Street

Free markets. Real solutions.

R Street Policy Study
No. 277
February 2023

U.S. Mineral Production Potential Unlikely to Satisfy Clean Energy Demands

By Philip Rossetti

Policymakers should understand that they are unlikely to achieve ambitious climate efforts without either reforms to expand domestic mineral production or a substantial increase in foreign production supplying U.S. consumption.

Table of Contents

Executive Summary

Despite political rhetoric and policies promoting the use of domestic critical minerals in clean energy through the Inflation Reduction Act and executive actions, the United States is well short of being able to supply enough minerals to fuel its own clean energy transition, much less to be a major global supplier of minerals needed for clean energy technology as politicians are keen to depict.[1] In this paper, we analyzed data from the U.S. Geological Survey (USGS) and International Energy Agency (IEA) and production estimates for 14 proposed copper, nickel and lithium mines in the United States to better understand the gap between current U.S. mineral production and potential mineral needs for a net-zero emission, clean energy transition. Our analysis found that although the United States has sufficient production market forces to satiate a large share of domestic copper and lithium demand, undue barriers to entry restrict production far below this potential—and below the scale that would be needed to supply a global clean energy transition.

1. "Interview by Tom Conway: Remarks by President Biden at a Virtual Event on Securing Critical Minerals for a Future Made in America," The White House, Feb. 22, 2022. https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/22/remarks-by-president-biden-at-a-virtual-event-on-securing-critical-minerals-for-a-future-made-in-america; H.R. 5376, Inflation Reduction Act, 117th Congress; "Defense Production Act Title III Presidential Determination for Critical Minerals in Large-Capacity Batteries," U.S. Department of Defense, April 5, 2022. https://www.defense.gov/News/Releases/Release/Article/2989973/defense-production-act-title-iii-presidential-determination-for-critical-materi.

The increase in mineral needs required for the United States to have a net-zero emission energy transition relative to current consumption is enormous. By 2040, annual mineral demand would need to increase by 121 percent for copper, 2,007 percent for cobalt, 504 percent for nickel and 13,267 percent for lithium.[2]

Our study also revealed that for a net-zero emission, clean energy transition, the United States would be import-reliant for copper, cobalt, nickel and lithium by 74 percent, 99 percent, 98 percent and 100 percent, respectively, at current U.S. production levels.[3] However, if major U.S. projects that are currently proposed for copper (such as Pebble and Resolution) and lithium (such as Thacker Pass and Rhyolite Ridge) were to enter operation, some of these projections could change significantly. If all proposed projects for copper, cobalt, nickel and lithium entered the market, the potential import reliance for these minerals for a net-zero emission energy transition would fall to 41 percent, 99 percent, 95 percent and 51 percent, respectively.[4]

The likelihood or timing of major mines entering the market in the United States is uncertain, though, and our own analysis of proposed mines found that practically every major project relevant for clean energy has been delayed over issues of permitting, leasing and litigation. This is problematic because, absent increased domestic production, the United States will remain reliant on foreign suppliers—a fact that is creating its own potential challenges.

While friendly nations are poised to be major suppliers of minerals needed for clean energy transitions in the United States, especially for copper and lithium, supply chain concerns are complicated by the fact that Chinese state-owned enterprises (SOEs) are dominant in ownership of refining capacity globally.[5] For example, a number of lithium projects in Australia are owned by Chinese companies, and some national security scholars believe that China is employing a concerted strategy to increase its influence over minerals that are increasing in demand.[6] Higher mineral demand driven by clean energy policies are certain to enrich mineral suppliers, including China, and will also reward nations that may be employing unethical mining practices like the Democratic Republic of the Congo's (DRC) use of child labor.[7]

U.S. policies focused on permitting and recycling could mitigate concerns related to mineral scarcity and overreliance on foreign suppliers but may not be enough to eliminate foreign dependency. Although a sizable domestic market share for copper and lithium is attainable and should materially contribute to mineral security in the form of enhanced continuity of supply and mitigating the pricing power of SOEs, a greater minerals market share for the United States and its allies is crucial to mineral

Pricing Power of SOEs and Their Impact on Dependency

U.S. policies focused on permitting and recycling could mitigate concerns related to mineral scarcity and overreliance on foreign suppliers but may not be enough to eliminate foreign dependency.

