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Fostering an Electric Future: A Federal Perspective on the U.S. Critical Mineral Supply Chain

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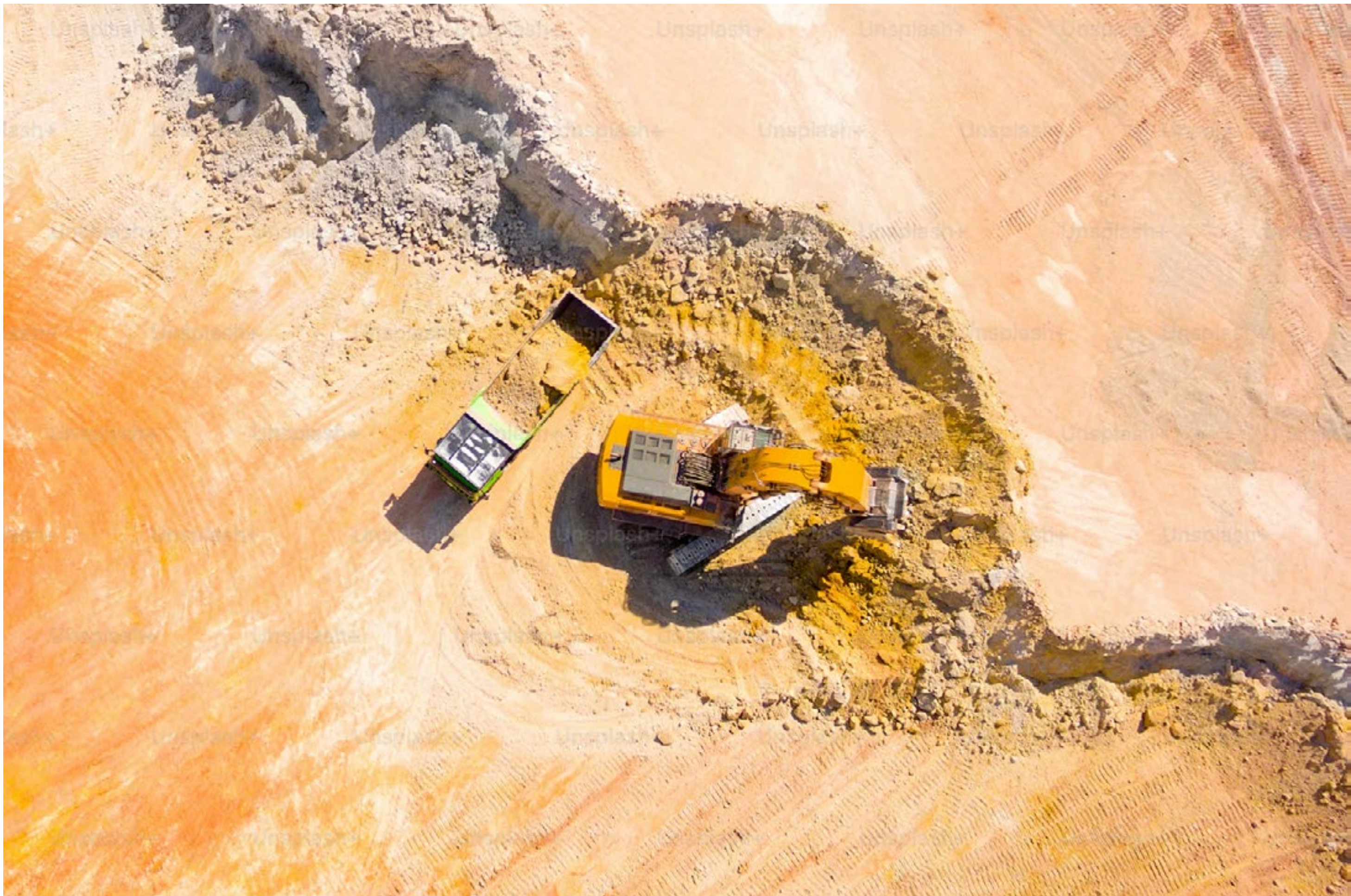
Contents

Glossary

AR—Argentina
AU—Australia
BIL—Bipartisan Infrastructure Law
BR—Brazil
BW—Botswana
CA—Canada
CDA—Copper Development Association
CHIPS—Creating Helpful Incentives to Produce Semiconductors Act
CL—Chile
CO—Colombia
CR—Costa Rica
DLE—direct lithium extraction
DOD—Department of Defense
DOE—Department of Energy
DR—Dominican Republic
DRC or CG—Democratic Republic of the Congo
ERMA—European Raw Materials Alliance
ERGI—Energy Resource Governance Initiative
E.U.—European Union
EV—electric vehicle
FRA—Fiscal Responsibility Act
FR—France
FTA—free-trade agreement
GR—Germany
GT—Guatemala
HN—Honduras
IDF—Intergovernmental Forum on Mining, Minerals, Metals, and Sustainability
ID—Indonesia
IL—Israel
IN—India
IRMA—Initiative for Responsible Mining Assurance
IT—Italy
IRA—Inflation Reduction Act
JO—Jordan
JP—Japan
KP—Democratic People's Republic of Korea
Kt—kiloton
Li—metallic lithium
LCE—lithium carbonate equivalent; =Li X 5.323
LCO—lithium cobalt battery
LDV—light-duty vehicle
LFP—lithium, iron, phosphate battery
LIB—lithium-ion battery
LPO—Loans Program Office
MSP—Minerals Security Partnership
MT—metric ton
MX—Mexico
NCA—lithium, nickel, cobalt, aluminum oxide battery
NI—Nicaragua
NMC—nickel, manganese, cobalt oxide battery
NM—Namibia
NO—Norway
OM—Oman
PA—Panama
PGII—Partnership for Global Infrastructure Investment
PH—the Philippines
SE—Sweden
SG—Singapore
SN—Senegal
SV—El Salvador
UK—United Kingdom
U.S.—United States
USGS—United States Geological Survey
ZM—Zambia

Executive Summary

Supporting the production of critical minerals—including lithium, nickel, cobalt, copper, manganese, graphite, and rare earth minerals—in the United States is key to addressing the growing demand for electric vehicles (EVs). The public and private sectors have already taken significant steps to incentivize critical minerals development and advanced manufacturing, and their actions have placed the U.S. on a trajectory toward building a robust, stable, sustainable, and reliable supply chain. Still, substantial work to expand the domestic critical mineral supply chain remains. Critical minerals are a global commodity: developing these resources domestically presents a meaningful opportunity to partner with allies to build transparency and cooperation. Moreover, international competitors have a head start building these supply chains, and some groups operate with minimal public and environmental oversight. Strategic multilateral initiatives, working groups, battery collection and recycling standardization, as well as continued federal support and investment will be required to sustain the transition to transportation electrification in the face of steep global competition and exponential demand.



Key Takeaways

- Critical minerals are indispensable to a clean energy economy, and the demand for critical minerals will continue to increase regardless of whether or not a single new EV is manufactured.
- As critical mineral mining and processing accelerates around the world, the U.S. must continue to invest in a domestic supply chain that can set a new global standard for sourcing the materials that will fuel the clean energy transition responsibly and sustainably.
- Critical mineral resources are widely dispersed across the globe, but production and processing are highly concentrated in several key geographical areas today.
  - ***Lithium***—Until recently, the U.S. had the world's fourth largest identified lithium resource. A recent discovery in Nevada has made the U.S. home to the largest global lithium resource[1]; abroad, Bolivia, Argentina, and Chile collectively are currently the leading extractors of lithium raw materials. Though China holds less than 7% of the global lithium resources and produces less than 15% of global lithium raw material, it produces nearly 60% of the world's refined lithium.
  - ***Copper***—Estimates suggest that existing U.S. reserves of this key mineral already surpass expected worldwide demand; likewise, recycled copper is also a significant contributor to U.S. supply. Abroad, more than 40% of global copper production occurs in Chile and Peru. However, China controls 40% of all copper processing capacity.
  - ***Nickel***—The USGS believes that Minnesota, Michigan, and Wisconsin contain as much nickel as some of the world's top producers. Abroad, Indonesia, Russia, Canada, Australia, and the Philippines have the world's largest nickel reserves, and China exercises significant influence over global markets by holding 68% of the world's processing capacity.
  - ***Cobalt***—The U.S. and key partners—especially Canada—have substantial cobalt reserves; abroad, the Democratic Republic of Congo produces 70% of cobalt today, and most of that cobalt is refined in China.
  - ***Graphite***—The U.S. imports virtually all of its graphite, though the U.S. government is investing in growing domestic graphite capacity. DOE noted that the funding will support the development of enough battery-grade graphite for nearly 1.2 million EVs per year and help reshore the supply chain. Abroad, Turkey holds over 25% of the world's graphite reserves—the largest in the world—though its processing capacity is extremely limited. By contrast, China mines 65% and processes nearly 100% of the world's graphite

for EVs.

  - ***Manganese***—The U.S. does not hold any manganese reserves; abroad, most manganese is found in South Africa, Gabon, Australia, and Brazil, in that order. Australia has a well-developed manganese mining sector, providing 16% of the world's manganese in 2022, and China processes over 90% of the global supply.
  - ***Rare Earth Elements***—Combined, the U.S. and Canada's REE reserves total nearly 15% of the global supply. Abroad, China has 37% of world reserves; Russia, Vietnam, and Brazil are each home to 18%. 85% of REEs are processed in China.

- Over the last 15 years, the U.S. has begun to recognize the necessity of building out a critical mineral supply chain to protect national security, energy security, decarbonization goals, and to boost the economy.
- However, new U.S. minerals projects have been inhibited by lengthy and uncertain permitting and litigation timelines, volatile market prices, uncertainty around the mechanics and stability of new federal programs, and a laissez-faire attitude toward sourcing minerals abroad.
- Executive and legislative efforts to improve the U.S.'s critical mineral capacity in the Bipartisan Infrastructure Law, Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act, and the Inflation Reduction Act have invested hundreds of billions of dollars in the industry. Additional federal incentives are needed that move beyond downstream activities and target domestic production of critical minerals.
- However, efforts to address the permitting process must decrease the timeline for permitting a mine in the U.S., which currently stands at over a decade and significantly stifles domestic development.
- Similarly, the federal government must establish a federal standard for battery recycling (in particular, streamlining transportation and labeling practices). These actions are central to establishing sustainable, transparent supply chains and will become critical as more batteries reach their end-of-life and large amounts of battery feedstock enter the domestic market because of growing global EV adoption. ZETA encourages EPA to move quickly to create federal standards for labeling, collecting, and recycling EV batteries, and to define the end-of-life responsibilities for each member of the value chain.
- Developing education and training programs will equip the critical minerals industry with a next-generation workforce. Likewise, expanding staff in offices with authority over permitting and regulation of critical minerals projects at key federal agencies will help address the growing importance of this sector to the clean energy economy.
- Reforming the USGS Critical Mineral list to designate copper as a critical mineral will also

help ensure that elements essential to the EV supply chain are appropriately considered in the legislative and regulatory process.

- The federal government must also facilitate increased environmental, social, and governance (ESG) coordination among public and private entities. Coordinating initiatives across federal agencies to increase the domestic supply of critical minerals and exploring the potential to expand public-private partnerships internationally represents an opportunity to encourage production with strategic partners and uphold strong governance standards to ensure fair labor practices, environmental protections, and community input. Encouraging the use of third-party auditors for private entities, in particular, can provide a pathway of transparency that is aligned with national and international benchmarks.
- Further international collaboration between the U.S. and its allies is critical for cultivating a reliable supply chain for critical minerals and battery components. Our sustainable, clean energy future hinges upon swift, targeted development of a diverse, ethical, sustainable, and transparent global minerals supply chain. The collective mineral resource endowment of democratic countries could produce enough minerals to enable the world to limit warming to 1.5 degrees Celsius.
    - As it relates to the EV industry, friendshoring is the intentional reorganization and diversification of the battery supply chain into states and economies aligned with the U.S. on social, ethical, environmental, and democratic values and practices. The U.S. and its partners must significantly friendshore production at unprecedented speed and scale to achieve ambitious ESG targets.
    - The U.S. has already brought together global partners to strengthen and diversify the minerals production industry around the world through several multilateral strategies. Moving forward, Canada, Japan, the E.U. and countries in the "Lithium Triangle"—Chile, Argentina, and Bolivia—can be key allies in this endeavor.

1. Introduction

As the world transitions towards a clean energy economy, the demand for critical minerals is surging. Critical minerals are determined by the U.S. government to be essential for the country's economy. These minerals play a pivotal role in the transition, primarily by facilitating the decarbonization of transportation systems, electric grids, and residential infrastructures. Even emissions control systems in internal combustion engine vehicles (ICEVs) today use multiple critical minerals.[2] Their importance is magnified in battery systems, which are central to electric vehicles (EVs) and energy storage solutions (ESS). Beyond batteries, these minerals are foundational to charging stations, transmission lines, and multiple vehicle components. They are also indispensable in fields ranging from national defense systems to consumer electronics.

