VedeniEnergy
Plugged Into The Energy Industry

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Securing Critical Minerals
for the Clean Energy Transition

WHITEPAPER

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Why Minerals Power the Future

The Clean Energy Imperative

The global push toward decarbonization is gaining speed, and this shift relies not on fossil fuels but on minerals—specifically a group now known as critical minerals. These include lithium, cobalt, nickel, graphite, manganese, copper, and rare earth elements like neodymium and praseodymium. They are essential parts of the clean energy technologies that drive electric vehicles (EVs), solar panels, wind turbines, and large-scale energy storage systems. Without these raw materials, the ambitious climate goals set by the United States and other countries remain difficult to achieve.

What sets critical minerals apart from other natural resources is their dual role: they are essential to national interests and face significant risks of supply disruption. The U.S. Department of Energy and the U.S. Geological Survey keep updating lists of minerals considered critical based on their importance to economic and energy security. These lists are not just academic—they influence investment decisions, federal funding priorities, and long-term industrial strategies. The clean energy transition relies heavily on these minerals, making their availability a key factor in building resilient and sustainable infrastructure.

A key characteristic of clean energy technologies is their higher mineral usage compared to traditional fossil fuel systems. For example, a typical electric vehicle requires six times more minerals than a gas-powered car. Its lithium-ion battery depends on lithium, nickel, cobalt, and graphite in complex arrangements to provide energy density, durability, and safety. In offshore wind turbines, high-performance permanent magnets need rare earth elements to decrease weight while enhancing efficiency. Even solar panels, often seen as relatively low in mineral content, still rely on high-purity silicon and silver for optimal function. As clean technologies grow, mineral demand increases exponentially.

Projections from international energy agencies are clear. By 2030, global demand for lithium is expected to triple, while the needs for nickel and cobalt will grow twofold or more. By 2040, some estimates indicate that mineral demand for clean energy applications could increase four times from current levels. Significantly, these projections are based on conservative assumptions. If governments adopt more aggressive climate policies or if emerging technologies—such as solid-state batteries or long-duration energy storage—become more widespread, the material demands will likely be even higher.

Despite their increasing importance, critical minerals are unevenly spread around the world. Most raw material extraction occurs in a few key regions. For example, the Democratic Republic of the Congo produces over 70% of the world's cobalt, while Australia, Chile, and China dominate lithium mining. Adding to the concentration risk, China controls more than 85% of the global capacity for rare earth element separation and a large portion of worldwide battery metal refining, heavily dominating midstream refining and processing activities.

This geographic imbalance creates significant vulnerabilities. The United States currently imports all of its supply of certain critical minerals, including natural graphite and manganese. Domestic production of others—such as lithium and cobalt—is limited to just a few mines and facilities. For example, the only active lithium production site in the U.S. as of 2024 is Albemarle's Silver Peak operation in Nevada. New projects are in development, but permitting, community opposition, and environmental regulations make timelines uncertain.

While expanding domestic extraction is important, it is not a complete solution. Many U.S. mineral deposits are found near protected lands or Indigenous territories, raising ethical and legal issues. Mining also has significant environmental impacts, including water use, habitat loss, and carbon emissions. Balancing the need for these materials with environmental responsibility will be a key challenge in the coming years.

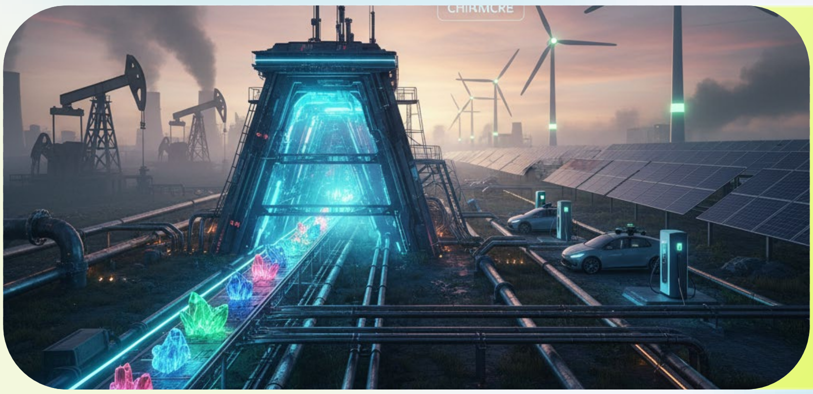
The mineral gap also presents a strategic threat. Without dependable and diverse access to critical materials, the United States risks lagging in clean energy deployment, electric vehicle production, and next-generation technology development. National defense systems, aerospace systems, and grid modernization all depend on rare and specialized materials. In this context, mineral security becomes a matter of national security. The effort to secure critical minerals is no longer just an industrial issue—it's a geopolitical race.

