency and substitution are likely. They might help, but they won't eliminate the need for minerals and new mining, and they will not proceed quickly enough to make a meaningful difference in the number and type of mines that the world needs to construct in the coming years. Fossil fuels — especially natural gas — will still be necessary to power our future under any energy scenario. Even if we continue to pursue the currently mandated energy transition, it is clear that achieving this transition is going to take much longer than NZE by 2050 policies envision. As we have shown, the world cannot produce enough of the minerals needed to achieve this timeline.

It's time for policymakers to recognize that worldwide mineral shortages require ambitious energy transition timelines to be extended into the future because NZE by 2050 will be impossible to achieve. Projected mineral demands far outstrip mineral supplies — especially for copper, *the* electricity metal, which is predicted to be in short supply starting in around 2030 (Figure 10). The world cannot mine enough copper and other energy transition minerals fast enough to satisfy demands based on current projections.

In addition to acknowledging the problems stemming from mineral shortages, policymakers must also consider the adverse impacts of attempting to adhere to the NZE 2050 timeframe and reassess current energy transition policies. It is time to conduct a thoughtful analysis of the pros and cons of pursuing the NZE timeline and fully consider the consequences of the current headlong push to achieve NZE by 2050. This analysis should focus on the following issues:

- The U.S. inappropriately relies on foreign countries for many of the minerals needed for an energy transition. Some of these countries produce minerals from mines that harm the environment and jeopardize mine workers' health and safety, with some mining operations using child labor;

- The U.S. could be producing more of the minerals needed to support energy transition objectives from domestic mines, which would be some of the cleanest and safest mines in the world. However, the Biden-Harris administration has taken recent actions that functionally outsource mining to foreign countries by putting U.S. lands off-limits to mining and obstruct several important proposed domestic mining projects;

- Federal and state policies that force closures of always available electricity from coal and natural gas powerplants and replacing them with weather-dependent and intermittent wind and solar energy facilities have seriously reduced the reliability of the electricity grid. As Federal Energy Regulatory (FERC), Mark Christie recently explained, the loss of dispatchable coal and natural gas powerplants threatens grid reliability because neighboring grid operators cannot lean on each other for power imports if neither has surplus power;[121]

- The world will continue to need natural gas and nuclear as bridge fuels during the transition to reduce CO_2 emissions — and in the case of nuclear power — virtually eliminate them, regardless of the pace at which the transition occurs. Coal will also be needed in the foreseeable future as the fuel source for several indispensable industrial processes including making steel and cement.

> **The world cannot mine enough copper and other energy transition minerals fast enough to satisfy demands based on current projections.**

- The dysfunctional federal permitting process for mines, transmission lines, and other energy infrastructure is currently creating an insurmountable obstacle to meeting energy transition goals and timelines;

- The mineral intensity of EVs drives a significant portion of the foreseeable mineral demand under any of the energy transition scenarios (See Figure 2). This suggests that a more sensible and readily achievable approach would be to transition to more gasoline hybrid vehicles rather than EVs because gasoline hybrids require much less copper to build than EVs[122]; and

- The astronomical costs for the transition may put it out of reach. A 2022 McKinsey & Co. report estimated that capital spending on physical assets and land-use systems to transition to NZE between 2021 and 2050 would cost about $275 trillion, or an average of $9.2 trillion per year.[123]

Avoiding — or at least minimizing — the adverse impacts of the energy transition should be a universally acceptable goal. These serious issues must thus be addressed in an honest and comprehensive evaluation of whether it makes sense to continue to pursue the current scale and timeframe of the NZE energy transition, whether the transition needs to be slowed down to reduce impacts, or whether it should be pursued at all. The answer to this complex question must consider a number of factors that include economic security, national defense, environmental protection, human rights and environmental justice, and a cost-benefit analysis. Who benefits, and who does not? What are the costs, and who pays for them?