Accelerating electric vehicle (EV) adoption will further expand the need for domestic critical mineral development and related supply chain investment. The IEA reports that in 2022, the EV market increased 60%.[3] S&P Global estimates that, due to the Inflation Reduction Act, U.S. projected demand for lithium will increase 15% by 2035 from estimates before the legislation (nickel, 14%; cobalt, 13%; and copper, 12%).[4] By 2040, the International Energy Agency expects demand for the critical minerals associated with clean energy technologies to increase between 400 and 600%.[5]

60%
increase in the EV market in 2022, according to the IEA

400-600%
increase critical mineral demand by 2040, according to the IEA

15%
increase in U.S. lithium demand due to the IRA

14%
increase in U.S. nickel demand due to the IRA

13%
increase in U.S. cobalt demand due to the IRA

12%
increase in U.S. copper demand due to the IRA

> As the global pace of mining and processing these minerals quickens, the U.S. stands in a prime position to spearhead a domestic industry. U.S. industry has the potential to establish a new global, gold standard that ensures that the materials supporting our clean energy transition are sourced responsibly and sustainably.

The majority of critical minerals used in U.S. products today are not produced or processed domestically. While the U.S. and North America have promising reserves of several key minerals, new production has lagged behind that of peer countries over the last two decades—a period during which dramatic growth in downstream manufacturing of mineral-intensive products like batteries and renewable energy equipment has occurred overseas. **New U.S. projects have been inhibited by lengthy and uncertain permitting and litigation timelines, volatile market prices, laissez-faire attitudes toward sourcing minerals abroad, and outsourcing of U.S. manufacturing capacity overseas.** As a result, U.S. demand for critical minerals from traditional domestic manufacturing industries has reduced or stagnated. Much of the global battery mineral supply is now concentrated within nations that moved with more urgency and have since erected barriers to market entry. But a wave of new U.S. downstream manufacturing capacity, alongside growing geopolitical concerns about where critical mineral and battery component supplies are most highly concentrated, creates an imperative to accelerate development of a localized supply chain for these crucial upstream materials.

Rhyolite Ridge, NV. Courtesy of Ioneer

1.2 Critical Mineral Development Today: the U.S. & Abroad

The U.S. has a long history of mining and processing commodities like iron, copper, uranium, gold, silver, and gravel tracing back to the early 19th century. However**,** a new mining era—one centered around developing resources for clean technologies—is beginning. Many of these resources are considered to be ***critical minerals***, defined in the Energy Act of 2020 as "non-fuel mineral[s] or mineral material essential to the economic or national security of the U.S. and which has a supply chain vulnerable to disruption."[6] These inputs are necessary for manufacturing many advanced-technology products, including wind turbines, solar panels, and EV batteries. In addition to green-fields mining—mining conducted in previously undeveloped areas—and synthetic production, as is the case with synthetic graphite, recycling also presents a new opportunity to extend the useful life of previously-developed minerals. Technologies to reclaim minerals from conventional mine tailings, end-of-life batteries, and other uses are also improving.

> Critical mineral resources are widely dispersed across the globe, but production and processing are highly concentrated in several key geographical areas today.

It is important to distinguish between "resources" and "reserves" when referring to mineral availability. Mineral resources refer to the quantity of a geologic commodity that exists in both discovered and undiscovered deposits. In other words, ***resources*** represent what geologists know or what they believe exists. According to the United States Geological Survey (USGS), a resource is "a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is regarded as feasible, either currently or at some future time."[7]

Minerals within a resource endowment with the most significant economic potential are known as ***reserves***. As defined by USGS, reserves are minerals within a country's endowment "which could be economically extracted or produced at the time of determination."[8]

It is also important to distinguish between mineral "production" and mineral "processing." For the purposes of this paper, mineral ***production*** will refer to the initial extraction of raw minerals, usually by mining. ***Processing*** refers to the conversion, refinement, or separation of minerals from their ores into a commercially viable material form.

DEFINITIONS

Resources:

what geologists know or what they believe exists

Reserves:

Minerals within a resource endowment with the most significant economic potential

Production:

the initial extraction of raw minerals, usually by mining

Processing:

the conversion, refinement, or separation of minerals from their ores into a commercially viable material form

Lithium

Lithium is a highly abundant element, but its chemical properties make it challenging to concentrate. As such, though finding trace amounts of lithium minerals is common, potentially commercial-scale lithium deposits are rare. Lithium's density and reactivity allow batteries to have a high voltage and increased charge storage per unit mass and volume.[9] Studies identify lithium availability as the primary limiting factor for EV battery production in the future; of the key minerals necessary for batteries, lithium may be the first to see global demand outpace supply.

> The U.S. has a number of promising lithium deposits and has the world's largest identified lithium resources.[10]

In addition, the characteristics of some U.S. deposits allow for refining to be done on-site, meaning that domestic sources of lithium battery materials are possible. As the public and private sectors have recognized the growing need for lithium, domestic exploration for the mineral has expanded. The most recent USGS Mineral Commodity Summaries demonstrate that domestic lithium reserves increased ~2,700%—from 35,000 metric tons (MT) Li in 2019 to 1,000,000 MT Li in 2022.[11,12] Forecasts regarding availability of lithium relative to global demand are optimistic. Global mine production is projected to grow from less than 800,000 MT lithium carbonate equivalent (LCE) annually to 3.6 million MT LCE in 2035—57% in free-trade agreement (FTA) countries and 5% in the U.S., according to S&P Global.[13] By comparison, the lithium requirement for EVs sold in the U.S. is projected to be 106,000 MT LCE by 2035.[14]

Lithium deposits are found across the U.S.—primarily in California, Nevada, Arkansas, North Carolina, and Maine—and many of these sites are being assessed to determine the feasibility of new lithium production. Feasibility is impacted by several factors, including deposit size, mineral concentration, other minerals present, the state regulations, and socioeconomic conditions that might generate opposition.[15] Albemarle's Silver Peak location in Nevada is the only operating lithium mine in the U.S. and is responsible for 1% of the world's lithium supply.

There are also many lithium projects under development throughout the U.S., ranging from early-stage geological exploration to design and permitting stages. DOE and Argonne National Laboratory identified 24 lithium production projects in the U.S. Four advanced development projects include an expansion at Silver Peak, Lithium America's Thacker Pass, Ioneer's Rhyolite Ridge, and Piedmont Lithium's proposed, fully integrated, spodumene ore-to-lithium hydroxide Carolina Lithium project.[16]

Albemarle intends to double production at Silver Peak by 2025.[17] In March 2023, construction began on Lithium America's Thacker Lithium mine in northern Nevada, where the company aims to initiate

Silver Peak Lithium Project, NV
Courtesy of Albemarle, Corp.

production in 2026. Ioneer's Rhyolite Ridge Project is in the final stage of the NEPA permitting process, has received a conditional loan commitment from the DOE LPO, and expects production of refined lithium materials in 2026.[18] Piedmont Lithium is developing a lithium hydroxide refinery in Tennessee, with first production targeted in 2026.[19] The refining and processing capabilities of these projects is key, as the majority of refined lithium is currently sourced from China.[20]

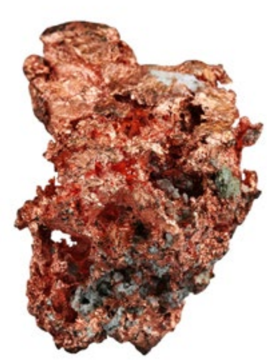
Pilot projects are being considered for lithium in California's Salton Sea, which would be co-located at existing geothermal facilities. **Estimates suggest that the Salton Sea has 32 million MT of LCE potential—nearly as large as the combined capacity of Bolivia and Chile.[21]** The California Department of Energy also states that lithium from the Salton Sea's Known Geothermal Resource Area "can produce more than 600,000 MT per year of lithium carbonate."[22] If true, the Salton Sea has the potential to approach the 2023 global lithium output level and satisfy more than one-third of current global lithium demand.[23]

Bolivia, Argentina, and Chile collectively hold more than half of the world's identified lithium resources, followed by the United States and Australia.[24] More than 75% of global lithium production takes place in Chile and Australia, and development is expanding. Australia, Chile, and Argentina have large planned increases in production capacity. Last year, the Argentinian state-controlled energy producer, YPF, joined private industry in extensive mineral exploration. By 2025, Argentina's lithium production is projected to triple.[25]

China holds less than 7% of the global lithium resources and produces less than 15% of global lithium raw material,[26] yet it produces nearly 60% of the world's refined lithium.[27] **China's dominance in lithium processing—and broader influence in the critical mineral supply chain—is largely the product of a deliberate industrial strategy** to purchase stakes in mining companies around the world, build out a processing industry within their borders, and offtake the materials these companies produce.

> The U.S. is capable of encouraging competitive investments overseas and the build-out of a domestic industry.

Copper



Copper is critical to transportation electrification and is the material of choice for many applications in electric vehicles and charging infrastructure, including battery current collectors, wire harnesses, electric motors, inverters, transformers, and busbars.[28] While not a USGS Critical Mineral, copper was recently added to the U.S. Department of Energy Critical Material list in July 2023.[29]

The U.S. is estimated to hold over 70 million MT in untapped copper reserves and resources. By comparison, current U.S. annual copper demand is around 2 million MT, and global copper production stood at 22 million MT in 2022.[30] On the other hand, global demand for copper is projected to exceed 23.5 million MT by 2030, meaning that existing U.S. reserves of this key mineral already surpass expected worldwide demand.[31,32]

There is considerable planned copper production in the United States. Ten major U.S. copper companies have operational mines and an additional ten projects are in the feasibility or pre-feasibility stages.[33] However, bringing additional supply to market has been stymied by a complicated U.S. mining permitting process with typical timelines spanning 7-10+ years. For instance, more than half of the untapped 70 million MT is attributable to five large projects which have yet to come online due to permitting issues. Equally concerning is the steady decline in U.S. copper refining capacity over the last two decades, resulting in more U.S.-mined copper being exported.

Recycled copper is also a significant contributor to U.S. copper supply. **According to USGS, copper recovered from scrap contributed to about 32% of the U.S. copper supply in 2022.[34]** Of this, 160,000 MT came from end-of-life, post-consumer scrap, and 670,000 MT came from pre-consumer scrap generated from manufacturing operations. Several new secondary production operations are coming online, a development that will allow the U.S. to recycle and refine more copper domestically, including complex scrap grades that were traditionally exported. While new U.S. recycling capacity will help bolster current supply levels, increased recycling alone will not be sufficient to meet demand.

More than 40% of global copper production occurs in Chile and Peru.[35] Globally, there are more than 2.1 billion MT of identified resources. USGS projects that some vulnerability also lies in the ability to expand domestic and FTA production as well as the concentration of copper refining, as China controls 40% of all copper processing capacity.[36] Similar to lithium, China mines less than 10% of the global copper supply, yet has a clear downstream advantage when it comes to processing of the material.[37]

Nickel

Stainless steel is the largest consumer of nickel today, but clean energy technologies are taking a growing share of demand.[38] Lithium-ion battery (LIB) chemistries like Nickel Cobalt Aluminum (NCA) and Nickel Manganese Cobalt (NMC) **rely on nickel for energy density and have used increasing ratios of nickel to other elements over time.**

The U.S. is home to an estimated 370 million MT[39] of nickel; **the USGS believes that Minnesota, Michigan, and Wisconsin contain as much nickel as some of the world's top producers.[40]** However, the U.S. currently imports a majority of the resource that is consumed, with 68% coming from allies in Canada, Norway, Australia, and Finland.[41] The U.S. EV market demand for nickel is expected to reach 695,000 MT by 2035.[42]

Indonesia, Russia, Canada, Australia, and the Philippines have the world's largest nickel reserves; Indonesia and Australia are each home to 22% of the world's supply.[43] As of 2023, Indonesia's share of the global nickel market has grown to 39%.[44] The Philippines follows with 16% of the global market share as the second largest producer in the world.[45]

While there are sufficient nickel resources within the U.S. and its allies, domestic nickel processing remains limited. Instead, China exercises significant influence over global markets by holding 68% of the world's processing capacity.[46]

Cobalt

Cobalt has historically been used in batteries to increase stability, energy density, and voltage.[47] The volatility of the cobalt market and the concentration of cobalt resources in countries where some mineral extraction practices have low environmental and labor standards is driving efforts to shift away from cobalt use. Cobalt is rarely mined as the primary product, instead mined as a byproduct of nickel and copper production.