To address these challenges, the U.S. government is adopting a comprehensive strategy. This includes federal investment in domestic mining and processing, collaborations with allied nations to ensure diverse supply chains, and research into alternative materials and recycling methods. Private companies are also investing significantly in domestic production, with some building vertically integrated supply chains from mine to battery. However, the gap between demand and supply continues to grow, and time is critical.

As the global energy transition advances, one thing becomes clear: minerals are the new oil. Their availability, cost, and sustainability will shape the pace and nature of decarbonization. In the clean energy future, it is not the wellhead but the mine shaft that holds the key to power.

CCS is critical for U.S. Decarbonization Goals

With fossil fuels still generating over half of U.S. electricity, Carbon Capture and Storage (CCS) offers a necessary pathway to cut emissions from existing infrastructure while maintaining grid reliability, supporting the Administration's 2035 carbon-free power target.



Policy and investment are driving CCS Growth

New federal regulations and funding under the Inflation Reduction Act and DOE programs are accelerating large-scale CCS deployment, with over 270 projects announced by late 2024, despite ongoing debate about its role in prolonging fossil fuel use.

The U.S. at Risk

Fragile Supply Chains & Foreign Dependence

The United States is quite vulnerable in the global race for critical minerals, a vulnerability that comes not only from limited domestic production but also from heavy reliance on foreign sources for both raw extraction and midstream processing. The supply chains supporting clean energy minerals and battery materials are far from resilient, leaving national security, industrial leadership, and clean energy goals exposed to potential disruptions.

U.S. reliance on imported critical minerals is staggering. For certain materials—including high-purity graphite, manganese, and specific rare earth elements—the country depends entirely on imports. More than half of its demand for 49 identified critical minerals is met through imports. China remains the leading supplier for many of these, providing over 80 percent of refined rare earths and nearly 100 percent of heavy rare earths vital to advanced technology. From 2019 to 2022, over 95 percent of the rare earths used in the U.S. were imported, mainly from China. In fact, China controls every major step from mining to purification and magnet production, giving it a strategic leverage over supply chains that support both civilian and military uses.

Rare earth permanent magnets—sintered NdFeB types vital to wind turbines and vehicle motors—are a significant concern. The United States lacks domestic capacity in nearly all midstream stages, from oxide separation through alloy production to magnet assembly. In contrast, China captures over 90 percent of global NdFeB magnet production and over 85 percent of light rare earth separation capacity. This concentration becomes a strategic risk when export restrictions or trade tensions occur, potentially affecting automotive, energy, and defense sectors.

Recent episodes illustrate these risks. In 2025, China imposed export licensing restrictions on seven strategic rare earths and related magnets, leading to supply chain delays in U.S. manufacturing and raising concerns in the defense sector. U.S. defense platforms like F-35 jets and submarine systems depend on components derived from rare earths; disruptions can threaten both operational performance and technological readiness. These export controls were introduced in response to U.S. tariffs, creating a cycle of volatility and showing how quickly supply dependencies can cause industrial instability.

Domestic efforts to address these risks encounter significant challenges. Developing a domestic processing system could take a decade or longer, even with tariffs or trade incentives promoting local production. Projects like MP Materials' Mountain Pass mine in California aim to reverse this trend, but the timelines, capital requirements, and regulatory hurdles mean that scalable supply is still years away. Graphite, essential for lithium-ion battery anodes, is another bottleneck: over 92 percent of global battery-grade natural graphite is produced in China, with U.S. production still in early stages and not competitive without strong policy support and innovation.

These dependencies go beyond rare earths. Copper demand in the U.S. is rising, especially for grid upgrades and clean energy infrastructure. However, only about half of the domestic copper needs are currently met by local production. Projects like the Santa Cruz Copper project in Arizona are emerging to increase domestic supply, but supply limitations remain a significant concern in the near term.

Beyond economics, there is a significant national security aspect. The Department of Defense has acknowledged that dependence on foreign sources for refined critical minerals presents a strategic risk. This vulnerability affects military supply chains, aerospace manufacturing, and advanced electronics. In response, policymakers have used tools such as Section 232 investigations into processed mineral imports and multiple filings under the Defense Production Act. Through targeted grants, procurement commitments, and expanding stockpiles, these efforts aim to bring critical parts of the supply chain back to the U.S. Agencies like the Defense Logistics Agency and the Bureau of Industry and Security at Commerce have conducted multi-year assessments of the industrial base to identify vulnerabilities and set resilience priorities.

Nevertheless, moving away from heavy reliance on China remains a difficult challenge. U.S. trade data often lack the detail needed to reveal firm-level dependencies or concentration risks, especially within the battery supply chain. While 30 percent of lithium-ion battery capacity is made domestically, many upstream components—including cathode materials, anodes, and separator films—are still connected to foreign production networks.