Finally, Minnesota and the U.S. have a clear role to play in becoming important, environmentally responsible domestic producers of copper, nickel, cobalt and other minerals needed for the energy transition and many other important purposes. Increasing domestic mineral production will accomplish two important objectives. First, it will reduce the U.S.' currently dangerous reliance on foreign minerals. Second, domestic mining from clean and safe mines to produce more of the minerals needed for many things including meeting energy transition goals will help the world achieve NZE sooner rather than later. It makes no sense to lock up U.S. minerals in no-go zones or in virtual permitting purgatory while the country and the world need these minerals now.

Endnotes

1 Fontinelle, Amy. "Paris Agreement/COP21: Meaning, History, Structure." Investopedia. Accessed September 7, 2024. https://www.investopedia.com/terms/p/paris-agreementcop21.asp.

2 "United Nations Climate Change Conference." Wikipedia, September 3, 2024. https://en.wikipedia.org/wiki/United_Nations_Climate_Change_Conference.

3 Orr, Isaac, Mitch Rolling, and John Phelan. "The High Cost of 100 Percent Carbon-Free Electricity by 2040." American Experiment, October 25, 2022. https://www.americanexperiment.org/reports/the-high-cost-of-100-percent-carbon-free-electricity-by-2040.

4 "How Many Pounds of Minerals Are Required by the Average Person in a Year?" How many pounds of minerals are required by the average person in a year? | U.S. Geological Survey. Accessed July 29, 2024. https://www.usgs.gov/faqs/how-many-pounds-minerals-are-required-average-person-a-year.

5 "MEC Mineral Baby 2023." Minerals Education Coalition, August 29, 2023. https://mineralseducationcoalition.org/mining-minerals-information/mining-mineral-statistics/mec-mineral-baby-2022/.

6 "Geologic Map with Sample Locations, Duluth Complex." Geologic Map with Sample Locatins, Duluth Complex | U.S. Geological Survey. Accessed July 29, 2024. https://www.usgs.gov/media/images/geologic-map-sample-locations-duluth-complex.

7 "Copper in the Home." Official site of Copper Development Association, Inc. (USA). Accessed August 16, 2024. https://www.copper.org/education/c-facts/home/.

8 U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024.

9 U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024.

10 Orr, Isaac M., Debra W. Struhsacker, and John Phelan. "Unearthing Prosperity: How Environmentally Responsible Mining Will Boost Minnesota's Economy." American Experiment, August 13, 2018. https://www.american-experiment.org/reports/unearthing-prosperity-how-environmentally-responsible-mining-will-boost-minnesotas-economy.

11 "Neodymium." American Chemical Society. Accessed August 16, 2024. https://www.acs.org/greenchemistry/research-innovation/endangered-elements/neodymium.html.

12 Gielen, Dolf, and Martina Lyons. "Critical Materials for the Energy Transition: Rare Earth ..." International Renewable Energy Agency. Accessed August 16, 2024. https://www.irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA_Rare_Earth_Elements_2022.pdf.

13 IEA. "Mineral Requirements for Clean Energy Transitions – the Role of Critical Minerals in Clean Energy Transitions – Analysis." International Energy Agency. Accessed July 29, 2024. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions.

14 "Innovation Needs in the Sustainable Development Scenario – Clean Energy Innovation – Analysis." IEA. Accessed August 16, 2024. https://www.iea.org/reports/clean-energy-innovation/innovation-needs-in-the-sustainable-development-scenario.

15 "Innovation Needs in the Sustainable Development Scenario – Clean Energy Innovation – Analysis." IEA. Accessed August 16, 2024. https://www.iea.org/reports/clean-energy-innovation/innovation-needs-in-the-sustainable-development-scenario.

16 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024, 8. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

17 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024, 92. https://www.iea.org/reports/global-critical-minerals-outlook-2024.

18 Yergin, Daniel, Tabitha Bailey, Mohsen Bonakdarpour, Mark Ferguson, Frank Hoffman, Aurian de La Noue, and Keerti Rajan. "The IRA and the US's Mineral Supply Challenge." IHS Markit, March 26, 2024. https://www.spglobal.com/marketintelligence/en/mi/research-analysis/us-ira-and-critical-mineral-supply-challenge.html.