By 2035, U.S. demand for cobalt needed in EV batteries will reach 53,000 MT.[48] The U.S. has around 1 million MT of cobalt resources, largely concentrated in Michigan, Minnesota, Idaho, and Alaska.[49] Jervois Mining USA recently constructed Idaho Cobalt Operations (ICO), near Salmon, Idaho—the only operating cobalt mine in the United States. The mine has reserves amounting to 3.8 million MT of ore grading 0.5% cobalt. Unfortunately, due to sustained, historically low cobalt prices, ICO was forced to suspend operations in February 2023. On June 15, 2023, the Department of Defense's Office of the Assistant Secretary for Industrial Base Policy (through its Manufacturing Capability Expansion and Investment Prioritization office) entered into a $15 million agreement with Jervois Mining USA to undertake mineral resource drilling that will accelerate the improved definition and expansion of currently-known cobalt resources and conduct feasibility studies to access a domestic U.S. cobalt refinery under the authority of the Defense Production Act. Jervois

Salmon Idaho Cobalt Project. Courtesy of Jervois Mining.

is continuing with these activities during the temporary suspension of operations.

Several U.S. partners have substantial cobalt reserves, representing an opportunity for diversifying the cobalt supply chain. Canada, in particular, is home to 220,000 MT of cobalt reserves.[50] Australia is home to an estimated 18% of global cobalt reserves, and an additional 8% of the world's cobalt can be found in Indonesia.[51]

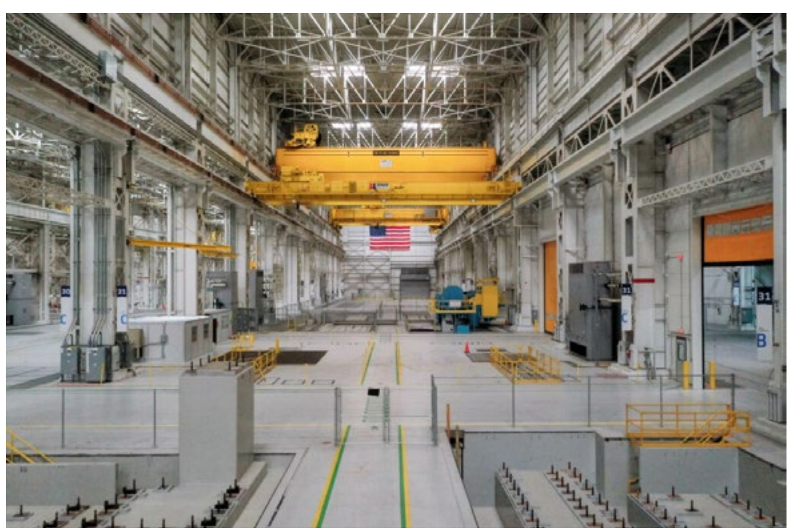
The Democratic Republic of the Congo (DRC) produces 70% of cobalt today.[52] In addition to owning many of the mines in the DRC, China processes the majority of cobalt sourced from the country. [53] A smaller portion of resources are sent to Finland and Belgium for processing.

Graphite

Graphite is especially important to the anode of an EV battery, where it constitutes the primary component material and can account for up to 45% of the components in an individual battery cell.[54] Both natural and synthetic graphite can be used in a battery anode, and the industry utilizes them in roughly the same quantities today. The IEA estimates that critical and strategic mineral demand for graphite will increase by a factor of eight by 2040—driven in part by growing EV manufacturing.[55]

As is the case with many other minerals, the U.S. imports virtually all of its graphite, though U.S. and allied presence in this space is growing. The U.S. has not produced natural graphite since the late-20th century. Canada-based Graphite One was awarded $37 million by the Department of Defense for a project in Alaska thought to be home to the largest natural graphite reserve in the U.S.[56]

In terms of synthetic graphite production, NOVONIX is an advanced battery materials and technology company planning to reach a synthetic graphite production capacity of 10,000 MT annually at its Riverside facility in Chattanooga, Tennessee. The company plans to add an incremental 30,000 MT production capacity by 2025, and reach 150,000 MT of total production capacity in North America by 2030. NOVONIX also has a $30 million partnership with LG Energy Solutions for graphite anode



Tennessee Graphite Facility
Courtesy of NOVONIX

material research and development, as well as a purchase agreement for 50,000 tons of artificial graphite anode should the R&D prove successful. Australian Syrah Resources will be sourcing flake graphite from its mine in Mozambique and refining the flake into anode active material at its refinery in Louisiana. Additionally, headquartered in Quebéc, Canada, Nouveau Monde Graphite is working toward developing 500,000 tons of graphite annually,[57] and produces graphite used at a Panasonic battery manufacturing facility in DeSoto, Kansas.

The U.S. government is investing in growing U.S. graphite capacity; in October 2022, DOE awarded $2.8 billion to build and expand commercial-scale facilities in 12 states to produce and process lithium, graphite, and other battery materials, manufacture components, and demonstrate new approaches, including manufacturing components from recycled materials. In the same press release, **DOE noted that the funding will support the development of enough battery-grade graphite for nearly 1.2 million EVs per year and help reshore the supply chain.[58]** With the help of these projects, Benchmark Mineral Intelligence projects that North American countries will process 26% of forecasted graphite demand by 2030. [59]

Globally, major U.S. allies (NATO countries and nations with a U.S. FTA) mine 8% of graphite for EV batteries; Securing America's Future Energy (SAFE) notes that Canada and Mexico have significant graphite reserves available, and the E.U. has the second largest processing capacity for synthetic graphite (10%).[60]

Turkey holds over 25% of the world's graphite reserves—the largest in the world—though its processing capacity is extremely limited.[61] By contrast, China mines 65% and processes nearly 100% of the world's graphite for EVs, thereby leading graphite production (followed by Mozambique, Madagascar, and Brazil, in that order).[62]

Manganese

Current EV batteries (including those most commonly found in the U.S.) primarily use lithium, nickel, manganese, and cobalt-based (NMC) chemistries in their cathodes and graphite-based anodes. In LIBs, manganese acts as a stabilizer among cathode material.[63] Emerging battery chemistries (in particular, NMC 8-1-1 batteries) present an opportunity to replace some cobalt use with manganese, further strengthening the material's importance.[64]

The U.S. does not hold any manganese reserves; the majority are found in South Africa, Gabon, Australia, and Brazil, in that order. Australia has a well-developed manganese mining sector, providing 16% of the world's manganese in 2022, and China processes over 90% of the global supply.[65] Unlike certain other minerals, limited manganese supply does not currently present a risk.[66]

The U.S. public and private sectors have recently demonstrated an interest in reshoring manganese processing. On the federal side, the Defense Production Act was invoked to rapidly accelerate the domestic production of critical minerals for EV and storage batteries, including manganese.[67] The private sector has similarly taken action to invest in domestic manganese development. In 2023, GM announced an investment of $85 million to expand domestic manganese sulfate production for EVs. The investment is done in partnership with Australian-based Element 25, which will build a manufacturing facility in Louisiana and provide GM with 32,500 MT of manganese sulfate annually. The facility will use Australian-mined manganese and will be the first such facility in the U.S. [68]

Rare Earth Elements (REE)

The rare earth elements (REE) are a group of 17 different minerals.[69] Rare earths—including neodymium—are primarily used in permanent magnets in EV motors, though ICE vehicles also use REEs in catalytic converters.

Combined, the U.S. and Canada's REE reserves total nearly 15% of the annual global supply.[70] Before the 1990s, California's Mountain Pass Mine was the world's largest source of REEs. The mine shut down in 2002, but was since reopened by MP Materials and is now operational. MP Materials received funding from the Department of Defense (DOD) to build a REE processing facility and intends to begin separation activities in 2023.[71] Additionally, Colorado-based NeoCorp Developments is developing its Elk Creek niobium, scandium, and titanium mine in Nebraska. The company has just secured an offtake agreement with Stellantis.

In April 2023, to establish domestic processing capacity, the Biden Administration announced a $16 million investment through the Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law, or BIL) to fund R&D into REE separation technologies.[72] Additional REE refining facilities are under development in Malaysia, Australia, and Canada.[73]

While the U.S. government is investing in REE separation technologies, global supplies of the minerals are concentrated elsewhere. China has 37% of world reserves; Russia, Vietnam, and Brazil are each home to 18%. China also dominates REE processing: 85% of REEs are processed in China.[74]

Piedmont Lithium Senior Exploration Geologist Zach Grimac explains Carolina Lithium's location within the Carolina Tin Spodumene Belt.

Courtesy of Piedmont Lithium

2. Critical Minerals and the EV Industry

While specific numbers vary, most U.S. EV sales projections forecast rapid growth. Coupled with growing consumer acceptance of EV technology and favorable federal policy, these projections are also becoming more optimistic. S&P Global Mobility conservatively estimates EVs will reach 40% of U.S. sales in 2030, with more bullish figures exceeding 50% penetration.[75] The passage of the Inflation Reduction Act (IRA) in 2022—which included tax credits for EV buyers and manufacturers—is only expected to increase these numbers. As a result of the IRA, the International Council on Clean Transportation estimates EVs will make up to 67% of the U.S. light-duty vehicle (LDV) market share by 2032.[76]

> BloombergNEF expects a 20% jump in EV adoption from pre-IRA estimates, predicting that there will be 3.2 million EVs on American roads by 2028.[77]

This boost in EV sales will demand a corresponding increase in battery manufacturing, resulting in an increased demand for the critical minerals necessary to build these technologies. Overall battery demand in North America is expected to grow by a factor of ten—from 49 GWh in 2021 to 484 GWh in 2030.[78] Today, lithium-ion battery technologies are the most common; they include lithium, cobalt, nickel, manganese, graphite, and REEs in their composition. The IEA estimates a 400-600% increase from current critical mineral demand by 2040, driven largely by global EV and battery storage needs.[79] Figure 1 illustrates the growth in battery mineral demand in 2040 compared to 2020 under two different growth scenarios.

Battery Materials
Courtesy of Redwood Materials

Figure 1: Model of the growth in key critical mineral demand for electric vehicle batteries in 2040.[80]

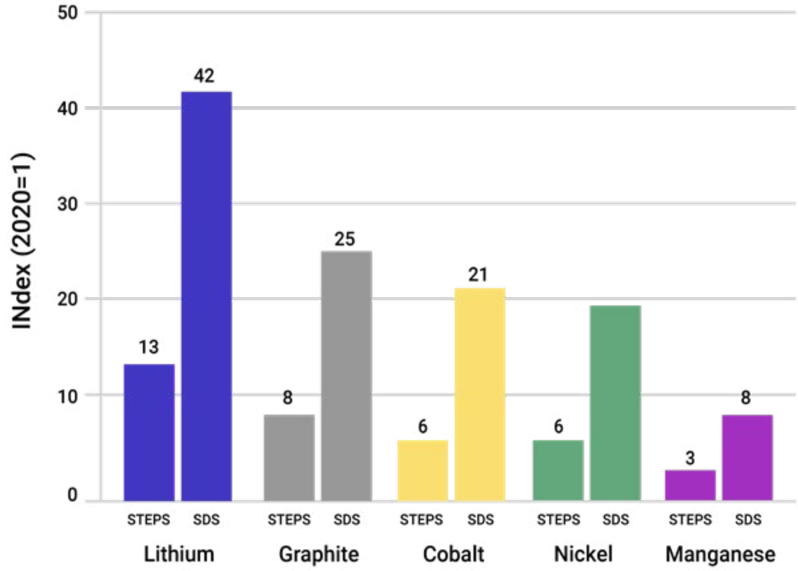


Figure 1: *STEPS = Stated Policies Scenario, an indication of where the energy system is heading based on a sector-by-sector analysis of today's policies and policy announcements; SDS = Sustainable Development Scenario, indicating what would be required in a trajectory consistent with meeting the Paris Agreement goals.*

Estimated U.S. reserves of key minerals are constantly changing as new sources are discovered. However, current estimates suggest that a considerable portion of the 320 GWh demand can be met domestically as the U.S. opens new mining and processing facilities. Figure X calculates the manufacturing capacity based on current U.S. reserves. **Accessing U.S. mineral potential is, however, greatly restricted by the ability of the domestic industry to scale at pace with demand.**

Table 1: Comparison of U.S. mineral reserves and manufacturing capacity.[81]

Element	U.S. Reserves (1000 Metric tons)	World Reserves (1000 Metric tons)	Total Manufacturing Capacity with U.S. reserves (GWh)	Total Manufacturing Capacity with world reserves (GWh)
Lithium	750	21,000	7,470	209,163
Voltage	53	7,100	703	94,164
Kilowatts	100	94,000	167	156,510
Rate of recharge	230,000	1,300,000	3,271,693	18,492,176

Table 1 : *This chart shows domestic and global reserves for lithium, cobalt, nickel, and manganese represented in metric tons. With reserves, the chart then provides the total U.S. and global manufacturing capacity represented in GWh. The data was collected by Argonne National Lab using USGS commodity reporting and* $LiNi_{.08}Co_{.01}Mn._{01}O_2$ *cathode batteries.*
Note: Lithium is expressed as Li

3. Encouraging Domestic Critical Mineral Development

3.1 Federal-Level Initiatives

The U.S. can advance the development of its domestic mining, processing, and recycling facilities to improve its energy security and ensure the feasibility of a clean energy future. However, the U.S. cannot do this alone; it will need to partner with allied countries and other ethically aligned democracies to expand global mining capabilities and boost battery mineral recycling to ensure that valuable minerals remain in use and build a closed-loop supply chain.