Efforts to diversify supply by engaging with allies such as Indonesia, Australia, Canada, Malaysia, and Greenland are gaining momentum. Negotiations with Indonesia focus on establishing transparent trade frameworks for critical minerals and lowering tariffs to secure supplies of nickel, tin, and rare earths. Proposed agreements with Myanmar, despite geopolitical sensitivities, have been considered to access heavy rare earth minerals outside China's control. Meanwhile, Greenland's substantial rare earth deposits are attracting U.S. interest, although environmental and infrastructural challenges have slowed commercial development.

Public commentary and expert opinion highlight a broader strategic necessity: economic independence from China is mandatory. Trade leverage over critical minerals has become a vital part of Beijing's geopolitical strategy, evident in recent trade disputes and export policies. Calls for regulatory reform, increased international cooperation, and reauthorization of the Defense Production Act stress that mineral supply chains can both support and limit U.S. leadership in clean energy and high-tech industries.

In the face of these pressures, a resilient renewable energy supply chain must confront risks on multiple levels. Building domestic extraction, processing, and recycling capacity is essential—but so is forming trusted partnerships, improving data transparency, overhauling permitting regulations, supporting research into substitutes and circular systems, and maintaining strategic stockpiles. Without such layered responses, the U.S. risks allowing fragile supply conditions to slow the very decarbonization it aims to accelerate.

Digging In

The Promise and Pitfalls of Domestic Mining

The push to increase domestic extraction of clean energy minerals has gained momentum in U.S. policy and private investment, driven by the understanding that true energy independence depends on control of both the mine shaft and the power grid. Recently, projects like Thacker Pass in Nevada, Idaho Cobalt Operations, and Santa Cruz in Arizona have transitioned from exploratory studies to active development, giving a preview of what a domestically based supply chain could look like. However, these projects also highlight the economic, legal, environmental, and social challenges that come with mineral development in the United States.

Lithium Americas and General Motors finalized a joint venture in late 2024 to develop the Thacker Pass lithium mine, the largest known lithium resource in North America. General Motors invested USD 625 million for a 38 percent stake, enabling Lithium Americas to secure a USD 2.26 billion loan from the U.S. Department of Energy. The project aims for an annual production of 40,000 tons of battery-grade lithium carbonate in Phase 1, enough to support roughly 800,000 electric vehicles per year. Engineering and procurement planning was over 60 percent complete by March 2025, with the first steel fabrication scheduled for September 2025 and full Phase 1 completion expected by late 2027. These milestones make the project one of the most well-funded and policy-supported domestic mineral developments on record. Despite this progress, construction has sparked environmental and Indigenous opposition, with claims of groundwater depletion threatening an endemic snail species and criticisms over the adequacy of tribal consultation efforts.

ICO is currently suspended and not producing. It was reopened by Jervois Global in 2022 in Lemhi County, Idaho, and is a rare example of domestic cobalt mining. Cobalt remains vital for EV batteries and aerospace alloys, making its supply a top priority for defense and energy security. However, ICO's status is fragile: production has varied with cobalt market fluctuations, and the site faces environmental challenges, including proximity to a Superfund cleanup area. While the Department of Defense has openly supported domestic cobalt efforts as key to reducing dependence on foreign sources, ICO's financial and operational viability still relies heavily on market trends and government support.

Another important mineral project is the Santa Cruz copper project in Arizona, developed by Ivanhoe Electric on 100 percent privately owned land supported by confirmed water rights. The Preliminary Feasibility Study released in mid-2025 estimates a 23-year mine life with total recoverable copper of 1.5 million tonnes, based on 136 million tonnes of ore at approximately 1.08 percent copper grade. About 72,000 tonnes of pure cathode copper per year is expected to be produced during the first 15 years. Construction is planned to start in 2026, with the first copper expected in 2028. The project benefits from streamlined permitting due to its private land status, avoiding many federal regulatory hurdles. The planned use of heap leaching and onsite cathode production represents a move toward more integrated mineral processing operations in the U.S.

Despite the potential of these projects, domestic mineral expansion faces systemic obstacles. Projects like Thacker Pass and Santa Cruz progress more quickly because they are located on private or non-federal lands where federal Environmental Impact Statements and lengthy approval processes can be minimized or avoided. However, many promising mineral-rich areas are on federal, tribal, or environmentally sensitive lands, which require extensive multi-agency permitting, consultation with Indigenous communities, and comprehensive environmental assessments.