2. R Street estimates based on USGS mineral commodity summaries and IEA data.
3. R Street estimates based on USGS mineral commodity summaries, proposed mining project production estimates and IEA estimated mineral demand under SDS and NZE scenarios.
4. Ibid.
5. "Share of top producing countries in total processing of selected minerals and fossil fuels, 2019," International Energy Agency, Nov. 9, 2022. https://www.iea.org/data-and-statistics/charts/share-of-top-producing-countries-in-total-processing-of-selected-minerals-and-fossil-fuels-2019.
6. Amit Katwala, "The World Can't Wean Itself Off Chinese Lithium," *Wired*, June 30, 2022. https://www.wired.co.uk/article/china-lithium-mining-production; Maria Pulina, "The Chinese policy of lithium and REEs mines' purchase," Center for International Crisis and Conflict Studies Université catholique de Louvain, May 2019, p. 19. https://cecrilouvain.be/wp-content/uploads/2019/06/Note-danalyse-62.pdf.
7. Michele Fabiola Lawson, "The DRC Mining Industry: Child Labor and Formalization of Small-Scale Mining," The Wilson Center, Sept. 1, 2021. https://www.wilsoncenter.org/blog-post/drc-mining-industry-child-labor-and-formalization-small-scale-mining.

security. The key issue is not whether the United States can supply its own minerals, but that undue barriers to market entry of mines will raise costs by exacerbating scarcity and the potential for foreign suppliers to leverage their position in supply chains to pressure other nations into foreign policy concessions, as China has attempted in the past with its rare earth element exports.[8]

Overall, this study finds that the United States could be a major producer of key minerals needed for clean energy technology, but production is still well below what would be needed for the most ambitious clean energy transition scenarios. Thus, as clean energy demand rises, policy discussions focused on remedying potential mineral scarcity will become increasingly important.

As clean energy demand rises, policy discussions focused on remedying potential mineral scarcity will become increasingly important.

Introduction

Politicians have frequently exhorted the importance of a clean energy transition, and such rhetoric is often accompanied by an expectation that the United States will be the supplier of clean energy technologies.[9] More recently, we have become increasingly aware that the mineral requirements needed to achieve a clean energy transition that accomplishes net-zero emissions globally is likely to be a limiting factor, as clean energy technology tends to be more mineral intensive than traditional technologies that use fossil fuels.[10] The IEA estimates that the annual production of minerals needed for clean energy would have to increase at least six times beyond current global production levels to achieve net-zero emissions globally.[11] This begs several key questions:

- Could the United States produce enough minerals to supply a domestic clean energy transition or to become a global supplier of the minerals needed?
- How likely is it that U.S. mineral production will expand?
- If the United States were not the source of minerals needed for clean energy, then how much of these minerals would likely come from friendly nations?

This analysis seeks to assess exactly how much copper, cobalt, nickel and lithium the United States would have to produce to ensure full domestic content of clean energy technology (rare earth metals are noteworthy, but, given their diversity, are not included in this analysis). With this information, policymakers will have a clearer picture of the gap between current U.S. mineral production and the production that would be needed to meet the mineral demands of a clean energy transition, as well as the important role global trade will play in supplying minerals that the United States cannot readily produce. This analysis will also explore the issues associated with other nations—particularly China—having an outsized level of influence in mineral supply chains that the United States would need to rely on during a clean energy transition.

8. Michael Green et al, "Counter-Coercion Series: Senkaku Islands Trawler Collision," Center for Strategic International Studies, May 18, 2017. https://amti.csis.org/counter-co-trawler-collision.
9. "Interview by Tom Conway: Remarks by President Biden at a Virtual Event on Securing Critical Minerals for a Future Made in America." https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/22/remarks-by-president-biden-at-a-virtual-event-on-securing-critical-minerals-for-a-future-made-in-america.
10. Philip Rossetti and George David Banks, "Foreign Mineral Supply Chain Dependence Threatens U.S. National Security," Citizens for Responsible Energy Solutions Forum, March 2022, p. 10. https://cresforum.org/wp-content/uploads/2022/03/CRES_WhitePager_CriticalMinerals_03212022_v1.pdf.
11. "The Role of Critical Minerals in Clean Energy Transition: Executive Summary," International Energy Agency, Oct. 26, 2022. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary.

Projected Mineral Needs for Clean Energy Transition in the United States

The United States is the world's largest consumer of energy.[12] It alone is responsible for 15 percent of total global energy demand, much of which is related to transportation.[13] The United States has the highest vehicle-per-capita rate the world, at 842 cars per 1,000 persons (compared to 629 in Western Europe and 183 in China) and consumes 20 percent of global liquid fuels.[14] Consequently, when considering the total amount of resources that would be required to transition to clean energy in the United States, this country would require an outsized share of the available global minerals.

The United States is the world's largest consumer of energy.

The country is responsible for

15%

of total global energy demand, much of which is related to transportation.

Methodology

For this analysis, we compared projected 2040 U.S. overall energy needs to the projected needs of the rest of the world to produce coefficients for estimating the needs for minerals pertinent to transportation energy demand and other energy consumption. These coefficients were then applied to estimated global mineral needs for a global clean energy transition for select minerals—copper, cobalt, nickel and lithium—to produce estimates for total mineral needs to satisfy U.S. energy demand. The estimates of minerals needed come in two forms: annual mineral demand and cumulative mineral demand.