The U.S. is currently facing a decades-long decline in mining and relies on imports for almost all of its critical mineral needs. As of 2018, the total number of authorized locatable hardrock operations on federal lands (excluding state- or privately-owned lands) was 3 for lithium, 16 for copper, and 1 for cobalt.[82] The country's only nickel mine is in Michigan, and the only rare earth mine is in California. **The number of metal mines in the U.S.—which include copper, lithium, nickel, cobalt, and rare earths—dropped significantly over the last decade, from 351 active mines in 2012 to 270 mines in 2021**.[83] The number of new mining applications themselves has also stagnated, from 72 in 2011 down to 32 applications in 2021.[84] This decline comes in part as a result of regulatory and financial barriers that discourage new mines—specifically, the lengthy and uncertain permitting process and high capital cost requirements. In addition, outsourcing of the U.S. manufacturing base to overseas locations has indirectly caused a decline or stagnation in demand for critical minerals from traditional manufacturing industries.

However, the U.S. is taking steps to maximize its domestic critical mineral supply and create a more welcoming regulatory environment for domestic critical mineral production and processing. **Over the last 15 years, the U.S. has begun to recognize the necessity of building out a critical mineral supply chain to protect national security, energy security, decarbonization goals, and economic vitality.**

3.1.1 Legislative Efforts

There have been several executive and legislative efforts to improve the U.S.'s critical mineral capacity. The commitments in the BIL, Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act, and the IRA bolster private and public sector commitments. These long-term investments reassure the industry that the clean energy future is here to stay. Additionally, the Biden administration has set a goal for 50% of all passenger vehicle sales to be electric by 2030, creating further certainty.[85] **As a result of federal commitments, over $128 billion in funding has been announced throughout the United States in upstream battery manufacturing, EV assembly, and battery recycling facilities**.[86] The federal government and private sector is realizing the immense economic opportunity of establishing a leadership position in the EV transition.

Lithium Technical Development Center in Reno, NV
Courtesy of Lithium Americas

The BIL also dedicated $7.9 billion to battery manufacturing, recycling, and critical mineral processing. This included $675 million for critical minerals research and development from the Department of Energy (DOE). **Combined with private-sector investments from the mining industry, the BIL's impact is estimated to be $14 billion**. The first $2.8 billion in federal funding was disbursed in 2022 to 21 different projects across the EV battery supply chain—from processing and manufacturing to final assembly.[87] In an effort to diversify the sourcing of the materials, DOE also announced $16 million in funding for projects related to rare earth and other critical mineral extraction from coal waste.[88]

DOE's Loan Program Office (LPO) also received an additional $20 billion in loan authority from the BIL. This funding can be used for projects related to battery manufacturing and recycling critical minerals. So far, the LPO has made conditional commitments for lithium processing at Ioneer's Rhyolite Ridge,[89] Syrah Vidalia for processing of anode material,[90] and Redwood Materials for battery recycling and remanufacturing.[91] While not a requirement of the statute, the LPO is largely focusing on processing and other downstream operations, rather than the mining stage of the supply chain.[92]

Additional provisions in the IRA include increasingly stringent critical mineral sourcing requirements to unlock the full electric vehicle tax credit and additional production tax credits of up to 10% of the cost of production of critical minerals. In 2023, at least 40% of minerals in an EV battery must come from North America or a free-trade agreement (FTA) country, with the percentage increasing every year. By 2024, no minerals may come from a "foreign entity of concern," which includes China and Russia, in order to qualify for the credit. The intent is that these provisions, coupled with generous production and manufacturing tax credits, will incentivize supply chains to move operations to the U.S. As a result of the IRA, several companies have already adjusted long-term planning to build plants in the U.S. and partner with FTA countries for mineral sourcing.

3.1.2 Executive Efforts

Strengthening domestic critical minerals supply chains has been a primary focus of the Biden-Harris administration In June 2021, the Administration released "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth," a report which found that U.S. minerals supply chains are "at serious risk of disruption.[93] In addition to assessing the state of critical material value chains, the report outlined recommendations for supply chain transparency, domestic production, Defense Production Act (DPA) activation, industry collaboration, workforce development, among others.

In March 2022, President Biden invoked the DPA to allow DOD to fund feasibility and modernization projects for mining and processing facilities.[94] With funding from the DPA, DOD invested $120 million in a rare earths separation plant in Texas with Lynas Rare Earths.[95] In March 2023, the Department of Defense announced funding of $15 million to Jervois Mining USA to expand its cobalt resource and study a U.S. cobalt refinery. **In 2022, the White House announced the American Battery Material Initiative to leverage Federal investments and activities to build a domestic critical minerals supply chain.[96] In February 2023, President Biden further expanded this authority to allow for large, longer-term investments in critical mineral projects.** This announcement paralleled the rollout of the $2.8 billion from DOE to U.S. critical minerals development.

To ensure there is a trained workforce for the critical mineral industry, **DOE and the Department of Labor created a workforce development strategy using BIL funding**.[97] These efforts will include retraining in fossil-fuel and automotive communities and enhancing additional training programs across the country. Together, these actions incentivize manufacturers and developers to create an American supply of critical minerals. Since the development strategy announcement, investments in the critical mineral supply chain have dramatically expanded in the country.

In August 2023, the **DOE's Advanced Materials and Manufacturing Technologies Office reactivated funding for the Critical Minerals Institute (CMI)**. The CMI, made up of three other DOE national laboratories, 15 universities, and 36 industry members, conducts research to "diversify supply, develop substitutes, and drive recycling and reuse of critical materials."[98] In the next five years, the DOE will potentially allocate $31 million to CMI. Through the DOE, another $150 million for the advancement of cost-effective and environmentally responsible critical minerals processing and refinement.

The next horizon for the Biden administration and Congress is to speed up the permitting of critical mineral mines on federal lands. In order to unlock the potential of these investments and initiatives, the U.S. must be able to permit and build more mines over the next decade. In addition to protecting environmental and social governance, the Administration's efforts to address the permitting process must decrease the timeline for permitting a mine in the U.S., which currently stands at 7-10 years and significantly stifles domestic development.[99]

4. Working Together: The Role of Friendshoring

International collaboration between the U.S. and its allies is critical for cultivating a reliable supply chain for critical minerals and battery components. Our sustainable, clean energy future hinges upon the swift, targeted development of a diverse, ethical, sustainable, and transparent global minerals supply chain. The vast dominance of the battery supply chain by any single economy is counterproductive to this goal. In response, a strategy commonly referred to as "friendshoring" has shaped U.S. foreign and economic policy. As it relates to the EV industry, ***friendshoring*** is the intentional reorganization and diversification of the battery supply chain into states and economies aligned with the U.S. on social, ethical, environmental, and democratic values and practices. Harnessing branches of the U.S. abroad to counsel sound mineral sector development among allied counties is an opportunity to expand and defend our position as a global leader. **U.S.-allied leadership is necessary in order to drive the minerals industry forward, secure economic and national security, and defend ethical value systems throughout the battery supply chain.**

Friendshoring:

the intentional reorganization and diversification of the battery supply chain into states and economies aligned with the U.S. on social, ethical, environmental, and democratic values and practices.

Although friendshoring is another opportunity to improve the domestic supply chain and allied relationships, it still relies on foreign supply chains to supplement critical mineral production and processing efforts. Any global challenge that creates significant delays in the movement of imported goods will also impact any trade regardless of being an allied nation or not. As the global supply picture tightens, friends (particularly where a large single point of failure exists) could sell more to non-friendly countries in the future. As an example, a recent study by S&P noted that "in 2022, 64% of the U.S.'s refined copper imports were from Chile but only 21% of this FTA country's exports of refined copper went to the United States, compared with 43% to China. As with lithium, Chile has a larger trade relationship with China than with the U.S. It is far from guaranteed that the U.S. will be Chile's major export destination for new capacity."[100]

4.1 The Urgent Need to Scale

A study by the Net Zero Industrial Policy Lab at Johns Hopkins University (published in the Carnegie Endowment for International Peace) demonstrated that:

> The collective mineral resource endowment of democratic countries could produce enough minerals to enable the world to limit warming to 1.5 degrees Celsius.

The study aggregated mineral resource capacity in all democratic countries and U.S. free trade agreement countries. The resulting data (Figure X) shows that with the exception of tellurium, global democracies have a surplus of minerals needed to achieve 2030 climate goals.[101]

Figure 3. Critical Mineral Reserves in Democratic Countries

Critical Mineral	2030 Global Demand 1.5oC Scenario (kt)	Democratic Countries' Reserves (kt)	Surplus or Deficit (kt)	2030 Democratic Demand as a % of Production Democratic Capacity
Boron	5	79,000	78,995	2%
Chromium	1,312	213,620	212,308	2%
Cobalt	1,246	2,302	1,056	3040%
Copper	23,568	1,235,800	1,212,232	130%
Graphite	30,181	75,200	45,019	8185%
Lithium	2,884	17,255	14,371	1006%
Manganese	3,205	1,338,000	1,334,795	8%
Molybdenum	296	6,876	6,580	59%
Nickel	10,914	60,000	49,086	239%
Selenium	23	23	0	557%
Silver	327	388	61	557%
Tellurium	35	11	-24	7816%
Tin	2,210	2,330	120	547%

Figure 3: *This chart originally appeared in the 2023 paper "Friendshoring Critical Minerals," published by Carnegie Endowment for International Peace. The chart demonstrates current reserves for critical minerals that exist within democratic countries and the surplus or deficit relative to global electric vehicle demand. The chart also includes projected demand in 2030 by democratic countries as a percentage of 2023 production capacity in those countries. The data reveals an urgent need to scale mining production. Notes: Lithium expressed in Li*

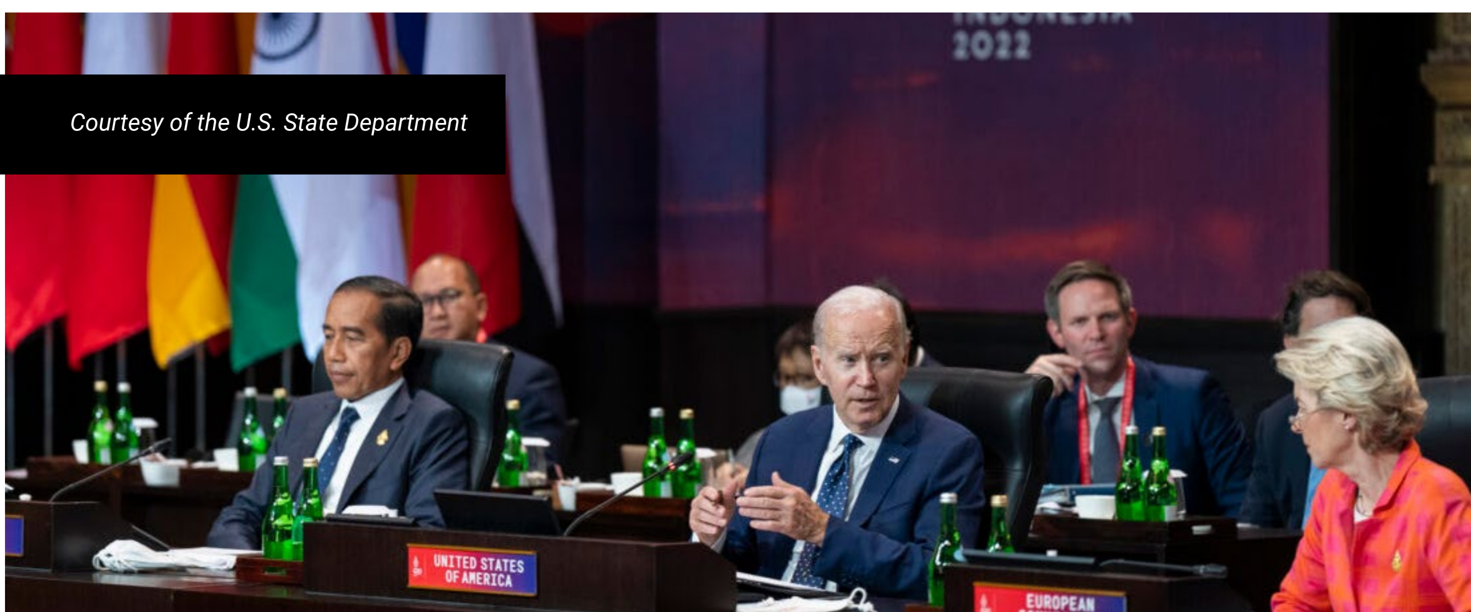
The study also addresses production capacity—a facet of the supply chain where U.S. allies and democratic nations around the world have an opportunity to make significant headway in order to address climate and security goals. The study concludes that ramping up production to scale "would require an extremely focused and targeted approach—nothing less than a highly coordinated joint industrial strategy."[102] The study concludes that **the U.S. and its partners must "significantly friendshore production" at unprecedented speed and scale. This, the study says, is the only way to achieve 2030 targets.[103]**

Other studies have reached similar conclusions. A 2022 study by the RAND Corporation, which addresses critical minerals through the lens of national security,[104] argued that, **when factoring in the time it takes to enact policy, industrial scale, and recover minerals, the United States needs to act immediately to diminish China's outsized share over the LIB supply chain.[105]** The study implores the United States to utilize the Department of Defense and Defense Industrial Base capabilities to swiftly address domestic and allied critical mineral supply chains.[106]

4.2 U.S. Global Leadership

At home, the Departments of Energy, Transportation, and Interior, as well as the Environmental Protection Agency, promote essential domestic initiatives to expedite and facilitate our clean energy future. Abroad, the Department of State is an important way for the federal government to uphold and expand U.S. leadership by shaping cohesive global strategies for achieving an international mining sector that is advantageous to the U.S. and by highlighting domestic operations as the gold standard.