Social and environmental justice issues influence high-profile projects. At Thacker Pass, opposition from Indigenous groups focuses on claims of inadequate prior informed consent, potential damage to culturally important watersheds, and risks to species like the Kings River pyrg snail. Similar conflicts arise around the Big Sandy lithium and Santa Cruz copper sites, where interests encompass tribal sovereignty, groundwater rights, and untouched wilderness ecosystems. Legal issues related to endangered species protections and archaeological concerns are common hurdles to speeding up permitting.

Economic constraints create additional obstacles. Mineral projects require multibillion-dollar investments before becoming profitable. Even with government loans, tax credits, and investor backing, the mining sector's lengthy development process and vulnerability to commodity price fluctuations make it a risky venture. Projects like Mountain Pass rare earth development and early-stage lithium initiatives in the Midwest continue to face difficulties in securing enough capital despite national urgency. Mining financing remains cautious, especially for vertically integrated domestic value chains where returns take decades.

Nevertheless, domestic mining presents significant opportunities. Thacker Pass, Idaho Cobalt Operations, and Santa Cruz Copper collectively indicate a path toward meeting much of the U.S. demand for lithium, cobalt, and copper. They lay the groundwork for downstream value chains such as battery manufacturing, EV assembly, and renewable energy production. Federal and defense agencies view these projects as strategic infrastructure, providing offtake agreements, stockpile purchases, and cost-sharing mechanisms to mitigate market uncertainty. Additionally, focusing on mine waste recovery and tailings reprocessing, including early-stage urban mining initiatives, could provide interim supplies and lessen environmental impacts as large-scale mines expand.

Ultimately, the promise of domestic critical mineral mining depends on a comprehensive strategy: streamlined yet thorough permitting, strong environmental and social governance, inclusive stakeholder engagement, stable public-private investment frameworks, and a long-term plan to align production with value-added processing. Without these elements, even the most promising mineral projects face delays or setbacks—along with the broader clean energy and battery supply initiatives they aim to support.

Made in America?

The Refining and Processing Gap

Although the United States has known deposits of rare earths, lithium, nickel, cobalt, graphite, and copper, its domestic capacity to process these into purified materials for industrial use is severely underdeveloped. The bottleneck in refining serves as a critical choke point in the U.S. clean energy and defense supply chains. Essentially, raw mining without integrated crushing, separation, smelting, and purification offers limited strategic value. Without strong midstream capabilities—including rare earth separation, battery-grade lithium and nickel processing, magnet manufacturing, and graphite purification—the country remains vulnerable to supply disruptions and foreign control.

Globally, China dominates refining operations for rare earth elements and battery metals, accounting for over eighty-five percent of global rare earth separation and more than ninety percent of heavy rare earth refining capacity. Despite renewed U.S. interest in rare earth mining—especially at California's Mountain Pass facility—large portions of concentrate are still shipped abroad for processing. Rebuilding a vertically integrated rare earth value chain, from mine to magnet, is crucial for strategic independence. The Department of Defense has provided over USD 300 million in grants and loans to MP Materials and Lynas USA to support oxide separation and rare earth permanent magnet manufacturing, indicating a federal effort to bring processing capabilities back home.

Battery materials processing capacity in the United States is also limited. For lithium, nickel, cobalt, and graphite, over ninety percent of refining capacity remains offshore, with China holding a dominant position. A recent study found that over 92 percent of anode-grade natural graphite is produced in China, and efforts by the U.S. to develop domestic graphite production remain economically uncompetitive without subsidies or innovation. Processing capital costs, economies of scale, and input expenses significantly increase domestic production costs, resulting in ongoing competitive disadvantages.

States like Oklahoma are emerging as new hubs for critical mineral processing. In Oklahoma, companies such as Westwin Elements operate the only nickel refinery in the U.S. and plan to expand into rare earths, lithium refining, battery recycling, and magnet assembly. Oklahoma's logistical advantages, political support, and pro-business regulations make it a model for regional industrial strategies aimed at closing the critical gap in U.S. midstream capacity.

Despite these efforts, midstream development remains slow and capital-intensive. Establishing new refining facilities generally takes ten to twenty years before they become operational, due to permitting, construction, and technology development obstacles. For example, Mountain Pass reopened rare earth mining years ago but still exported raw ore abroad as recently as 2019 because of the lack of U.S.-based separation infrastructure. Even projects currently under construction face delays caused by wastewater permitting, environmental reviews, investor hesitancy, and regulatory uncertainty.

Policy tools such as section 232 trade investigations, Defense Production Act authority, and the Inflation Reduction Act's tax credit Section 48C are key to supporting domestic refining infrastructure. These tools have provided funding for projects like the MP Materials 10X Facility to produce rare earth metals and magnets domestically, along with investments in domestic battery materials processors. However, expert analyses suggest that reactivating DPA authority beyond 2025 and maintaining clear federal policies are essential to keep investor confidence high.