For this analysis, we compared projected 2040 U.S. overall energy needs to the projected needs of the rest of the world to produce coefficients for estimating the needs for minerals pertinent to transportation energy demand and other energy consumption.

The estimated annual demand for minerals required to satisfy U.S. energy needs is based on the IEA's published data on critical mineral demand for energy under two scenarios. The first scenario is the Sustainable Development Scenario (SDS), which is an estimate of the minerals needed to achieve an energy transition consistent with the United Nations' Sustainable Development Goals.[15] The second scenario is the Net-Zero Emission (NZE) scenario, which estimates the minerals that would be required to support a global technological energy transition to net-zero emissions.[16] The U.S. share of mineral needs is estimated by R Street, based on projected total U.S. energy consumption in 2040.

The estimated cumulative mineral demand uses the same estimates of U.S. share of mineral needs as the annual demand estimate but is applied to an average of three comprehensive estimates of global mineral needs to achieve net-zero emissions, two of which are peer reviewed.[17] Taken together, the annual and cumulative estimates offer insight on both the level of production scale and the amount of minerals that would be needed for the United States to have an entirely zero-emission energy

12. U.S. Energy Information Administration, "International Energy Outlook," Department of Energy, October 2021, Table A1. https://www.eia.gov/outlooks/ieo/data/pdf/ref/A01_r.pdf.
13. Ibid.
14. Ibid., Table A5. https://www.eia.gov/outlooks/ieo/data/pdf/ref/A05_r.pdf; Stacy C. Davis and Robert G. Boundy, "Transportation Energy Data Book: Edition 40," Oak Ridge National Laboratory, June 2022, Table 3.7. https://tedb.ornl.gov/wp-content/uploads/2022/03/TEDB_Ed_40.pdf#page=84.
15. "The Role of Critical Minerals in Clean Energy Transition," International Energy Agency, May 2021, pp. 42-115. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.
16. "The Role of Critical Minerals in Clean Energy Transition: Executive Summary," International Energy Agency. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary.
17. Elsa Dominish et al., "Responsible minerals sourcing for renewable energy," Institute for Sustainable Futures, 2019, p. 21. https://earthworks.org/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf; Alicia Valero et al., "Material bottlenecks in the future development of green technologies," *Renewable and Sustainable Energy Reviews* 93 (October 2018), pp. 178-200. https://www.sciencedirect.com/science/article/abs/pii/S1364032118303861; André Månberger and Björn Stenqvist, "Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development," *Energy Policy* 119 (August 2018), pp. 226-241. https://www.sciencedirect.com/science/article/pii/S0301421518302726.

system as envisioned under existing net-zero scenarios. It should be noted, though, that the limitations of net-zero emission analyses thus far are that they consider only current or near-future technology and do not properly account for the important effects of innovation in attaining emission outcomes. Still, they do give good insight as to whether these emission outcomes are achievable with current technologies and resource estimates.

Results

The minerals required for clean energy consumption and production in the United States are economically and environmentally significant. Relative to current levels of consumption estimated by the USGS, to achieve U.S. clean energy under the NZE scenario by 2040, mineral demand would increase by 121 percent for copper, 2,007 percent for cobalt, 504 percent for nickel and 13,267 percent for lithium.[18] In some cases, such as that of lithium, even current global levels of production (100,000 metric tons) are insufficient to meet the level of expected demand for a U.S. clean energy transition (265,332 metric tons), much less a net-zero emission world (Figure 1).[19] And while the United States is a major producer of minerals, it is worth noting that despite policy pushes for domestic mineral exploration and clean energy efforts, U.S. production for most minerals is unlikely to reach domestic self-sufficiency.[20]

While the United States is a major producer of minerals, it is worth noting that despite policy pushes for domestic mineral exploration and clean energy efforts, U.S. production for most minerals is unlikely to reach domestic self-sufficiency.