Led by the Department of State, the U.S. has brought together global partners to strengthen and diversify the minerals production industry around the world through several multilateral strategies. The Quadrilateral Security Dialogue—occurring between the United States, Australia, India, and Japan—brings the U.S. and powers of the Indo-Pacific region together to discuss critical minerals strategy.[107] In 2019, the Energy Resource Governance Initiative (ERGI) was created by the U.S. and joined by the founding countries Canada, Australia, Peru, and Botswana. In 2021, the U.S. joined the Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development (IGF). In June 2022, the U.S. helped launch two major international partnerships: the Partnership for Global Infrastructure and Investment (PGII) and the Minerals Security Partnership (MSP). Driven by State Department leadership, these initiates (along with ERGI) represent mechanisms through which the U.S. has the opportunity to assert its global influence and push for secure, diversified mineral supply chains.[108]



Courtesy of the U.S. State Department

Timeline

The U.S. network of relationships that target critical minerals strategies is swiftly growing.

May 2018	Department of the Interior publishes initial list of minerals critical to the U.S. economy
September 2019	Energy Resource Governance Initiative formed
November 18, 2019	U.S.-Australia Memorandum of Understanding on Critical Minerals
June 9, 2020	U.S. Canada-Joint Action Plan on Critical Minerals
July 2020	U.S.-Canada-Australia Critical Minerals Mapping Initiative
June 14, 2022	Partnership for Global Infrastructure and Investment founded
June 26, 2022	Minerals Security Partnership founded
November 15, 2022	U.S.-G7-Indonesia Just Energy Transition Partnership
February 2023	Italy joins Minerals Security Partnership
March 2023	U.S.-Japan Agreement on Battery Minerals
March 2023	U.S. begins talks with the E.U. about a potential minerals deal
April 2023	Philippines and Malaysia seek negotiations with the U.S. on a minerals deal
May 2023	The MSP holds talks with Argentina about a potential minerals deal
May 20, 2023	U.S.-Australia Climate, Critical Minerals and Clean Energy Transformation Compact
June 8, 2023	U.S. and E.U. announce The Atlantic Declaration: A Framework for a Twenty-First Century U.S.-UK Economic Partnership
June 24, 2023	India joins Minerals Security Partnership
June 26, 2023	U.S.-Mongolia MOU to Collaborate on Critical Minerals
July 20, 2023	E.U. Council authorizes negotiations with the U.S. on the potential Critical Minerals Agreement
September 7, 2023	Indonesia asks the U.S. for a trade deal

4.3 Multilateral Initiatives

Energy Resource Governance Initiative

ERGI was founded in 2019 to serve the broad goal of "obtaining and disseminating best practices across the international mining sector." At launch, ERGI consisted of five founding member countries: Australia, Botswana, Canada, Peru, and the United States.[109] Individually, the founding members have robust mineral production sectors. Together as ERGI, member countries promote "value beyond compliance" through three primary strategies:

1. ***Promote sound mining sector governance and resilient energy mineral supply chains by bringing countries together to engage in advancing governance principles, sharing best practices, and encouraging a level playing field for investment***
2. ***Encourage governments to incorporate responsible mineral supply chain sourcing principles into their national climate strategies and clean energy technology procurement plans***
3. ***Encourage companies, including green and renewable energy, to source 100 percent of their critical mineral supply from responsible and environmentally sound supply chains by 2030.***

At ERGI's convening in 2020, fifteen countries in addition to the founding members joined to reemphasize the principles and strategies for achieving resilient battery supply chains.[110] In order to achieve these principles, ERGI established a toolkit that draws from the practices of successful, ethical mining sectors in member countries and highlights model mine practices. The ERGI toolkit provides guidance on resource management, project development, production, and social governance.[111] **ERGI presents an important model that the federal government should continue to promote both at home and in emerging mining sectors abroad.**

In addition to ERGI, some minerals have their own successful voluntary industry standards including those published by ICMM and IFC, as well as commodity-specific systems such as the Copper Mark, the Aluminum Stewardship Initiative and Responsible Steel.

Courtesy of the U.S. Export-Import Bank

4.4 Mineral Security Partnership

Founded on June 14, 2022, the MSP brings together the U.S., Australia, Canada, Finland, France, Germany, Japan, Korea, Sweden, the United Kingdom, Italy, and the European Union. MSP aims to strengthen information-sharing between partner countries, increase investment in secure critical minerals supply chains, and develop recycling technologies. As of January 2023, the MSP had evaluated over 170 mineral production refining and recycling projects around the world in participating countries; ultimately, 16 projects were selected as pilots.[112] Through its oversight, MSP seeks to advocate for higher standards, greater transparency, good environmental practices, more transparency, and local benefits among the projects it adopts. MSP also helps facilitate investment and off-take agreements to help incentivize the continued adherence to social and environmental practices. This partnership may explore using loans from the Export-Import Bank of the United States to on-shore and friend-shore the supply chain.

> "This is not just a U.S. initiative. This is a multilateral initiative."—U.S. Ambassador to Argentina on the Minerals Security Partnership.[113]

The goal of the MSP is to diversify and strengthen the mineral supply chain while promoting ESG values. A 2023 study revealed that success will remain dependent on several factors, including inclusivity and diligence.[114] First, the paper noted the importance of ensuring that the current MSP membership represents a wide net of democratic states and entities with mineral production capacity. MSP members should seek to find ways to partner with ESG-abiding projects. The same paper assessed MSP membership and participation, noting that non-member countries (including Argentina, Brazil, the DRC, Mongolia, Mozambique, Namibia, Tanzania, and Zambia, Angola, Botswana, DRC, South Africa, Tanzania, Uganda, and Zambia) attended the September 2022 MSP meeting.[115] Additionally, the paper noted that—though engaged in the U.S. in other ways—nickel-rich Indonesia and the Philippines have not yet participated in the MSP, nor have copper-rich Chile and Peru, or lithium-rich Bolivia.[116] As the Net Zero study demonstrated, the resources in these mineral-rich countries are essential for the success of the global battery industry. Ensuring that Indonesia, the Philippines, Chile, Peru, and Bolivia are involved in MSP discussions and strategy development will be important to supply chain cultivation that is actually characterized by ESG values.

4.4.1 Partnership for Global Infrastructure and Investments

The Partnership for Global Infrastructure and Investments is another critical pathway through which the U.S. is securing the battery supply chain. In June 2022, the United States and its G7 partners launched PGII to build clean energy supply chains. Argentina, India, Indonesia, Senegal, and South Africa were invited to participate. This partnership focuses on increasing the logistical and economic capacity of low- and middle-income countries to mobilize supply chains, while adhering to value-driven practices, by providing $600 billion over five years in grants, federal financing, and private sector investments. PGII target projects include a vast array of sectors in energy, medicine, minerals, and gender equality. Through this partnership, the U.S. and its G7 partners formalized discussions with Indonesia through the Just Energy Transition Partnership. Indonesia is still not, however, an FTA partner, which disqualifies the country's nickel from satisfying the requirements of the IRA.

PGII is understood by the U.S. Department of State to be the U.S.-allied initiative to counter the economic reach established by China through the Belt and Road Initiative. The goal of the State Department is to position the United States as a more ideal, reliable business partner than China. PGII officials position sustainability and long-term development of host-country economies as a central goal of joint ventures. This perspective contrasts with China's business strategy, which has often entailed the outsourcing of Chinese workers for projects in partner countries rather than long-term workforce development initiatives.

Figure 4. U.S. Critical Minerals Governance Landscape

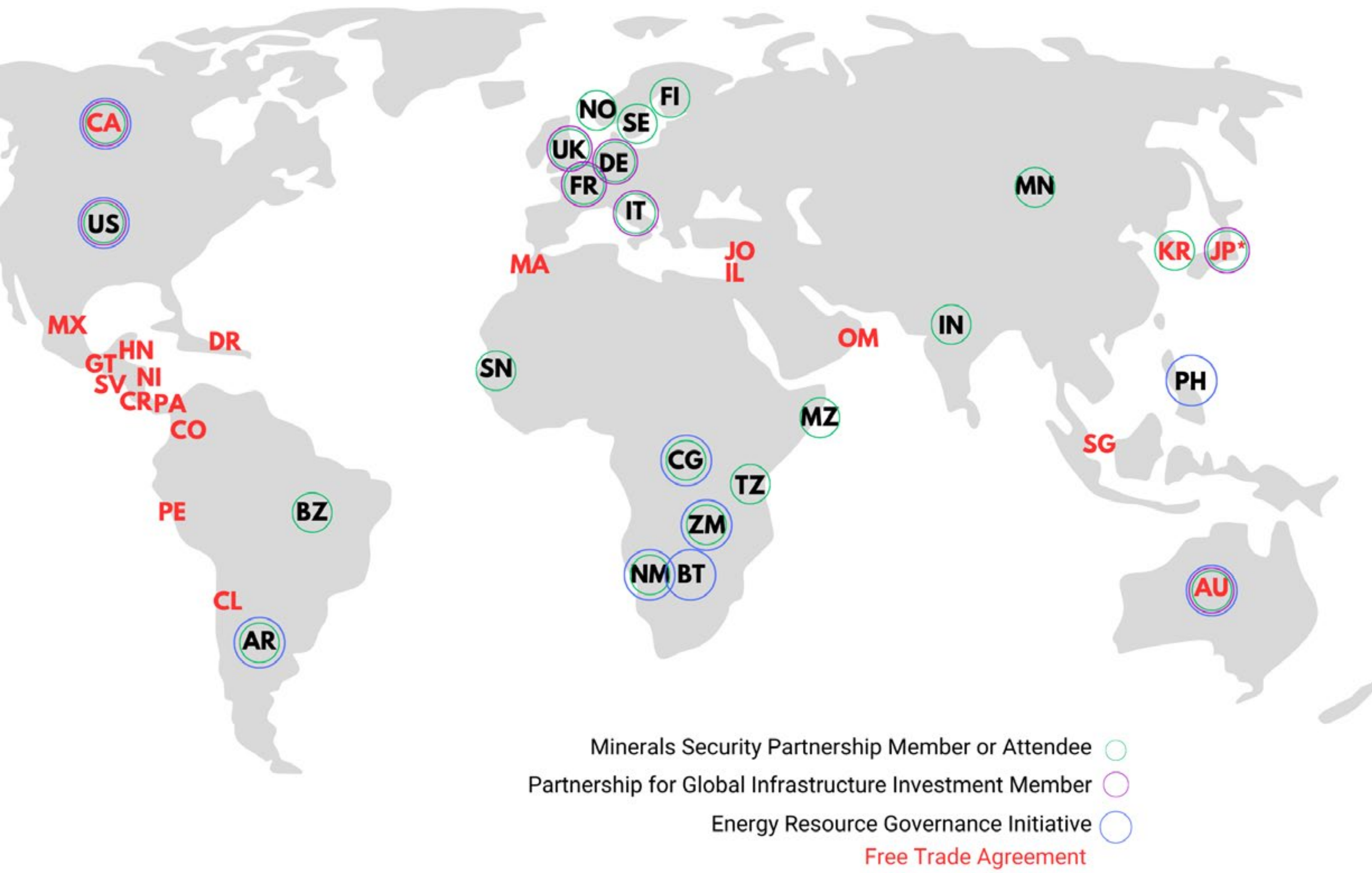


Figure 4: *This map provides a visual overview of the growing number of countries with whom the U.S. either have critical minerals partnerships with as of June 2023 or have been significantly engaged by U.S. multilateral organizations. The map focuses on countries associated with the ERGI, MSP, PGII, as all of these target ethical mining sector development. U.S. FTA countries are also shown in red. Nations that appear on the map are the United States (US), Canada (CA), Peru (PE), Brazil (BR), Argentina (AR), Norway (NO), Sweden (SE), United Kingdom (UK), France (FR), Germany (GR), Italy (IT), Senegal (SN), the Democratic Republic of the Congo (CG), Zambia (ZM), Namibia (NM), Botswana (BW), India (IN), the Democratic People's Republic of Korea (KP), Japan (JP), the Philippines (PH), Mongolia (MN), Australia (AU), Chile (CL), Colombia (CO), Costa Rica (CR), Dominican Republic (DR), El Salvador (SV), Guatemala (GT), Honduras (HN), Israel (IL), Jordan (JO), Mexico (MX), Morocco (MA), Nicaragua (NI), Oman (OM), Panama (PA), and Singapore (SG).*

**Japan has a nontraditional free trade agreement that specifically targets critical minerals.*

4.5 Key Relationships

The United States has engaged its closest allies to secure a reliable critical minerals supply chain. While significant progress has been made through multilateral initiatives, continuing to foster direct diplomatic relations with critical mineral-intensive allies is essential to climate goals. The following examples showcase vital countries needed to strengthen domestic battery production.