Interlinked challenges—market risk, technological complexity, environmental permitting, and workforce shortages—highlight the depth of the refining deficit. Still, boosting domestic processing is achievable through a coordinated strategy that aligns federal investment, allied sourcing via friend-shoring, regional industrial hubs, and innovation in affordable, environmentally friendly refining technologies, including recovery from geothermal brines and tailings.

In summary, even as the United States expands domestic mineral extraction, its failure to capture value through refining and processing threatens both industrial and national security goals. Addressing this gap requires urgent investment in midstream capacity, decisive regulatory reform, and consistent policy support. Without these elements, domestic mining risks becoming a symbolic gesture rather than the strategic foundation needed to power the clean energy economy.

Strategic Alliances

Securing Global Partnerships for Resilience

With limited domestic capacity to mine and refine critical minerals, the United States needs to form strategic alliances with like-minded countries to ensure resilient supply chains for clean energy minerals and battery components. Building relationships through both multilateral and bilateral partnerships helps the U.S. diversify suppliers, lower geopolitical risks, and develop trusted economic ecosystems that reflect democratic values and environmental standards.

The United States' involvement in the Minerals Security Partnership (MSP) is a key part of this international approach. Launched in 2022, the MSP unites countries like Canada, Australia, Japan, members of the European Union, and others to coordinate policies, investments, and industrial strategies focused on securing supply chains for lithium, nickel, cobalt, rare earth elements, and copper. Through collaboration in multilateral forums and exchanging best practices, these nations aim to promote transparent and sustainable extraction and processing methods that boost overall resilience.

Australia plays a key role in such alliances. In May 2023, the U.S. and Australian governments formalized a Climate, Critical Minerals, and Clean Energy Transformation Compact. The compact establishes a lasting framework to boost bilateral cooperation on clean energy technologies, coordinate investment flows, support responsible end-to-end supply chains, and foster shared industrial value creation. The compact directs agencies to develop a joint action plan for exchanging policy measures, infrastructure investments, and workforce development by the end of that year.

Canada has become a nearby partner providing access to essential minerals needed for energy transition and defense purposes. In January 2020, the Canada–U.S. Joint Action Plan on Critical Minerals Collaboration was introduced to enhance cooperation on industry engagement, resource mapping, supply chain transparency, and research efforts. More recently, investments totaling tens of millions of USD through the Defense Production Act support projects in Canadian companies like Fortune Minerals and Lomiko Metals. These initiatives aim to produce cobalt sulfate and battery-grade graphite, offering mutual benefits for North American supply security.

Asia-Pacific partners also play a role in U.S. diversification efforts—most notably Indonesia, a key supplier of nickel and tin. The U.S. government is working with Jakarta to negotiate supply agreements that focus on value-added exports rather than bulk raw commodities, matching U.S. needs for refined, high-purity materials. This represents a significant shift toward organizing upstream production around strategic goals and quality standards.

Public-private development finance institutions play a key role in fostering such partnerships. The U.S. International Development Finance Corporation (DFC) has invested in crucial mineral projects in regions like sub-Saharan Africa and Latin America. These public financing strategies aim to create trust-based production corridors with countries that meet high standards of governance, transparency, and ESG compliance. Supporting mining, transport logistics, refining infrastructure, and downstream processing is seen as a dual-purpose investment—advancing foreign policy goals while improving access to minerals.

Beyond extraction, these alliances expand to joint efforts in R&D collaboration and circular economy innovation. Shared research platforms with allied governments explore advanced battery chemistries, extraction from geothermal brines, rare earth separation technologies, and recycling methods. The cooperation aims to reduce reliance on high-risk materials and promote next-generation substitutes that align with environmental and supply resilience goals.

Partnerships also offer mechanisms for collective crisis response. MSP member states coordinate emergency stockpiles, jointly monitor export controls or disruptions, and collaborate when geopolitical events threaten mineral flows. This coordinated approach increases leverage and allows for quick mitigation in the event of export restrictions or supply chain shocks.

Nonetheless, forming alliances is complicated. Differences in regulatory frameworks, environmental standards, indigenous rights regimes, and trade policies can create friction. Ensuring responsible extraction requires enforceable ESG safeguards and stakeholder engagement procedures. Trade agreements must be carefully designed to prevent currency distortions, exploitative practices, or supply chain secrecy. Continuous diplomacy and oversight are vital to avoid repeating colonial extraction patterns in emerging alliances.

Strategic partnerships play a key role in strengthening the U.S. renewable energy supply chain. By sourcing from trusted partners and fostering shared industrial development, the United States reduces its vulnerability to adversarial supply pressures. Diversifying imports of clean energy minerals and integrating downstream processing—either domestically or in allied countries—boosts national resilience. This approach allows the United States to move from supply dependence to strategic positioning—solidifying its role in the global clean energy shift.