19 Orr, Isaac. "Wind Turbines Require Nine Tons of Copper, Which Is the Weight of an Average School Bus." American Experiment, February 13, 2023. https://www.americanexperiment.org/wind-turbines-require-nine-tons-of-copper-which-is-the-weight-of-an-average-school-bus/.

20 Slav, Irina. "Offshore Wind Requires 63,000lbs of Copper per Turbine." OilPrice.com, May 17, 2021. https://oilprice.com/Latest-Energy-News/World-News/Offshore-Wind-Requires-63000lbs-Of-Copper-Per-Turbine.html.

21 "Metals and Minerals in Wind Turbines." National Wind Watch, August 30, 2013. https://www.wind-watch.org/documents/metals-and-minerals-in-wind-turbines/.

22 "Copper: Powering up the Electric Vehicle." Copper: Powering Up The Electric Vehicle | Wood Mackenzie, August 13, 2019. https://www.woodmac.com/news/opinion/copper-powering-up-the-electric-vehicle/.

23 "Copper: Powering up the Electric Vehicle." Copper: Powering Up The Electric Vehicle | Wood Mackenzie, August 13, 2019. https://www.woodmac.com/news/opinion/copper-powering-up-the-electric-vehicle/.

24 "EPRI Study: Data Centers Could Consume up to 9% of U.S. Electricity Generation by 2030." EPRI Home. Electric Power Research Institute, May 29, 2024. Electric Power Research Institute. https://www.epri.com/about/media-resources/press-release/q5vU86fr8TKxATfX8IHf1U48Vw4r1DZF.

25 "Electricity 2024 - Analysis and Forecast to 2026." International Energy Agency. Accessed July 29, 2024. https://iea.blob.core.windows.net/assets/6b2fd954-2017-408e-bf08-952fdd62118a/Electricity2024-Analysisandforecastto2026.pdf.

26 Kampshoff, Philipp, Adi Kumar, Shannon Peloquin, and Shivika Sahdev. "Building the Electric-Vehicle Charging Infrastructure America Needs." McKinsey & Company, April 18, 2022. https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs.

27 "AI Is Poised to Drive 160% Increase in Data Center Power Demand." Goldman Sachs, May 14, 2024. https://www.goldmansachs.com/intelligence/pages/AI-poised-to-drive-160-increase-in-power-demand.html.

28 *"Full Committee Hearing to Examine the Opportunities, Risks, and Challenges Associated with Growth in Demand for Electric Power in the United States," 2024.* Accessed July 29, 2024. https://www.energy.senate.gov/services/files/7F2AC3C4-87CB-4562-99F8-5BB999FC6433

29 Venditti, Bruno, and Athul Alexander. "Why Copper Is Critical for Data Centers." Elements by Visual Capitalist, October 18, 2023. https://elements.visualcapitalist.com/why-copper-is-critical-for-data-centers/.

30 Hoppe, Joseph, and Christian Moess Larson. "AI Siphons Copper Supplies Needed for Green Transition." *The Wall Street Journal*. June 6, 2024. https://www.wsj.com/articles/ai-siphons-copper-supplies-needed-for-green-transition-8fef79e6?st=p148o01celdz15z&reflink=desktopwebshare_permalink.

31 Shan, Lee Ying. "Copper Futures Hit Record High as Data Center Build-up, EV Growth Fuels Demand." *CNBC*, May 15, 2024. https://www.cnbc.com/2024/05/15/copper-futures-hit-record-high-as-data-center-build-up-ev-growth-fuels-demand.html.

32 Lazenby, Henry. "Hundreds of New Mines Required to Meet 2030 Battery Metals Demand — IEA Report - Mining.Com." Mining.com, August 5, 2022. https://www.mining.com/hundreds-of-new-mines-required-to-meet-2030-battery-metals-demand-iea-report/.