Figure 1: Annual Current Production, Current Consumption and Anticipated Demand Under Clean Energy Transition Scenarios[21]

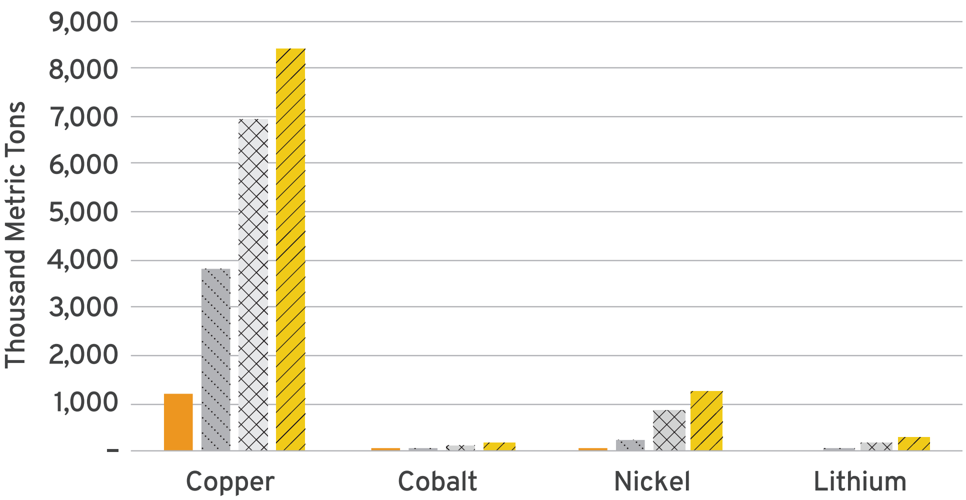
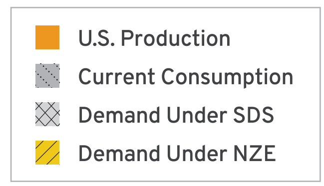


Figure 1: Chart Legend



Overall, conventional political rhetoric that typically focuses on global emission targets of net-zero, or even net-negative, may not fully appreciate the challenges that mineral scarcity may present to technological cost and availability. When considering cumulative mineral demand, even estimated current global reserves are insufficient for some minerals (Table 1).

18. U.S. Geological Survey, "Mineral Commodity Summaries 2022," U.S. Department of the Interior, Jan. 31, 2022. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf; R Street estimates based on USGS mineral commodity summaries and IEA data.
19. Ibid.
20. Biden. https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/22/remarks-by-president-biden-at-a-virtual-event-on-securing-critical-minerals-for-a-future-made-in-america.
21. U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf.

Table 1: Cumulative Mineral Demand and Current Reserves for United States and World to Reach Net-Zero Emissions[22]

	Mineral (thousand metric tons)			
	Copper	Cobalt	Nickel	Lithium
Cumulative U.S. Demand	38,494	3,100	10,003	5,745
U.S. Reserves	48,000	69	340	750
Global Cumulative Demand	313,868	17,573	81,561	32,566
Global Reserves	880,000	7,600	95,000	22,000

Data derived from R Street estimates based on USGS mineral commodity summaries and averaged estimates from footnoted sources.

Key Definition

Resources:
The total estimated volume of a mineral existing on Earth including what is not viable to extract currently.

It should be noted that reserves are a metric of mineral availability under present conditions of cost, technology and knowledge of deposits. Another relevant metric is "resources," which is the total estimated volume of a mineral existing on Earth including what is not viable to extract currently.[23] For example, even though the United States has only 750,000 metric tons of lithium reserves, it has 9.1 million tons of estimated resources, indicating significant future potential for production.[24] A wide margin between reserves and resources is noteworthy, as it indicates a potential boon that could be unlocked by innovation and—when coupled with high projected demand—a large potential for private sector interest, investment and development. For some minerals, though, there simply is insufficient availability; one study noted that even when considering global mineral resources, a global net-zero emission energy transition with current technology could require more of certain minerals (e.g., cobalt) than what is realistically available.[25]

Given its unique position as the world's largest energy consumer, the United States would likely bear a significant portion of any cost burdens induced by mineral scarcity encountered in pursuit of global net-zero emissions.

As the world's largest energy consumer, the United States would likely bear a significant portion of any cost burdens induced by mineral scarcity encountered in pursuit of global net-zero emissions.

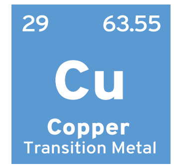
Production Expansion Potential

Although much political rhetoric centers around the goal of becoming more self-reliant on the production of critical minerals, our ability to achieve this goal depends largely on the geologic availability of those minerals within the United States. Thus, assessing the potential of key planned U.S. mineral projects sheds light on U.S. production expansion potential (Table 2).

22. Dominish et al. https://earthworks.org/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf; Valero et al. https://www.sciencedirect.com/science/article/abs/pii/S1364032118303861; and Månberger and Stenqvist. https://www.sciencedirect.com/science/article/pii/S0301421518302726.
23. "What is the difference between assessed 'resources' and 'reserves'?" U.S. Geological Survey, last accessed Jan. 11, 2023. https://www.usgs.gov/faqs/what-difference-between-assessed-resources-and-reserves.
24. U.S. Geological Survey, p. 100. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf.
25. Rossetti and Banks, p. 10. https://cresforum.org/wp-content/uploads/2022/03/CRES_WhitePager_CriticalMinerals_03212022_v1.pdf.