Canada

Canada is America's largest trade partner. As a producer of thirteen critical minerals including cadmium, nickel, and zinc, Canada is also the foremost supplier of tellurium and aluminum to the United States.[117] In addition to these minerals, Canada demonstrates significant geological potential for the production of cobalt, graphite, and lithium.[118]

U.S.-Canadian relations have been strengthened by legislation that bolsters North American manufacturing, including the Inflation Reduction Act, the Defense Production Act, and the CHIPS and Science Act.

> In 2020, the U.S.-Canada minerals trade totaled $95.6 billion and Canadian minerals development firms have $40 billion in investments within U.S. borders.[119]

Canada's federal government has demonstrated its commitment to reliable mineral supply chains by investing in its own domestic mining and processing industries. In 2021, Canada invested $35.7 million to support mineral production research and development, including capital and wages. It also allocated $12 million in grant funding to project pilots and demonstrations. In 2023, Canada further equipped its minerals sector with $249.5 million as part of a larger $2.88 billion investment package directed at critical mineral research and development. Additionally, the government is separately funding the development of six major minerals projects in the country through a $14 million funding allocation.[120]

Australia

Australia, a close ally of the United States, is the top global producer of lithium and a leading producer of several other critical minerals. In 2021, Australia produced 6.7 million MT of lithium, 7.97 million MT of graphite, and 1.582 million MT of cobalt.[121] The U.S. has formally collaborated with Australia on critical minerals supply chain development since 2019. In 2021, this commitment was reemphasized through diplomatic meetings related to the Indo-Pacific Partnership. The two nations affirmed their continued commitment to mutual environmental and social governance, traceability standards, project finance throughout the supply chain, and engagement with production, processing, and end-users.

In May 2023, the U.S. and Australia committed to the Climate, Critical Minerals, and Clean Energy Transformation Compact, which will coordinate policies and investments within the two nations to expand and diversify responsible clean energy and critical minerals supply chains.[122] Under the Compact, both countries pledged to promote minerals within and beyond the Indo-Pacific.

Japan

Japan is another close U.S. ally, a global leader in battery technology, and a major minerals importer. In July 2022, Japan and the United States launched the U.S.-Japan Economic Policy Consultative Committee to "foster supply chain resilience in strategic sectors, including, in particular, semiconductors, batteries, and critical minerals."[123]

While Japan does not currently produce critical minerals, its involvement in the battery and minerals industry is important to supply chain resilience. A 2022 Joint Statement from the two nations recognized the role that Japan's increased investment in the U.S. battery industry has played in strengthening the supply chain. **On March 28, 2023, Japan and the U.S. entered into a critical minerals agreement establishing Japanese minerals as qualifying material under Section 30D of the Inflation Reduction Act** (Clean Vehicle Consumer Incentives) sourcing requirements. In late April 2023, the Japanese government announced that it would subsidize half the cost of critical minerals projects in the country, with the intention of targeting lithium, nickel, manganese, cobalt, and graphite.[124] The commitment parallels the Japanese government's intention to expand its domestic battery components manufacturing from 20GWh in 2023 to 150 GWh a year by 2030.[125]

The Lithium Triangle

The largest known geological reserves of lithium are located in Latin America and concentrated in Argentina, Chile, and Bolivia—known collectively as the "Lithium Triangle." More than half of the world's known lithium exists in this region: 21% in Argentina and 11% in Chile.[126] Together, Argentina and Chile supply 35% of the world's lithium. Bolivia, which holds roughly as much as the current global reserve within its geology, has not yet developed a robust critical minerals sector.[127]

> ***Chile***
>
> Besides being the second largest producer of lithium, Chile is the world's leading producer of copper—responsible for 27% of the global supply. Copper exports represent a third of the Chilean federal government's income, and **Chile has had a free trade agreement with the United States in place since 2004.** In April 2023, the Chilean government announced the nationalization of their lithium reserves.[128]
>
> ***Argentina***
>
> **In May 2023, the U.S. and its 13 collaborating partners invited Argentina to a Mineral Security Partnership meeting.** The meeting allowed the MSP to better understand Argentina's domestic mining sector, and Argentina was also invited to participate in

convenings of the Partnership for Infrastructure and Investments.[129] However, China has been investing heavily into the Argentine lithium industry.

Bolivia 

The minerals production sector is one of the largest in the Bolivian economy. However, despite the tremendous economic opportunity, a secure lithium industry has struggled to materialize in Bolivia—largely due to fragile institutional capacity. In June 2023, China invested aggressively in Bolivian mining projects.[130]

European Union (E.U.) 

In 2011, the E.U. released a list of 14 minerals it defined as critical to its national security. Growing awareness of the battery supply chain's significance among E.U. leadership has led to an expansion of that list, which by 2020 stood at 30 minerals.[131] In the same year, the E.U. launched the European Raw Materials Alliance (ERMA) with the goal of supporting swift, targeted development of minerals production and processing within E.U. nations.[132] In 2022, critical mineral exports from the European Union to the EV industry totaled ~$9.1 billion.[133]

As an importer of EV battery minerals, the E.U. has also adopted friend-shoring as a strategy similar to that of the U.S. In March 2023, the E.U. passed the Critical Raw Materials Act, which set a goal that "not more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing [will come] from a single third country" by 2030.[134] In the same month, negotiations with the U.S. began to establish a trade agreement targeting E.U. mineral exports. On June 14, 2023, the E.U. adopted negotiating directives with the goal of reaching an agreement that would establish E.U. mineral exports as qualifying materials under the Inflation Reduction Act's 30D Clean Vehicle Tax Credit. **Securing a critical minerals agreement with the United States is of strategic importance to the E.U. and complements U.S.-E.U. collaboration on minerals supply chain initiatives around the world.** [135]

5. Critical Mineral Recycling

Recycling facility in McKinney, TX
Courtesy of Princeton NuEnergy

5.1 Current State & Potential

Unlike fossil fuels, using critical minerals comes with the possibility of establishing circular, sustainable production processes. Minerals only have to be mined once; after they are incorporated into a product like a cellphone, laptop, or EV battery, they can be removed and repurposed without losing their value at the end of the product's useful life. This cycle of use is defined as a circular supply chain—one that repurposes essential materials instead of relying on disposable, consumable, single-use alternatives.[136] Aside from the environmental benefits, circular supply chains can also be a more economical business model for producers: "second-hand," recycled, or repurposed components are often cheaper than virgin materials, and critical minerals are a perfect example of this. Moreover, studies have shown that recycled battery materials work just as well, if not better than, newly mined ones.[137]

Electronic waste, or "e-waste," refers to all types of electronics discarded at the end of their useful life. It is one of the fastest-growing waste streams in the U.S.,[138] a factor compounded by the increasingly short lifespan of consumer electronics. E-waste electronics often contain valuable amounts of critical minerals—nickel, lithium, platinum—and other key elements like gold and copper. In fact, the United Nations Global e-Waste Monitor found that metals discarded in consumer electronics in 2019 are worth approximately $57 billion USD.[139] **As another example, there is enough cobalt in 166 cell phone batteries to produce an EV battery, and consumer electronics are expected to be the primary source of recycled cobalt until 2035.[140]**

The value of the global market for EV battery recycling alone is estimated to reach $8.6 billion in the next five years.[141] These metals are recoverable through a process sometimes called "urban mining," and using them is economical: a 2018 study analyzing the ability to extract useful metals from discarded

Recycled smart phones pre disassembly
Courtesy of Redwood Materials

televisions sets in China found that "ingots of pure copper and gold could be recovered from e-waste streams at costs that are comparable to those encountered in virgin mining of ores," and concluded that these methods could be scaled to other metals and countries.[142] Despite the rapid growth in this sector, only 17% of battery-containing e-waste.[143]

Larger products like solar panels, wind turbines, or EV batteries are also a significant source of secondhand critical minerals. However, in 2023, fewer than 5% of lithium-ion batteries were recycled.[144] **As more EVs are manufactured and reach the end of their useful life the amount of critical minerals available for reuse will grow in tandem**. Raw materials used for an EV battery do not have to be repurposed into another EV battery—instead, they have a variety of applications. For example, used EV batteries could deliver an additional 5 to 8 years of service in "second-life" applications like grid-scale energy storage, which can improve the reliability of the energy grid as more renewable energy resources come online and as extreme weather events across the country impact grid conditions.[145] Projections suggest that the quantity of end-of-life EV batteries will grow rapidly after 2030, and by 2040, the IEA estimates available copper, lithium, nickel, and cobalt recycled from batteries could reduce the demand for virgin materials by as much as 10%.[146]

Recycling critical minerals has implications for national and economic security. Unlike oil and gas, critical minerals are not depleted when they are used.

> Importing critical minerals into the U.S. for inclusion in EV batteries, for example, presents an interesting consideration: because the minerals are recyclable, they are only required to be imported once. As soon as they are in the U.S., "their acquisition adds to the domestic mineral stock that is available for domestic recycling in the future"—and for use in other technologies as necessary, not just EVs.[147]

Similarly, reliance on critical minerals as an energy input offers more protection from price instability for the consumer: during an oil price shock, all consumers are affected by higher prices and lower supply. In the event of a mineral price shock, only new products and those relying on imported minerals would be affected.[148] The benefits of domestic recycling for supply chain security are further enhanced by localization of the battery value chain—i.e. colocating processing, refining, and battery manufacturing. For example, battery recycler and manufacturer Redwood

Recycling Spoke in Tuscaloosa, AL
Courtesy of Li-Cycle

Materials selected South Carolina for its Battery Minerals Campus due to its proximity to other major projects in America's "Battery Belt."

Scalable recycling processes already exist in the U.S., and the private and public sectors are actively engaged in research that will accelerate the adoption of this technology. **Battery recycling companies like Li-Cycle, Redwood Materials, Princeton NuEnergy, and 6k Inc. take end-of-use batteries to preserve the value of the minerals**. Similarly, Tesla has successfully installed the first phase of their cell recycling facility at Gigafactory Nevada for in-house processing of both battery manufacturing scrap and end-of-life batteries. By the end of 2021, this facility achieved a production rate of over 50 tons of recycled material per week. The types of batteries that can be used as feedstock depends on the recycler in question; U.S.-based recyclers currently utilize a wide array of recycling methodologies and thus have different acceptable feedstock specifications. That said, the most commonly used and commercialized chemistry formats (e.g., NMC, NCA, LFP, LCO) are generally accepted.