33 United Nations Conference on Trade and Development. 2024. *The sustainable energy revolution: Trade and development implications in critical energy transition minerals markets and maritime transport.* Fourteenth session. TD/B/C.I/57. Available at https://unctad.org/system/files/official-document/cid57_en.pdf.

34 "Benchmark Says over 330 Mines Needed by 2035 to Meet Battery Demand." ACME Lithium Inc., September 15, 2022. https://acmelithium.com/2022/09/14/benchmark-says-over-330-mines-needed-by-2035-to-meet-battery-demand/.

35 IEA. "Mineral Requirements for Clean Energy Transitions – the Role of Critical Minerals in Clean Energy Transitions – Analysis." International Energy Agency. Accessed July 29, 2024. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-require-

ments-for-clean-energy-transitions.
36 "U.S. Uranium Production up in 2022 after Reaching Record Lows in 2021 - U.S. Energy Information Administration (EIA)." U.S. uranium production up in 2022 after reaching record lows in 2021 - U.S. Energy Information Administration (EIA), August 17, 2023. https://www.eia.gov/todayinenergy/detail.php?id=60160.
37 Wischer, Gregory. "Tariffs Can Help Make the US a Minerals Powerhouse Again." *The Hill*. Accessed August 26, 2024. https://thehill.com/opinion/4833515-us-minerals-tariffs-security/.
38 Liu, Siyi, Amy Lv, and Dominique Patton. "China to Restrict Exports of Chipmaking Materials as US Mulls New Curbs." *Reuters*, July 3, 2023. https://www.reuters.com/markets/commodities/china-restrict-exports-chipmaking-materials-us-mulls-new-curbs-2023-07-04/.
39 Lv, Amy, and Dominique Patton. "China Export Curbs Choke off Shipments of Gallium, Germanium for Second Month." *Reuters*, October 19, 2023. https://www.reuters.com/world/china/china-export-curbs-choke-off-shipments-gallium-germanium-second-month-2023-10-20/.
40 Baskaran, Gracelin. "What China's Ban on Rare Earths Processing Technology Exports Means." Center for Strategic and International Studies, January 8, 2024. https://www.csis.org/analysis/what-chinas-ban-rare-earths-processing-technology-exports-means#:~:text=The%20rollout%20of%20major%20export,to%20both%20build%20domestic%20capabilities
41 "Heavy Rare Earths: What Are Rare Earths?" DY6 Metals, July 5, 2024. https://dy6metals.com/heavy-rare-earth/.
42 "China to Limit Antimony Exports in Latest Critical Mineral Curbs." *CNN*. August 15, 2024. https://www.cnn.com/2024/08/15/tech/china-antimony-export-ban-intl-hnk/index.html.
43 Shaw, Alfie. "China to Continue Canadian Mining Investments despite Scrutiny." Mining Technology, March 15, 2024. https://www.mining-technology.com/news/china-will-continue-to-invest-in-canadas-critical-mineral-industry-despite-pushback/.
44 The Hermosa Project is also planning to produce manganese when it goes into operation, which will also lessen our current 100 percent reliance on Gabon for manganese, which is another critical mineral. (See Figure 1). "Hermosa." South32. Accessed July 29, 2024. https://www.south32.net/what-we-do/our-locations/americas/hermosa.
45 U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024, 29 and 202.
46 U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024, 74 and 80.
47 U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024, 10 and 12.
48 "Exploration for Metallic Mineral Resources in Minnesota: Copper, Nickel, and Platinum Group Metals, Duluth Complex Map." Map. Minnesota Department of Natural Resources, February 2017. https://files.dnr.state.mn.us/lands_minerals/mpes_projects/mnmin2017_coppernickel.pdf.
49 Orr, Isaac M., Debra W. Struhsacker, and John Phelan. "Unearthing Prosperity: How Environmentally Responsible Mining Will Boost Minnesota's Economy." American Experiment, August 13, 2018. https://www.americanexperiment.org/reports/unearthing-prosperity-how-environmentally-responsible-mining-will-boost-minnesotas-economy.
50 "August 2016 - Exploration for Metallic Mineral Resources in Minnesota: Copper, Nickel, and Platinum Group Metals, Duluth Complex Map." August 2016. Map. *Minnesota Department of Natural Resources*. https://files.dnr.state.mn.us/lands_minerals/mpes_projects/mnmin2016_coppernickel_duluthcomplex.pdf.