Table 2: Proposed U.S. Mining Projects and Their Estimated Production Potential

	Mine Name	State	Estimated Annual Production (metric tons)	Production as a Percent of U.S. NZE Demand
Copper	Back Forty Mine[26]	Michigan	3,175	0
	Black Butte[27]	Montana	120,000	3
	NorthMet[28]	Minnesota	26,308	1
	Pebble[29]	Alaska	559,000	12
	Resolution[30]	Arizona	453,592	14
	Rosemont (Copper World)[31]	Arizona	86,000	2
	Tamarack[32]	Michigan	9,200	0
	Twin Metals[33]	Minnesota	50,370	1
Nickel	Tamarack[34]	Michigan	16,500	2
	Twin Metals[35]	Minnesota	16,060	2
Lithium	Clayton Valley[36]	Nevada	27,400	10
	John L. Featherstone Plant[37]	California	17,600	7
	Rhyolite Ridge[38]	Nevada	24,000	8
	Thacker Pass[39]	Nevada	66,000	25



These proposed mining projects could considerably expand U.S. production potential of key minerals (Figure 2). Two proposed copper mines, Pebble Mine in Alaska and Resolution Copper in Arizona, would together almost double current U.S. copper production.[40] Additionally, although the United States currently has only one nickel mine in operation and has historically relied on importing this mineral, two proposed projects would roughly triple current production—though even this volume falls well short of what would be needed for total self-reliance under the NZE.[41] Lithium also has considerable potential in the United States, with large projects like Thacker Pass potentially able to supply significant amounts of lithium for a clean energy transition.

26. "Operations," Back Forty Mine, last accessed Dec. 22, 2022. https://backfortymine.com/operations.
27. "Black Butte Project," Mining Data Solutions, last accessed Dec. 22, 2022. https://miningdataonline.com/property/3427/Black-Butte-Project.aspx.
28. "NorthMet Project," Mining Data Solutions, last accessed Dec. 22, 2022. https://miningdataonline.com/property/1868/NorthMet-Project.aspx.
29. "Pebble Project," Mining Data Solutions, last accessed Dec. 22, 2022. https://miningdataonline.com/property/594/Pebble-Project.aspx.
30. "Project Overview," Resolution Copper, last accessed Dec. 22, 2022. https://resolutioncopper.com/project-overview.
31. "Copper World (Phase I) Project," Mining Data Solutions, last accessed Dec. 22, 2022. https://miningdataonline.com/property/499/Copper-World-Phase-I-Complex.aspx.
32. "Tamarack Nickel Project," Talon Metals Corp., January 2022, p. 26. https://talonmetals.com/wp-content/uploads/2022/01/TLO_Presentation_Jan_2022.pdf.
33. "Mine Plan of Operations," Twin Metals Minnesota LLC, Dec. 18, 2019, p. 142. https://www.twin-metals.com/wp-content/uploads/2020/05/TMM-Mine-Plan-of-Operations_2019-1218-R.pdf.
34. "Tamarack Nickel Project," p. 26. https://talonmetals.com/wp-content/uploads/2022/01/TLO_Presentation_Jan_2022.pdf.
35. "Mine Plan of Operations," p. 142. https://www.twin-metals.com/wp-content/uploads/2020/05/TMM-Mine-Plan-of-Operations_2019-1218-R.pdf.
36. "Clayton Valley Lithium Project, Nevada," Cypress Development Corp., last accessed Dec. 22, 2022. https://cypressdevelopmentcorp.com/projects/nevada/clayton-valley-lithium-project-nevada.
37. "Report of the Blue Ribbon Commission on Lithium Extraction in California," California Energy Commission, Dec. 1, 2022, p. 33. https://efiling.energy.ca.gov/GetDocument.aspx?tn=247861.
38. "Rhyolite Ridge Lithium-Boron Project," Ioneer, last accessed Dec. 22, 2022. https://rhyolite-ridge.ioneer.com/ryholite-ridge-project.
39. Bureau of Land Management, "Thacker Pass Lithium Mine Project: Final Environmental Impact Statement," Department of the Interior, p. 28. https://eplanning.blm.gov/public_projects/1503166/200352542/20030633/250036832/Thacker%20Pass_FEIS_Chapters1-6_508.pdf#page=28.
40. R Street estimate based on estimated mine production and current USGS data.
41. Garret Ellison, "Rising EV demand puts America's only nickel mine in the spotlight," Michigan Live, July 16, 2022. https://www.mlive.com/public-interest/2022/07/rising-ev-demand-puts-americas-only-nickel-mine-in-the-spotlight.html.