Figure 5. Overview of Battery Recycling

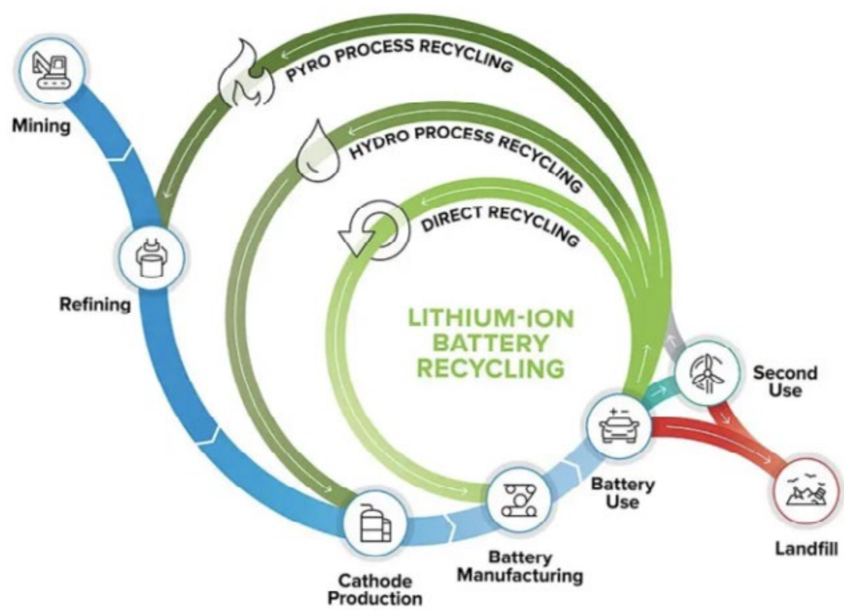


Figure 5[149]: *This figure demonstrates the standard life cycle of a Lithium-ion battery, highlighting the various types of recycling processes and their contribution to a circular supply chain.*

Recycling critical minerals will not eliminate the need for virgin materials, even in a hypothetical scenario where 100% of all existing critical minerals are recycled.[150] At the same time, as the demand for battery materials continues to grow, the market for recycling batteries will similarly see an increase in supply and demand. Even so, "the emissions from the mineral production and operation of clean energy technologies are just 6% of that of coal and gas generation," and increasing recycling can help bring that number down further.[151]

There are several additional actions policymakers can take to accelerate mineral recycling. It is clear that the federal government is aware of the scope of the issue: the Bipartisan Infrastructure Law supplements private-sector funding with government investment and goals explicitly designed to promote supply chain circularity. Battery initiatives are governed primarily by two agencies: EPA and DOE. EPA is tasked with developing standardized recycling guidelines by November 15, 2023 and standing up a voluntary recycling program. DOE is responsible for providing over $6 billion in grant funding to the following programs:

$3 billion
to a Battery Material Processing Program

$200 million
to an EV battery design, recycling, and reuse program

$3 billion
to battery manufacturing and recycling initiatives

$15 million
to retailer collection systems

$10 million
to a Li-ion battery recycling prize competition

$60 million
in research and design focused on cost reduction for battery logistics and processing

Together, both agencies also administer an additional $110 million in grants for battery collection and recycling projects.[152]

Ultimately, establishing leadership, clarity, and standardizing processes at the federal level will help improve the state of recycling technologies and processes in the U.S. and correct for the absence of a regulatory framework governing this key industry.[153] Federal action could preempt contradictory state rules by defining the end-of-life responsibilities for each member of the value chain and establishing appropriate end-of-life pathways for EV batteries, including both recycling and repurposing options.

5.2 Transportation & Handling

Under current regulations, transportation logistics account for over half of the cost of recycling an EV battery.[154] The material handling, packing, transporting, storage of LIBs is costly: as a Class 9 hazardous material, LIBs require special handling for transportation when not installed in a vehicle, increasing the costs and complicating the recycling process.

In May 2023, EPA released a memorandum to clarify how hazardous waste regulations for universal waste and recycling apply to lithium-ion batteries. The released regulations clarify that removal of hazardous waste batteries from devices, sorting, battery discharge, and disassembly of batteries into cells or modules prior to recycling does not require a Resource Conservation and Recovery Act (RCRA) Hazardous Waste treatment permit; however, a recycler that stores hazardous waste before recycling must obtain an RCRA Part B permit.[155]

5.3 Labeling

Labeling also presents an opportunity to provide additional clarification. **The absence of mutually agreed-upon, industry-standard best practices for material packing, labeling, and transportation often complicate the recycling process**. Providing lithium battery generators with a set of holistic best practices that establish guidance for all activities involved in EOL materials management (e.g., on-site storage, material packing, labeling, safe transportation measures, etc.) would remove friction and cost for recyclers—and would address lingering safety concerns related to not knowing the composition of the battery.

5.4 Consumer Education

Consumers have a considerable role to play in battery supply chain circularity by ensuring the return of spent Li-ion batteries to collection locations. **The misinformation about battery recycling and lack of awareness about electronics recycling opportunities can be a barrier to achieving a steady second-life battery supply: a March 2023 survey demonstrated that 47% of Americans do not believe that LIBs are recyclable**.[156] Educating consumers about recycling processes and effectiveness, as well as providing them with convenient collection points, can minimize the amount of waste that ends up in landfills, and greatly contribute to the aforementioned opportunity to "urban mine" our old consumer electronics and devices.

Battery Recycling Hub Operation in Rochester, NY
Courtesy of Li-Cycle

6. Recommendations

6.1 Bipartisan Permitting Reform

The linchpin component of domestic minerals supply chain security is improving timelines for the permitting and judicial review processes needed to safely and responsibly increase domestic mineral production and processing capacity. The passage of the BIL, IRA, and, most recently, the Fiscal Responsibility Act (FRA), have led to important developments on permitting reform. Through these legislative achievements, the federal government increased funding for research and development of critical minerals, incentivized domestic production, and streamlined the application process for current and future projects. These advancements demonstrate the federal government's commitment to building a robust supply chain, but significant legislative work remains.

It is critical to ensure that projects that produce domestic sources of critical minerals are eligible for expedited timelines, including environmental assessments

The FRA provides new authorities that may expedite approval for critical mineral projects. For example, assigning a lead agency to oversee the projects will simplify interagency coordination and encourage timely reviews. Another notable provision of the legislation was its modification of the National Environmental Policy Act (NEPA) to set a "reasonable time" limit for environmental assessments (one year) and environmental impact statements (two years). Ensuring that projects that will produce domestic sources of critical minerals are eligible for the expedited timelines, including environmental assessments, is imperative for securing a reliable supply chain.

The federal government can also support greater domestic production by streamlining early-stage critical mineral exploration activities under a 5-acre notice of intent by immediately crediting back land that has been reclaimed and reseeded.

Addressing legal review risks of permitted projects is also essential to building production capacity in the U.S. In the case a project is litigated, ZETA recommends creating a 150-day deadline for legal appeal of the lead agency's final decision to ensure litigation risk does not unnecessarily delay properly-permitted, high-priority critical mineral and battery projects. The federal government can also support greater domestic production by streamlining early-stage critical mineral exploration activities under a 5-acre notice of intent by immediately crediting back land that has been reclaimed and reseeded.

ZETA urges federal policymakers to remain firmly committed to acting on meaningful permitting reform that focuses on process efficiency and mitigating harmful delays while protecting environmental and social values. The U.S. minerals production sector is eager to lead the global critical minerals industry by example. The U.S. must do more to cultivate a robust domestic sector that meets the demand and urgency of the energy transition and global climate goals.

6.2 Increased Environmental, Social, and Governance (ESG) Coordination Among Public and Private Entities

ZETA urges federal policymakers to remain firmly concentrated on meaningful permitting reform that focuses on process efficiency while protecting environmental and social values.

The BIL and IRA established several government-funded programs and working groups to build out critical mineral supply chains. Continuing to fund several of these programs will be essential to maintaining momentum. Likewise, coordinating initiatives across federal agencies to increase the domestic supply of critical minerals and exploring the potential to expand public-private partnerships internationally represents an opportunity to encourage production with strategic partners and uphold strong governance standards to ensure fair labor practices, environmental protections, and community input. By utilizing third-party auditors, private entities can provide a pathway of transparency that is aligned with national and international ESG benchmarks.

Critical minerals companies are ensuring that they are operating at the highest levels of sustainability and promoting social responsibility. Third-party audits also report on emissions, water usage, community engagement, and employee diversity. These uniform business standards help ensure that American companies are among the most sustainable and community engagement-oriented critical minerals development companies in the world.

6.3 A Federal Standard for Battery Recycling

In light of increased funding to the midstream battery manufacturing supply chain, the value of the global market for EV battery recycling alone is estimated to reach $8.6 billion in the next five years. The BIL granted EPA the authority to set a federal standard for battery recycling by 2028; however, to reduce the possibility of a regulatory framework fragmented by different state initiatives, ZETA encourages EPA to move quickly to create federal standards for labeling, collecting, and recycling EV batteries, and to define the end-of-life responsibilities for each member of the value chain. Doing so will promote consistency in the feedstock system for recyclers and second-life applications.

ZETA encourages EPA to move quickly to create federal standards for labeling, collecting, and recycling EV batteries, and to define the end-of-life responsibilities for each member of the value chain.

6.4 USGS Critical Mineral List Reforms

Due to its importance to national and economic security, ZETA strongly urges the addition of copper to the USGS Critical Minerals list. Copper's inclusion in the USGS list would follow the precedent set by the updated DOE Critical Material list, which forecasts future supply risks and balances those with the importance to the energy sector.

A recent report by S&P Global states that copper is "the metal of electrification," playing a major role in state and national economic development, national security, and infrastructure.[157] Likewise, a recent report by the Copper Development Association (CDA) found that analyzing copper's supply risk score using data available through the first half of 2022 places the score above the USGS (0.40) threshold for automatic inclusion on the list.[158]

Designating copper as a critical mineral will benefit and protect the United States as the country continues to substantially invest in a variety of copper-intensive applications. By recognizing copper as a "critical mineral," the United States' federal government can more effectively ensure a secure and reliable supply of domestic copper resources in the years to come.

6.5 Workforce Development

Nearly 340,000 Americans already work in the domestic EV sector,[159] and the EV industry is expected to create over two million jobs in the United States in the coming decades—contingent on private investment and sustained funding mechanisms.[160] The $2.8 billion in grants released as part of the Infrastructure Investment and Jobs Act to build out the EV supply chain will benefit communities throughout America,[161] but the domestic critical mineral supply chain workforces will continue to face staffing challenges due to aging and retired personnel, lack of availability and access to coordinated STEM education, misconceptions about the mining industry, and foreign competition for talent and emerging technology.

An educated, competitive workforce is a requirement of a successful industry. According to the Society for Mining, Metallurgy, and Exploration, approximately 221,000 workers—roughly half of the workforce—will be replaced or retired by 2029. The Center for Strategic and International Studies reports that in 2020, only 327 degrees in mining and mineral engineering were awarded in 2020 in the U.S.[162]

Developing minerals education and workforce training programs will equip the next-generation of skilled laborers with the tools they need to succeed in a 21st century critical minerals industry. To prepare the next-generation of workers for success in the EV industry, U.S. curriculum from early education through professional studies should include an increased emphasis on earth studies and energy minerals adjacent subjects. In particular, educational programs directed at cultivating a workforce for minerals production, processing, and refining, as well as battery-related production, assembly, and recycling will be essential to securing our energy future.

To prepare the next-generation of workers for success in the EV industry, U.S. curriculum from early education through professional studies should include an increased emphasis on earth studies and energy minerals adjacent subjects.

Another way to incentivize employment in communities is to ensure that workers have the proper skills to manufacture EVs and related technologies. To improve equity in workforce development, ZETA recommends DOE and DOT work with State Workforce Development Agencies to create new industry opportunities in addition to pre-existing training programs by individual organizations in the private sector. A variety of training programs allows flexibility to ensure employment is accessible for all, and efforts should be targeted at removing barriers to entry for local workers, not creating new, restrictive requirements.

> To improve access and education standards, ZETA also encourages the federal government to create grant programs that would allow mining schools to receive funds to recruit students and provide new insights into the critical mineral sector.

Finally, ZETA also encourages targeted expansion of federal agency staffing in offices with authority over permitting and regulation of critical minerals projects. Well-staffed agencies are necessary in order to avoid costly procedural inefficiency that contributes to project delay and domestic supply constraints.