51 "Explore Minnesota - Titanium." Minnesota Department of Natural Resources, March 2016. http://files.dnr.state.mn.us/lands_minerals/mcc_docs/2016_explore_titanium.pdf.
52 "Projects." NewRange, February 20, 2024. https://www.newrangecoppernickel.com/about/projects/.
53 "Mineral Resources We Need for Cleaner Energy." NewRange, April 8, 2024. https://www.newrangecoppernickel.com/domestic-clean-energy/.
54 "Newrange Reviewing Options after U.S. Army Corps of Engineers Decision." Newsfile, June 6, 2023. https://www.newsfilecorp.com/release/169017.
55 Kraker, Dan. "Biden Administration Cancels Twin Metals' Leases to Mine near BWCA." *MPRNews*. January 27, 2022. https://www.mprnews.org/story/2022/01/26/biden-administration-cancels-twin-metals-leases.
56 Twin Metals Minn. LLC v. United States (United States District Court, District of Columbia September 6, 2023). https://ecf.dcd.uscourts.gov/cgi-bin/show_public_doc?2022cv2506-62
57 "Twin Metals Minnesota Appeals Dismissal of Federal Lawsuit." Twin Metals, November 3, 2023. https://www.twin-metals.com/press-release/twin-metals-minnesota-appeals-dismissal-of-federal-lawsuit/.
58 Kraker, Dan. "Feds Propose Mining Moratorium in Bwca Watershed." MPR News, October 20, 2021. https://www.mprnews.org/story/2021/10/20/feds-propose-20year-mining-moratorium-in-the-watershed-of-the-boundary-waters.
59 Bureau of Land Management. "Public Land Order No. 7917 for Withdrawal of Federal Lands; Cook, Lake, and Saint Louis Counties, MN." *Federal Register* 88, no. 20 (January 31, 2023): 6308, https://www.govinfo.gov/content/pkg/FR-2023-01-31/pdf/2023-01969.pdf.
60 Callahan, James T., and Rich Nolan. "America's Energy Future Requires Permitting American Mines." *RealClearEnergy*, July 11, 2024. https://www.realclearenergy.org/articles/2024/07/11/americas_energy_future_requires_permitting_american_mines_1043994.html?blm_aid=47104.
61 "The USA's Only High-Grade Nickel Resources for The ..." Talon Metals Corp, July 2024. https://talonmetals.com/wp-content/uploads/2024/08/Talon-Moving-Forward_July_2024.pdf.
62 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
63 G7 Ministers' Meeting on Climate, Energy, and Environment, "Annex to the Climate, Energy and Environment Ministers' Communiqué Five-Point Plan for Critical Minerals Security," April 17, 2023, https://www.meti.go.jp/press/2023/04/20230417004/20230417004-5.pdf.
64 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 9. https://www.iea.org/reports/global-critical-minerals-outlook-2024
65 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 109. https://www.iea.org/reports/global-critical-minerals-outlook-2024
66 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 110. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
67 Schoffstall, Steve. "Copper: Wired for the Future." Sprott, February 27, 2024. https://sprott.com/insights/copper-wired-for-the-future/.
68 Metelec. "The Power of Copper in Electric Vehicles." Metelec, February 16, 2024. https://www.metelec.com/the-power-of-copper-in-electric-vehicles/.
69"Copper Facts." 12 Interesting Facts. Accessed August 16, 2024. https://www.copper.org/education/c-facts/.
70 Mills, Rick. "Copper: Humanity's First and Most Important Future Metal." Mining.com, July 17, 2024. https://www.mining.com/copper-humanitys-first-and-most-important-future-metal/.
71 "How China Is Reshaping the Global Copper Market." Benchmark Source, August 16, 2024. https://source.benchmarkminerals.com/article/how-china-is-reshaping-the-global-copper-market.
72 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 112. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
73 Sloan, Dylan. "Hopes of a 10-Year EV Transition Are 'irrational' Pipe Dreams Because We Don't Have Enough Battery Materials-Opening up a Single Copper Mine Takes 23 Years." Fortune, May 30, 2024. https://fortune.com/2024/05/30/electric-vehicles-ev-transition-copper-mining-shortage-research-minerals-metals/#.
74 Cathles, Lawrence M., and Adam C. Simon. "Copper Mining and Vehicle Electrification Report Download: IEF Reports." International Energy Forum, May 2024. https://www.ief.org/focus/ief-reports/copper-mining-and-vehicle-electrification/copper-mining-and-vehicle-electrification-report-download.