These planned projects, particularly those for copper and lithium, could reduce domestic reliance on foreign supply chains considerably, especially if the United States were to more heavily pursue a clean energy agenda.

Of note, one mine that is no longer on the list of proposed projects is a cobalt mine that opened in October 2022 in Idaho.[42] The cobalt mine is expected to produce 1,915 metric tons of cobalt annually, which could increase U.S. cobalt production from 700 metric tons annually to 2,615.[43]

Figure 2: Current and Planned U.S. Mineral Production Relative to Mineral Needs for NZE Demand[44]

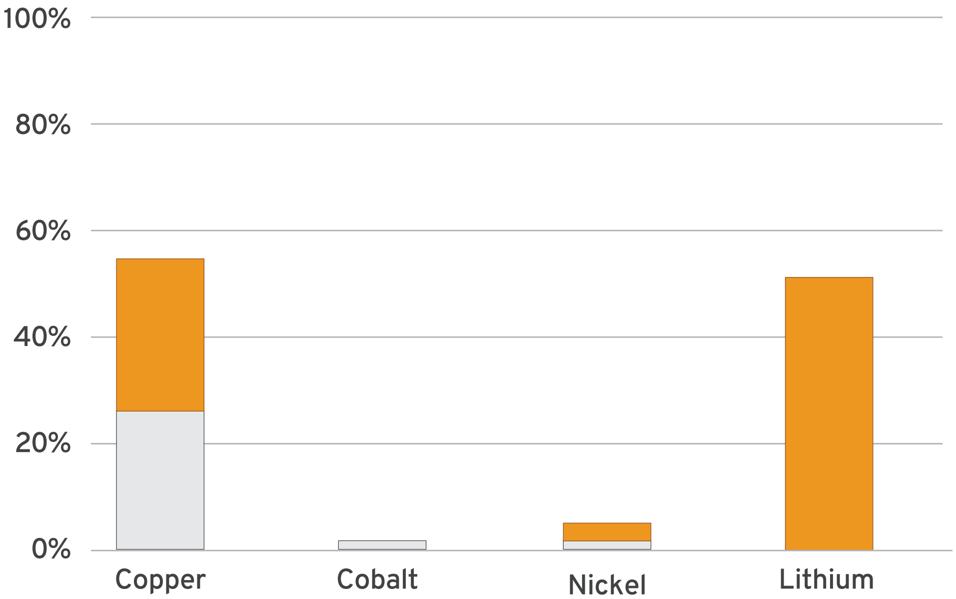
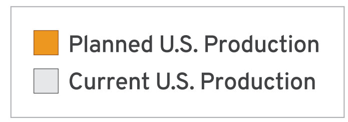


Figure 2: Chart Legend



However, expectations of increased production of minerals in the United States through planned projects such as these should be tempered because of challenges related to litigation and permitting. For example, both of the major planned projects for copper—Pebble and Resolution—have faced litigation issues that make it uncertain when or if they will go into operation.[45] Similarly, Thacker Pass, the largest proposed lithium project in the United States and one of the largest in the world, was approved in January 2021 but has since been delayed by litigation asserting that the associated environmental reviews were rushed.[46] Another lithium project, Rhyolite Ridge, has been unable to secure permitting over its potential impact to the habitat of an endangered species of buckwheat.[47] Furthermore, the Twin Metals nickel mine had its leases canceled in January 2022 after the Biden administration asserted that

Expectations of increased production of minerals should be tempered because of challenges related to litigation and permitting.

42. Kirk Siegler and Eric Whitney, "In Idaho, America's first, and only, cobalt mine in decades is opening," NPR, Oct. 8, 2022. https://www.npr.org/2022/10/08/1127310649/in-idaho-americas-first-and-only-cobalt-mine-in-decades-is-opening.
43. Michael Holtz, "Idaho Is Sitting on One of the Most Important Elements on Earth," *The Atlantic*, Jan. 24, 2022. https://www.theatlantic.com/science/archive/2022/01/cobalt-clean-energy-climate-change-idaho/621321.
44. U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf and estimated production from proposed mining projects.
45. Sebastien Malo, "9th Circuit revives lawsuit over Alaska's Pebble Mine project," *Reuters*, June 18, 2021. https://www.reuters.com/legal/litigation/9th-circuit-revives-lawsuit-over-alaskas-pebble-mine-project-2021-06-18; Ernest Scheyder, "Full 9th US Circuit to tackle complex Resolution Copper mining case," *Reuters*, Nov. 18, 2022. https://www.reuters.com/markets/commodities/full-9th-us-circuit-tackle-complex-resolution-copper-mining-case-2022-11-18.
46. Ernest Scheyder, "U.S. court sets January 2023 hearing for Lithium Americas mine suit," *Reuters*, Oct. 6, 2022. https://www.reuters.com/legal/us-court-sets-january-2023-hearing-lithium-americas-mine-suit-2022-10-06.
47. Ernest Scheyder, "U.S. to list Nevada flower as endangered, dealing blow to lithium mine," *Reuters*, June 3, 2021. https://www.reuters.com/business/environment/us-officials-list-nevada-flower-endangered-dealing-blow-ioneer-2021-06-03.