From Waste to Wealth

Recycling & Urban Mining for Battery Materials

The emerging field of urban mining offers a valuable complement to traditional extraction methods by recovering lithium, cobalt, nickel, copper, graphite, and rare earth elements from used batteries and electronic waste. Instead of relying solely on new mining, recycling and recovery provide environmental and supply chain advantages, decreasing dependence on raw imports and supporting what economists call circular supply—a system that extends the use of critical materials. Advances in technology and policy interest have shifted this area from niche research to a vital industrial focus.

At the core of this effort is Redwood Materials, founded by former Tesla executive J.B. Straubel. Operating facilities in Nevada and South Carolina, Redwood recovers more than 95 percent of lithium, cobalt, nickel, and copper from incoming battery packs and production scrap. Their hydrometallurgical and proprietary reductive calcination process enables them to process over 15 GWh of batteries annually and expand to nearly 60,000 tons by 2024. Currently, Redwood receives over 20 GWh of used lithium-ion batteries each year—about 250,000 EV-equivalent packs—accounting for roughly 90 percent of North America's battery recycling throughput. Some batteries are repurposed, while the rest are processed into refined materials ready for reuse in cathodes, anode copper foils, and other components. These circular processes reduce greenhouse gas emissions compared to virgin mining and help ensure a secure domestic material supply.

Scaling recycling yields is not only technically feasible but also strategically crucial. According to modeling by the International Energy Agency, increasing critical mineral recycling could cut future demand for newly mined copper and cobalt by up to 40 percent, and lithium and nickel by up to 25 percent by mid-century under net-zero pathways. Expanding urban mining capacity is expected to significantly shorten the timeline needed to meet rising demand by reusing materials already circulating. Research from Stanford and other institutions confirms the environmental benefit—showing that closed-loop recycling can cut carbon emissions by up to 50 percent compared to new extraction while recovering high-purity materials at scale.

Public policy is starting to support these developments. The U.S. Department of Energy's Battery and Critical Mineral Recycling Program allocates over USD 125 million for research, demonstration, and commercialization of innovative recycling technologies, including those that improve battery design for disassembly, encourage consumer participation, and expand recovery infrastructure. Federal resource inventory initiatives now include mapping mineral-rich mine waste and tailings sites, creating new opportunities to reclaim strategic minerals from legacy sites. In July 2025, the Department of the Interior issued an order directing agencies to make mine waste recovery projects eligible for federal funding, broadening access to resources such as zinc, tellurium, and uranium through legacy tailings reprocessing.

Despite current progress, challenges persist. The U.S. recycles only about 50 percent of available lithium-ion batteries—10 percent domestically and the rest abroad—with lead-acid battery recycling rates serving as a distant benchmark at around 99 percent. Barriers to expanding capacity include limited availability of end-of-life EV batteries in the near term, high logistics costs, a lack of standardized collection infrastructure, and technological challenges in recovering materials from mixed chemistries. One forecast predicts that by 2030, U.S. recycling facilities might process the equivalent of 1.3 million EV batteries annually, but supply constraints and delayed return cycles will likely mean only about 341,000 units are available for processing.

Multiple companies beyond Redwood are contributing to the urban mining ecosystem. American Battery Technology Company is developing hydrometallurgical recycling systems and demonstrating lithium hydroxide production from unconventional resources in Nevada. Firms like LiCycle and U.S. Strategic Metals are building black mass recovery facilities to extract and process cathode materials. These ventures aim to recover nickel, cobalt, lithium, and copper from manufacturing scrap and used battery feedstocks through integrated reclamation and refining processes.

Urban mining also includes electronics recycling and municipal waste. Recent congressional hearings highlighted e-waste retrieval—recovering critical minerals from discarded smartphones, laptops, and tablets. Lawmakers focused on national security and energy independence goals alongside environmental justice concerns, advocating for better recycling infrastructure and extended producer responsibility. The growth of AI-driven data centers is increasing the number of GPUs and server hardware reaching end of life, utilizing new sources of precious and strategic minerals.

Gradually, recycling is evolving from a pilot project into a comprehensive solution. Companies like Redwood are building an ecosystem that combines recycling, repurposing, and manufacturing: second-life batteries are used in grid storage for AI data centers, while recycled materials support the production of battery-grade components. This dual role—a mix of urban mining and reuse capacity—is essential for achieving resource circularity and supply resilience.

In conclusion, recycling and urban mining are key, scalable strategies to secure battery and clean energy minerals in the United States. These methods help reduce environmental impacts, buffer supply disruptions, and build a domestic reserve independent of foreign sources. However, fully realizing their potential depends on expanding collection systems, supporting technology commercialization, improving regulatory clarity, and encouraging consumer and industry shifts toward circular economic models.