75 "Inflation Reduction Act: Impact on North America Metals and Minerals Market." S&P Global, August 2023. https://cdn.ihsmarkit.com/www/prot/pdf/0823/Impact-IRA-Metals-Minerals-Report-FINAL-August2023.pdf.
76 Nassar, N. T., T. E. Graedel, and E. M. Harper. "By-Product Metals Are Technologically Essential but Have Problematic Supply." *Science Advances* 1, no. 3 (April 3, 2015). https://doi.org/10.1126/sciadv.1400180.
77 "Rio Tinto to Build New Tellurium Plant at Kennecott Mine." Rio Tinto, March 8, 2021. https://www.riotinto.com/news/releases/2021/Rio-Tinto-to-build-new-tellurium-plant-at-Kennecott-mine.
78 Hund, Kirsten, Daniele La Porta, Thao P. Fabregas, Tim Laing, and John Drexhage. "Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition." World Bank Group, 2020, p. 37. https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf.
79 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 120. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
80 *Written Testimony of Michelle Michot Foss, Ph.D.: Testimony Before the Subcommittee on Environment, Manufacturing, & Critical Minerals,* 118th Cong. (2024) (statement of Michelle Michot Foss, fellow for energy, minerals, & materials at Rice Univeresity's Baker Institute for Public Policy, Center for Energy Studies). https://d1dth6e84htgma.cloudfront.net/06_13_24_ENV_Testimony_Foss_6bfa03fc5e.pdf
81 Cathles, Lawrence M., and Adam C. Simon. "Copper Mining and Vehicle Electrification Report Download: IEF Reports." International Energy Forum, May 2024: 6. https://www.ief.org/focus/ief-reports/copper-mining-and-vehicle-electrification/copper-mining-and-vehicle-electrification-report-download.
82 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 8. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
83 "How China Is Reshaping the Global Copper Market." Benchmark Source, August 16, 2024. https://source.benchmarkminerals.com/article/how-china-is-reshaping-the-global-copper-market.
84 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 8. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
85 Krohn, Ulf. "The Future of Battery Technology: Chemistries, Comparisons, and the Close Prospects." Polarium, May 3, 2024. https://polarium.com/insights/the-future-of-battery-technology-chemistries-comparisons-and-the-close-prospects/.
86 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 28. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
87 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 29. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
88 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 236. https://www.iea.org/reports/global-critical-minerals-outlook-2024
89 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 236. https://www.iea.org/reports/global-critical-minerals-outlook-2024
90 "Global Critical Minerals Outlook 2024." International Energy Agency, 2024: 118, 122. https://www.iea.org/reports/global-critical-minerals-outlook-2024.
91 Cathles, Lawrence M., and Adam C. Simon. "Copper Mining and Vehicle Electrification Report Download: IEF Reports." International Energy Forum, May 2024: 15. https://www.ief.org/focus/ief-reports/copper-mining-and-vehicle-electrification/copper-mining-and-vehicle-electrification-report-download.
92 "The Future of Copper: Will the Looming Supply Gap Short-Circuit the Energy Transition?" The future of Copper in the Energy Transition, July 2022. https://www.spglobal.com/marketintelligence/en/mi/info/0722/futureofcopper.html.
93 Michaux, Simon P. "The Mining of Minerals and the Limits to Growth." ResearchGate, March 3, 2021. https://www.researchgate.net/publication/351712079_The_Mining_of_Minerals_and_the_Limits_to_Growth.
94 National Research Council, *Hardrock Mining on Federal Lands* (Washington, D.C.: National Academy Press, 1999), p. 24.