the Trump administration had improperly approved them.[48] Additionally, the Biden administration has issued a moratorium on new mining leases in the area that Twin Metals sought to operate, citing potential impacts to hunting, fishing, tourism and ecology.[49]

Approving new mines typically takes years, as the large environmental footprints of these types of projects almost always require review under the National Environmental Policy Act (NEPA) and the preparation of an associated environmental impact statement. The full process of navigating NEPA typically takes 4.5 years, though it can be longer for larger projects.[50] Consequently, projects can be cancelled before they are approved. For example, a 2010 plan to reopen the Bear Lodge rare earth mine in Wyoming after Chinese embargoes elevated prices failed when the project was unable to secure permitting before China resumed rare earth exports, causing the project to no longer be economically viable.[51] Of note, Bear Lodge has received renewed attention recently due to its potential to produce neodymium, an essential rare earth metal for wind turbines.[52]

Potential Production Expansion Barriers: Prohibitive to New Market Entry

1. Approving new mines through NEPA typically takes years.
2. Beyond NEPA, additional permitting, siting, political and litigation issues exist.

Beyond NEPA there are additional permitting, siting, political and litigation issues relevant to mining. The proposed Thacker Pass lithium mine is encountering challenges over its potential impact to sacred indigenous lands.[53] The proposed Pebble copper mine has been opposed for its potential impact on other industries such as fishing and tourism.[54] While it is ultimately up to policymakers to prioritize and balance various issues related to mining, challenges such as these mean that a singular policy proposal or reform would be unlikely to fully unlock potential mineral resources in the United States.

Simply put, even though the United States has the physical capacity and technology to expand mineral production substantially and politicians are seeking increased production and utilization of domestic minerals needed for clean energy technology, there are few recent examples of large-scale mining operations entering the market without permitting or litigation challenges. Importantly, in the challenges referenced above, these issues are not simply a matter of delay or cost but can also be prohibitive to new market entry. Although opponents of new mineral projects may desire such an outcome, policymakers should bear in mind that this will diminish the United States' ability to quickly and cost effectively transition to low-carbon energy sources.

48. Ernest Scheyder, "Biden administration kills Antofagasta's Minnesota copper project," *Reuters*, Jan. 26, 2022. https://www.reuters.com/business/sustainable-business/biden-administration-kills-antofagastas-minnesota-copper-project-2022-01-26.
49. Lisa Friedman, "Biden Administration Sets a Mining Ban in Boundary Waters Wilderness," *The New York Times*, Jan. 26, 2023. https://www.nytimes.com/2023/01/26/climate/mining-ban-boundary-waters-copper.html.
50. Philip Rossetti, "Addressing NEPA-Related Infrastructure Delays," R Street Policy Study No. 234, July 2021, p. 3. https://www.rstreet.org/wp-content/uploads/2021/07/FINAL_RSTREET234.pdf.
51. Greg Fladager, "Canadian company suspends work on Wyoming rare earth mine," *Billings Gazette*, Jan. 25, 2016. https://billingsgazette.com/news/state-and-regional/wyoming/canadian-company-suspends-work-on-wyoming-rare-earth-mine/article_180dbb2c-7d26-5ffb-acd6-94638400938f.html.
52. Shane Lasley, "Rare earths project reemerges in Wyoming," *Metal Tech News*, Oct. 13, 2021. https://www.metaltechnews.com/story/2021/10/13/tech-metals/rare-earths-project-reemerges-in-wyoming/735.html.
53. Briana Flin, "'Like putting a lithium mine on Arlington cemetery'; the fight to save sacred land in Nevada," *The Guardian*, Dec. 2, 2021. https://www.theguardian.com/us-news/2021/dec/02/thacker-pass-lithium-mine-fight-save-sacred-land-nevada.
54. "Adventure Travel Companies Threatened by Proposed Pebble Mine," Adventure Travel Trade Association, April 5, 2019. https://www.adventuretravelnews.com/adventure-travel-companies-threatened-by-proposed-pebble-mine.

Foreign Trade and Dependency

Given the significant volume of minerals needed for a global energy transition like that outlined in the NZE, it should be expected that the successful implementation of clean energy policies will be contingent on robust international trade and the development of mineral resources. Table 3 estimates the percentage of U.S. mineral requirements for clean energy transitions that would need to come from foreign sources.