What's Working

Two U.S. Case Studies in Critical Mineral Strategy

This section presents two landmark case studies highlighting successful efforts to strengthen the domestic critical mineral supply chain in the United States. Each one demonstrates the connection between extraction, processing, industrial policy, and public-private cooperation.

MP Materials, based in Las Vegas, owns and operates the Mountain Pass rare earth mine, the only fully integrated facility in the U.S. producing rare earth oxides and processing them for metal and magnet manufacturing. Historically, Mountain Pass contributed about sixteen percent of global rare earth oxide production. Since its 2017 revival under MP Materials, the site has advanced through a phased strategy of building a vertically integrated value chain. Key milestones include resuming oxide separation, starting expansion into neodymium-praseodymium (NdPr) metal production, and securing critical downstream agreements. In July 2025, MP Materials entered a transformative public-private partnership with the U.S. Department of Defense. Under this deal, DoD became MP's largest shareholder—holding up to fifteen percent equity—and committed to a ten-year offtake agreement covering all output from a second magnet manufacturing plant, called the 10X Facility. To support this, DoD is providing a $150 million loan, while JPMorgan and Goldman Sachs have pledged $1 billion in debt financing. A price floor contract guarantees a minimum of USD 110 per kilogram for NdPr oxide equivalent purchases, shielding MP from commodity price swings. The 10X Facility is scheduled to be operational by 2028 and will scale capacity to 10,000 metric tons of NdFeB magnets annually. Meanwhile, MP has started developing domestic heavy rare earth separation infrastructure at Mountain Pass, enhancing U.S. access to dysprosium and terbium, elements previously sourced entirely overseas.

MP Materials also secured commercial commitments that reinforce its emerging role as a key supply source. Apple announced a multi-year USD 500 million sourcing deal with MP to buy rare earth

magnets for electronics starting in 2027, along with plans to co-develop a recycling plant for recovered materials at Mountain Pass.

General Motors has committed to buying magnets from MP's Texas plant beginning late 2025, strengthening a domestic supply chain for U.S.-made EV motors. This synergy of defense and commercial demand with manufacturing capacity demonstrates a scaled, vertically integrated model that can support U.S. rare earth independence and the broader clean energy effort.

Redwood Materials, founded by former Tesla CTO J.B. Straubel, exemplifies a strategic supply chain innovation—this time focusing on second-life battery recycling, urban mining, and battery materials manufacturing. Operating at scale from facilities in Nevada and South Carolina, Redwood processes used lithium-ion batteries and manufacturing scrap into refined lithium, nickel, cobalt, copper, and graphite. Its proprietary hydrometallurgical and reductive calcination process recovers over ninety-five percent of these critical metals. Redwood handles over 20 GWh of battery feedstock annually—equivalent to around 250,000 EV packs—and plans capacity expansion up to 100 GWh by 2025, aiming to recycle materials equal to one million EVs.

Redwood strengthened downstream integration through a series of high-profile partnerships. In November 2022, Panasonic Energy of North America signed a multibillion-dollar agreement to source recycled cathode active materials and copper foil from Redwood for its new battery plant in Kansas, scheduled to open in 2025. This represents the first-time cathode active material will be produced in North America at gigafactory scale, reducing reliance on imported precursor chemicals. Additional partnerships include Ford Motor Company—which supports California battery collection networks—and agreements with Toyota, Volkswagen, Volvo, and Amazon through recycling of EV cells and consumer electronics. These supply relationships create a strong domestic circular ecosystem, feeding refined battery inputs directly into North American EV and energy storage manufacturing.

Collectively, these case studies highlight the vital importance of integrating extraction, processing, recycling, and downstream demand commitments. MP Materials demonstrates how integrating mining with federally guaranteed capital, long-term offtake contracts, and price stability can attract institutional investment, accelerate capacity growth, and reassure commercial and defense customers of material availability. Redwood Materials demonstrates the value of recycling and urban mining, turning end-of-life batteries and electronic waste into high-quality materials, reducing environmental impacts and supply chain risks, while serving as a bridge until new mines come online.

Each case also reveals ongoing challenges. MP Materials still needs to reduce dependence on a single major player for scaling heavy rare earth separation, and must address worries about concentration risk and overreliance on DoD-sponsored demand. Investor confidence remains cautious across the sector, due to high capital costs and long payback periods. MP Materials must deliver the 10X Facility on schedule, produce commercial volumes, and stay competitive if global prices fluctuate or oversight becomes stricter. Redwood must expand its logistics and collection infrastructure while cutting costs to compete with cheaper foreign processing. Refeeding black mass from mixed-cell chemistries requires technology improvements and a clear supply chain to ensure purity and dependability.