Lithium Hydroxide Manufacturing Facility in Bessemer City, NV
Courtesy of Livent

7. Conclusion

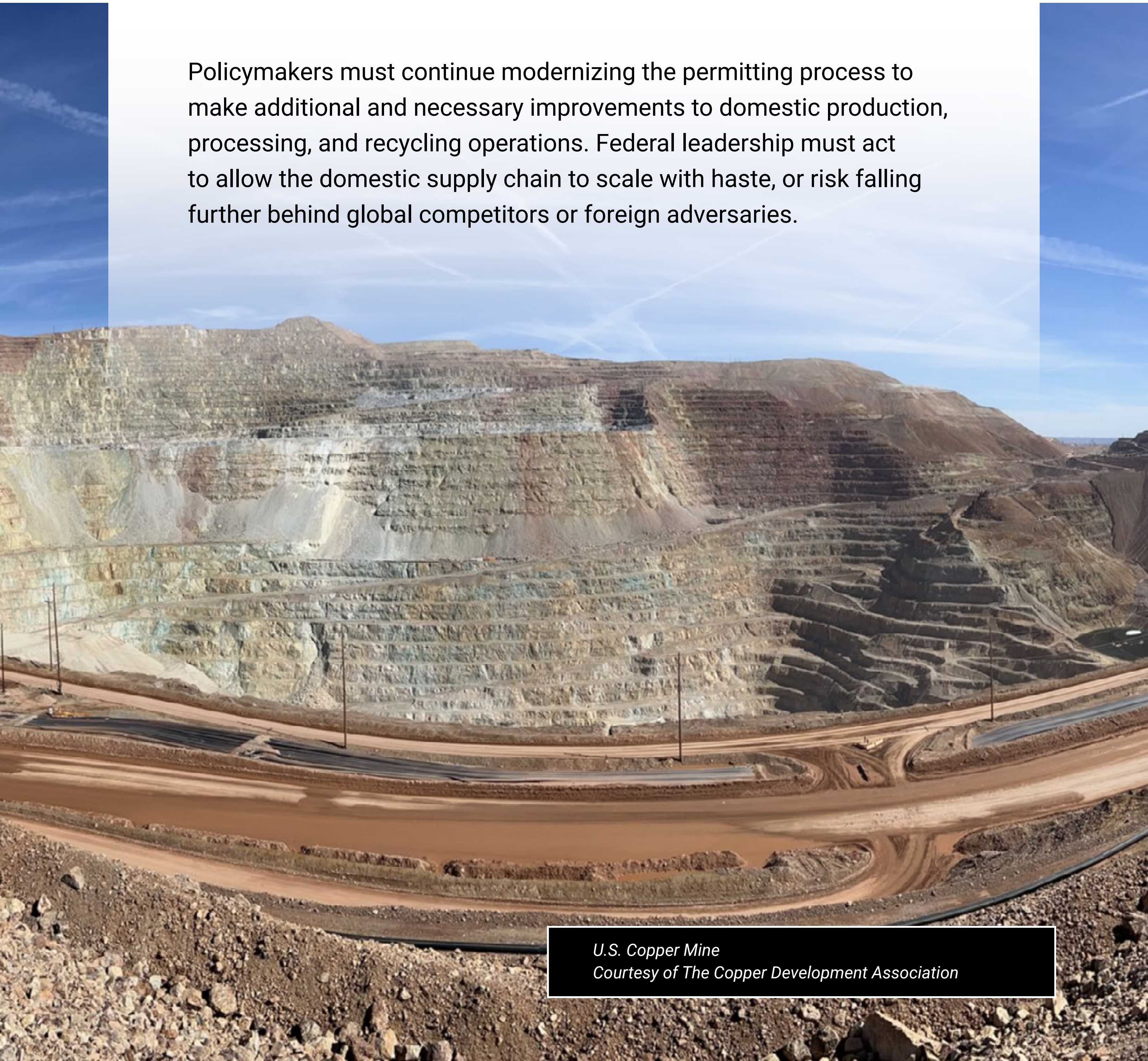
Due to its robust mineral endowment and strong technological capability, the United States is well positioned to rapidly build its domestic supply chains through private investment, federal initiatives, research and development, and international partnerships. However, challenges— including growing a well-trained workforce, navigating uncertain federal programs and the lingering need for permitting reform—remain. The availability of critical minerals will continue to impact national security, electric vehicle deployment, and renewable energy manufacturing for years to come. Private sector investments and federal incentives will effectively increase domestic critical mineral processing and battery production to be a meaningful part of the solution. However, the U.S. will also continue to rely on global market interventions and trade policies, friendshoring, free trade agreements, and strategic partnerships to meet the global demand for these commodities.

As more batteries reach their end-of-life, battery recycling will become more significant in the critical minerals ecosystem. We are rapidly approaching a situation where large amounts of battery feedstock enter the domestic market because of growing global EV adoption. Ensuring we have the proper incentives and regulations in place to dismantle and recycle batteries appropriately will require continued leadership from policymakers and industry alike. A closed-loop system that encapsulates second-life applications, such as energy storage systems, provides opportunities for using depleted EV batteries and protects them from needless disposal. The U.S. has an opportunity to ensure that recycled critical minerals reenter the ecosystem as raw materials that can be used again and again in the production of lithium-ion batteries and other goods.

Copper Wire
Courtesy of The Copper Development Association

The critical mineral supply chain in the United States supports a variety of national security, advanced manufacturing, and transportation initiatives. The transition to an electrified future reduces emissions and is essential to an energy-secure future. At a time when the electric vehicle industry and consumer market are growing exponentially, the U.S. stands ready to become a global leader in the domestic critical mineral and battery production supply chain. The federal government must continue facilitating and strengthening strategic partnerships that retain high labor and environmental protections, reach the shared goal of national security and transportation electrification, and enable domestic companies to compete with established global players who often operate under different, more lenient rules.

Policymakers must continue modernizing the permitting process to make additional and necessary improvements to domestic production, processing, and recycling operations. Federal leadership must act to allow the domestic supply chain to scale with haste, or risk falling further behind global competitors or foreign adversaries.



U.S. Copper Mine
Courtesy of The Copper Development Association

8. Appendix

8.1 ZETA Critical Minerals Developers & Processors

The private sector is actively working to onshore our critical minerals supply chain. ZETA represents a host of companies seeking to expand America's critical mineral production and battery manufacturing capacity.

8.2 Lithium

Piedmont Lithium

Piedmont Lithium is a U.S.-based company. It is a producer of lithium with a portfolio of projects that includes Tennessee Lithium, a proposed merchant lithium hydroxide manufacturing plant in McMinn County, Tennessee, and Carolina Lithium, a proposed, fully integrated spodumene concentrate-to-lithium hydroxide project in Gaston County, North Carolina. The balance of the portfolio consists of strategic investments in lithium assets in Quebec, Canada with Sayona Mining, including the producing North American Lithium mine, and in Ghana, West Africa with Atlantic Lithium Limited, including the Ewoyaa Lithium Project.

Through this strategic portfolio, the company plans to produce 60,000 MT of lithium hydroxide annually, which is expected to be supported by the production of, or offtake rights to, approximately 525,000 metric tons of spodumene concentrate annually.

Albemarle Corporation

Albemarle Corporation produced 5,000 MT of lithium carbonate equivalent (LCE) in 2019, and it has a maximum capacity of 10,000 MT of LCE per year at its Silver Peak, Nevada plant.[163]

Albemarle owns the land on Kings Mountain, a former lithium mine. In 2022, Albemarle announced it was in the early stages of potentially reopening Kings Mountain, which closed in 1988 under the ownership of Foote Mineral.[164] A 2022 study reported the possibility that 2,500,000 MT of lithium ore resources remain in the deposit.[165] As of May 2023, Albemarle was still in the planning phase, with geological data collection for a pre-feasibility being conducted along with NEPA environmental assessments.[166]

Lithium Americas Corporation

The Thacker Pass Lithium Project is located in Humboldt County, Nevada and operated by Lithium Americas Corporation.[167] The deposit at Thacker Pass is part of the McDermitt Caldera, a large volcanic field, and was first discovered in 1977.[168]

The 2018 PFS states that the measured, indicated and inferred LCE resource at Thacker Pass is estimated to be 8,283,000 metric tons, and reserves estimated at 3,135,000 metric tons with expected production at 60,000 metric tons per year [169] As of April 2023, Lithium Americas' most up-to-date DFS numbers show the measured, indicated and inferred LCE resource is estimated at

19,100,000, reserves estimated at 3,700,000 metric tons and expected production stands at 80,000 metric tons of LCE per year. [170]

Lithium Americas secured an offtake agreement with investor General Motors, which committed to invest $650,000,000 in the development of the Thacker Pass Project. In exchange, Lithium Americas will direct lithium carbonate to GM in order to support the annual production of 1,000,000 EVs. Construction on Thacker Pass began on the project in March 2023 and production is expected to begin by 2026.

Ioneer

Located in Esmeralda County, Nevada, the Rhyolite Ridge Lithium-Boron Project is twelve miles from the Silver Peak project. Rhyolite Ridge is in the final stage of the NEPA permitting process and has received a conditional commitment for a loan of up to $700 million from the DOE LPO.[171] Rhyolite Ridge's unique mineralogy allows for lithium to be extracted and refined into lithium battery materials onsite. In 2020, mineral resource estimates within the Definitive Feasibility Study of the deposit stood at 146,500,000 MT Li and 1,260,000,000 MT LCE.[172] These estimates reflect a 280% increase in reserves from the preceding Feasibility Study. On April 26, 2023, however, Ioneer released updated numbers that represent a 140% increase in the amount of lithium tonnage at the site and a 168% increase in the projected LCE.

The updated resource estimates also suggest that the LCE content within the confines of Ioneer's leased property alone could yield enough lithium to power 50,000,000 electric vehicles; "further expansion [is] pending additional exploration."[173]

Livent Lithium

Livent is a U.S. based chemical manufacturing company with lithium development projects in Argentina and Canada. Livent also has processing facilities in North Carolina, U.S. where they produce 15,000 MT of lithium hydroxide per year.

8.3 Cobalt

Jervois

Jervois Mining USA Limited is building one of the United States' first primary cobalt production operations. Its production could represent 15–20% of U.S. annual consumption, and the Operation was expected to produce 1,915 MT of cobalt per year beginning in 2022,[174] though the project was paused in early 2023. As of July 2023, construction has resumed and is supported by a grant from the Department of Defense.

8.4 Graphite

NOVONIX

NOVONIX is an advanced battery materials and technology company planning to reach a synthetic graphite production capacity of up to 20,000 MT annually at its Riverside facility in Chattanooga, Tennessee. The company plans to add an incremental 30,000 MT production site towards its goal of 150,000 MT of total production capacity in North America by 2030.

8.5 Copper

Copper Development Association

A U.S-based, not-for-profit association of the global copper industry, the Copper Development Association's (CDA) goal is to enhance and expand domestic copper production by influencing the use of copper and copper alloys through research, development and education, as well as technical and end-user support. CDA is committed to promoting the proper use of copper materials in sustainable, efficient applications for business, industry and the home. A full list of CDA member companies including copper producers, fabricators and wire & cable companies can be found at https://copper.org/about/cda-members.php.

These critical minerals companies are ensuring that they are operating at the highest levels of sustainability and promoting social responsibility. Many of these producers are members of the Initiative for Responsible Mining Assurance (IRMA) and other sustainable mining organizations.[175] They also report on emissions, water usage, community engagement, and employee diversity. These uniform business standards help ensure that American companies are among the most sustainable and community engagement-oriented critical minerals development companies in the world.

8.6 Battery Materials Recycling

Redwood Materials

With facilities in Nevada and South Carolina, Redwood Materials is a leading battery innovator and a pioneer in domestic battery recycling and processing. As of 2022, Redwood was receiving 20,000 MT of material—to power an estimated 60,000-80,000 electric vehicles.[176] The company is able to recover an average 95% of the material elements, which they use to remanufacture anode and cathode components. Redwood's domestically produced battery components propel the circular supply chain for batteries by supplying U.S. based battery cell manufacturers with material.[177]

Princeton Nu Energy

Headquartered in Bordentown, New Jersey, Princeton NuEnergy (PNE) has launched the United States' first lithium-ion battery direct recycling facility in McKinney, Texas. A patented LPAS™ (low-temperature plasma-assisted separation) process recycles spent batteries to produce battery grade cathode and anode materials that can be returned to cell manufacturing. A $10 million DOE EERE grant awarded to PNE as lead partner with three national labs and UC Irvine will facilitate research into upcycling to meet next generation cathode and anode requirements. PNE plans to launch two U.S.-based commercially scaled recycling plants in the next two years.

6k Inc.

6K uses proprietary advanced plasma processing and industrial systems to create materials that are enabling the next-generation of commercial and consumer products, at lower cost, sustainably.

The 6K ENERGY division launched its $25 million Battery Center of Excellence in the 2022. The Center is capable of pilot production with up to 500 MWh of capacity. The 6K ADDITIVE division includes a 45-acre ISO9001 24/7 operation facility that reclaims and processes over a million pounds of Ti64 per year and has recently built and commissioned a state-of-the-art 48,000 square foot production facility for additive manufacturing powders.[178]

Li-Cycle

Based in Canada, Li-Cycle utilizes their innovative and environmentally friendly Spoke & Hub Technologies™ to provide an end-of-life solution for all lithium-ion batteries. With four operating facilities in North America, Li-Cycle processes 51,000 MT of lithium-ion battery materials per year. By the end of 2023, Li-Cycle expects its annual processing capacity to be 81,000 MT of lithium-ion battery material.[179]

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