95 Leshy, John D. 2021. "America's Public Lands—A Look Back, A Look Ahead." In *AI67 Annual Institute Proceedings*. The Foundation for Natural Resources and Energy Law.
96 Bureau of Land Management. "Public Land Order No. 7917 for Withdrawal of Federal Lands; Cook, Lake, and Saint Louis Counties, MN." *Federal Register* 88, no. 20 (January 31, 2023): 6308, https://www.govinfo.gov/content/pkg/FR-2023-01-31/pdf/2023-01969.pdf.
97 "Mining on Federal Lands: More than 800 Operations Authorized to Mine and Total Mineral Production Is Unknown." GAO, May 28, 2020, p. 19. https://www.gao.gov/products/gao-20-461r.
98 "Public Land Statistics." Bureau of Land Management, 2022. https://www.blm.gov/about/data/public-land-statistics.
99 "Twin Metals Minnesota Mine Plan of Operations." Twin Metals, June 6, 2020. https://www.twin-metals.com/resource/twin-metals-minnesota-mine-plan-of-operations/ .
100 Biden, Joseph R. "Executive Order on America's Supply Chains." The White House, February 24, 2021. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/.
101 Darbonne, Nissa. "Energy Secretary Granholm on US Permit Hurdles: 'It's Crazy!'" Hart Energy, March 16, 2023. https://www.hartenergy.com/exclusives/energy-secretary-granholm-us-permit-hurdles-its-crazy-204477.
102 Cai, Ashley. "How Booming Electricity Demand Is StallingEfforts to Retire Coal and Gas, in Charts." *The Wall Street Journal*. August 17, 2024, sec. Business. https://www.wsj.com/business/energy-oil/electricity-demand-coal-gas-retirement-charts-dd07029a.
103 "Biden-Harris Administration Announces $1.3 Billion to Build out Nation's Electric Transmission and Releases New Study Identifying Critical Grid Needs | Department of Energy." Energy.gov, October 30, 2023. https://www.energy.gov/articles/biden-harris-administration-announces-13-billion-build-out-nations-electric-transmission
104 "Summary." In *Accelerating Decarbonization in the United States*, 14. Washington, D.C.: National Academies Press, 2024.
105 *Hearing to Examine Opportunities to Improve Project Reviews for a Cleaner and Stronger Economy Testimony Before the United States Senate Committee on Environment and Public Works,* 118th Cong. (2024) (statement of Martin J. Durbin, Senior Vice President, Policy; President, Global Energy Institute, U.S. Chamber of Commerce) https://www.epw.senate.gov/public/_cache/files/3/a/3ab70f54-e3bd-496c-a5f9-707941dcba4a/BA1AC565531A69F233B1B9A7F56A73CE.04-26-2023-durbin-testimony.pdf
106 *Hearing to Examine Opportunities to Improve Project Reviews for a Cleaner and Stronger Economy: Testimony before the U.S. Senate Committee on Environment and Public Works,* 118th Cong. (2024) (statement of Christina Hayes, Executive Director, Americans for a Clean Energy Grid). https://www.epw.senate.gov/public/_cache/files/9/e/9e894ea0-e189-4a29-a91a-0137f6457cce/6A724CE3FF6E4C9985233C70A78DA459.04-26-2023-hayes-testimony-updated.pdf
107 Smil, Vaclav. "Halfway between Kyoto and 2050: Zero Carbon Is a Highly Unlikely Outcome." Fraser Institute, May 28, 2024. 1, https://www.fraserinstitute.org/studies/halfway-between-kyoto-and-2050.
108 Smil, Vaclav. "Halfway between Kyoto and 2050: Zero Carbon Is a Highly Unlikely Outcome." Fraser Institute, May 28, 2024. 29, https://www.fraserinstitute.org/studies/halfway-between-kyoto-and-2050.
109 "NewRange Embarks on Project-Wide Studies to Further Enhance Environmental Safeguards and Project Performance." *NewRange Copper Nickel*, August 14, 2024. NewRange Copper Nickel. https://www.newrangecoppernickel.com/newrange-embarks-on-project-wide-studies-to-further-enhance-environmental-safeguards-and-project-performance/?blm_aid=0&blm_aid=47104.
110 "Permit to Mine - Financial Assurance Fact Sheet." Minnesota Department of Natural Resources. Accessed August 19, 2024. https://files.dnr.state.mn.us/lands_minerals/northmet/permit_to_mine/fact_sheets/financial_assurance_fs.pdf.
111 "Global Critical Minerals Outlook 2024." International Energy Agency,