Nevertheless, both companies serve as models for expanding U.S. access to clean energy minerals. Their achievements come from coordinated efforts between federal policy tools—including Defense Production Act authority, spectroscopy price floor subsidies, and low-cost loans—and private sector innovation. The story they promote highlights the value of vertically integrated supply strategies: from ore or end-of-life feedstock to refined materials supplied to U.S.-based manufacturing. These approaches lower reliance on foreign manufacturing intermediaries, reduce global logistics chains, and enhance regulatory compliance, traceability, and ESG standards.

Looking ahead, maintaining this momentum depends on replicating these models across other critical mineral types and regions. Promoting competition through parallel initiatives—such as expanded lithium projects, nickel sulfate refineries, and graphite purification facilities—is essential. Equally important is investing in workforce development for metallurgical, chemical, and battery engineering skills; implementing regulatory reforms to support project timelines without sacrificing transparency; and continuing to emphasize public-private coordination to ensure demand signals and capital availability stay aligned.

In the clean energy era, MP Materials and Redwood Materials are no longer niche companies—they are key players in infrastructure. Their case studies demonstrate a clear path forward: supply security driven not by isolation but by integrated collaboration across extraction, processing, and consumption. Their models show how the United States can regain strategic control over vital materials and create a resilient, circular, and domestically based renewable energy supply chain.

Building a Resilient U.S. Renewable Energy Supply Chain

Building a strong and resilient U.S. renewable energy supply chain requires integrating domestic extraction, processing, recycling, strategic alliances, workforce development, data transparency, and policy frameworks into a unified system. This section combines insights from earlier parts into a clear vision for securing critical minerals and establishing a stable renewable energy supply chain.

True resilience starts with vertical integration. Combining domestic mines like Thacker Pass and Mountain Pass with recycling innovators such as Redwood Materials provides essential capacity, from raw ore or spent batteries to refined components for manufacturing. The success of these efforts depends on permitting reform, ongoing public-private financing, and inclusive community engagement that preserves environmental and social integrity.

International alliances remain vital to diversification strategies. The Minerals Security Partnership, U.S.–Australia pacts, and collaborations with Canada and Indonesia all support shared supply routes. These partnerships strengthen trade in refined or processed materials, foster joint R&D efforts, and facilitate coordinated crisis response and stockpiling plans.

Urban mining and recycling offer essential leverage. As large numbers of batteries reach end-of-life in the coming years, U.S.-based recycling can provide a significant share of lithium, cobalt, nickel, copper, and graphite. Federal initiatives, such as the Department of Energy's Battery and Critical Mineral Recycling program, along with directives to repurpose mine waste, support expanding collection and material recovery.

Key policy tools such as the Defense Production Act, federal procurement guarantees, Inflation Reduction Act credits, and trade remedies like Section 232 help align capital, demand, and regulatory support behind strategic mineral projects. Clear and consistent policy signals are vital for maintaining investor confidence.

Workforce investments are equally essential. Reports from the Department of Energy highlight the importance of expanding educational pipelines and training programs across mining, refining, materials science, and recycling sectors. Workforce gaps limit project timelines; closing them through partnerships with universities, community colleges, and vocational training programs is crucial.

Supply chain transparency needs to improve. Unlike fossil fuels, critical minerals often pass through opaque global layers. Investing in tools such as provenance tracking, ESG certifications, and traceability systems will boost supply reliability and consumer trust.

Strategic stockpiling and contractual tools strengthen resilience. The Department of Defense's reserve of critical minerals and long-term offtake agreements offer price stability and demand signals for emerging suppliers. Coordination among allied nations enhances crisis preparedness.

Innovation remains the long-term driver of supply independence. Emerging technologies—such as recovery from geothermal brines, tailings-based refining, and low-cobalt or cobalt-free chemistries—affect mineral demand trajectories. Continued R&D funding and pilot deployment promote substitution, efficiency, and environmental compatibility.

By coordinating across these pillars—domestic and allied extraction, processing and recycling infrastructure, workforce development, traceability systems, policy levers, and innovative research—the United States can turn fragile mineral reliance into strategic self-sufficiency. A resilient renewable energy supply chain not only advances decarbonization goals but also bolsters U.S. industrial sovereignty and technological leadership. The choices made today about the critical mineral supply structure will shape America's role—either as a leader or laggard—in the global clean energy transition.

- **Integration & alliances:** Combine domestic mining/recycling with global partnerships for secure supply.
- **Policy & workforce:** Strong policies, skilled labor, and transparency drive stability.
- **Innovation & resilience:** Recycling, new tech, and stockpiling strengthen independence.

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