2024: 158. https://www.iea.org/reports/global-critical-minerals-outlook-2024
112 "The Role of Critical Minerals in Clean Energy Transitions." International Energy Agency. Accessed August 16, 2024. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.
113"White House Official Urges US Mining Projects in Nations Deemed 'risky' by Corporations." *FOX News*, May 7, 2024. https://www.foxnews.com/world/white-house-official-urges-us-mining-projects-nations-deemed-risky-corporations?blm_aid=47104.
114 "How China Is Reshaping the Global Copper Market." Benchmark Source, August 16, 2024. https://source.benchmarkminerals.com/article/how-china-is-reshaping-the-global-copper-market.
115 "EV Acceleration Challenge." The White House, December 20, 2023. https://www.whitehouse.gov/cleanenergy/ev-acceleration-challenge/#:~:text=As%20part%20of%20President%20Biden's,in%20order%20to%20actively%20support.
116 "Biden-Harris Administration Proposes Strongest-Ever Pollution Standards for Cars and Trucks to Accelerate Transition to a Clean-Transportation Future," April 12, 2023. Environmental Protection Agency. https://www.epa.gov/newsreleases/biden-harris-administration-proposes-strongest-ever-pollution-standards-cars-and.
117 "The Long-Term Strategy of the United States." The White House, November 2021. https://www.whitehouse.gov/wp-content/uploads/2021/10/us-long-term-strategy.pdf.
118 "Agrivoltaics: Solar and Agriculture Co-Location | Department of Energy." Solar Energy Technologies Office, August 20, 2024. https://www.energy.gov/eere/solar/agrivoltaics-solar-and-agriculture-co-location.
119 Bryce, Robert. "Not in Our Backyard." Center of the American Experiment, April 2021. https://files.americanexperiment.org/wp-content/uploads/2021/04/Not-in-Our-Backyard-Robert-Bryce.pdf.
120 Dunbar, Elizabeth. "Timeline: PolyMet's History in Minnesota." *MPRNews*, December 2, 2013. https://www.mprnews.org/story/2013/12/02/polymet-timeline.
121 "Dispatchable Power Remains Irreplaceable." Count on Coal, September 4, 2024. https://www.countoncoal.org/2024/09/dispatchable-power-remains-irreplaceable/.
122 Cathles, Lawrence M., and Adam C. Simon. "Copper Mining and Vehicle Electrification Report Download: IEF Reports." International Energy Forum, May 2024: 1-2. https://www.ief.org/focus/ief-reports/copper-mining-and-vehicle-electrification/copper-mining-and-vehicle-electrification-report-download.
123 "The Net-Zero Transition: What It Would Cost, What It Could Bring." McKinsey & Company, January 2022. https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20net%20zero%20transition%20what%20it%20would%20cost%20what%20it%20could%20bring/the-net-zero-transition-executive-summary.pdf.

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