Successful clean energy policies will be contingent on robust international trade.

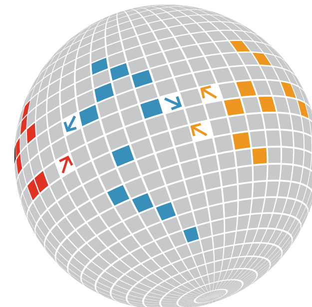


Table 3: Import Dependency to Achieve SDS or NZE Scenario Targets with and Without Increased Domestic Production[55]

	SDS (%)	NZE (%)	SDS with Increased Production (%)	NZE with Increased Production (%)
Copper	61	74	13	41
Cobalt	97	98	97	98
Nickel	97	98	92	95
Lithium	100	100	16	51

Estimates based on data from USGS; proposed mining project production estimates; and IEA estimated mineral demand under SDS and NZE scenarios.

A key concern related to the international trade of minerals is that clean energy policies will likely increase the demand for minerals that are produced or refined by adversarial nations or nations engaging in unethical practices. For example, the world's largest producer of cobalt, the DRC, uses child labor in the mineral's production.[56] The high demand for lithium-ion batteries (which require cobalt) for electronics and electric vehicles (EVs) makes it more likely that the DRC will continue to use child labor.

KEY CONCERN

Clean energy policies will likely increase the demand for minerals that are produced or refined by adversarial nations or nations engaging in unethical practices (i.e., child labor).

More recently, politicians have been focusing on the potential for Chinese and Russian impact on mineral supply chains and are questioning whether policies designed to encourage transitions to mineral-intensive energy and transportation resources will create a dependency on these nations (Figure 3).[57] This is a source of concern, as both countries are major suppliers of critical minerals that would be needed for a clean energy transition. To illustrate this issue, China embargoed exports of rare earth materials to Japan after the Senkaku Boat Incident to pres USGS sure them diplomatically, and the Department of Defense has since focused on reducing reliance on Chinese minerals for strategic purposes.[58]

55. U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf.
56. Lawson. https://www.wilsoncenter.org/blog-post/drc-mining-industry-child-labor-and-formalization-small-scale-mining.
57. Energy & Commerce Committee Republicans, "E&C Republicans Promote Securing America's Critical Minerals Supply Act," U.S. House of Representatives, June 27, 2022. https://energycommerce.house.gov/posts/ec-republicans-promote-securing-americas-critical-minerals-supply-act.
58. Green et al. https://amti.csis.org/counter-co-trawler-collision; Bryant Harris, "Congress and Pentagon seek to shore up strategic mineral stockpile dominated by China," *Defense News*, May 23, 2022. https://www.defensenews.com/congress/2022/05/23/congress-and-pentagon-seek-to-shore-up-strategic-mineral-stockpile-dominated-by-china.

Figure 3: Global Share of the Production of Select Minerals by Country[59]

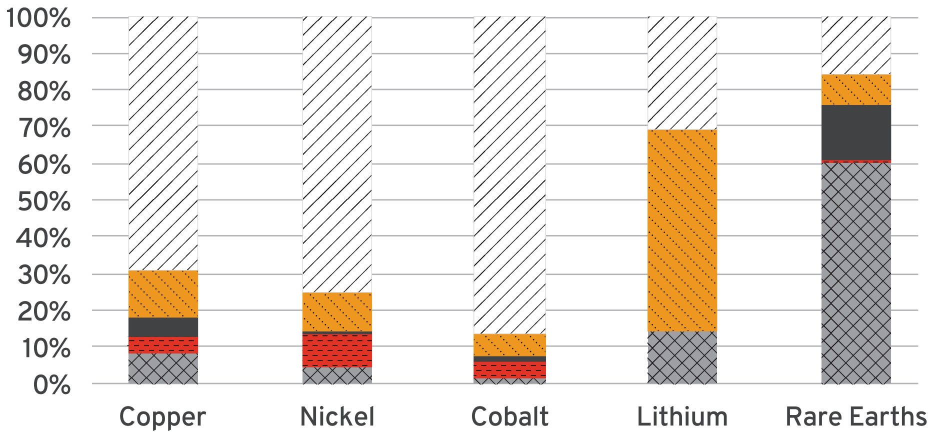


Figure 3: Chart Legend

*Friendly nations defined as either members of NATO or free trade agreements with the United States.

Importantly, even though China is only a limited producer of copper, nickel, cobalt and lithium, it has become a dominant player in the supply chains of those minerals through its ownership of mineral refining, whereby even mineral production in ostensibly friendly nations is still reliant on Chinese companies (Figure 4).[60]

Figure 4: Chinese Share of Global Production vs. Share of Refining for Select Minerals[61]

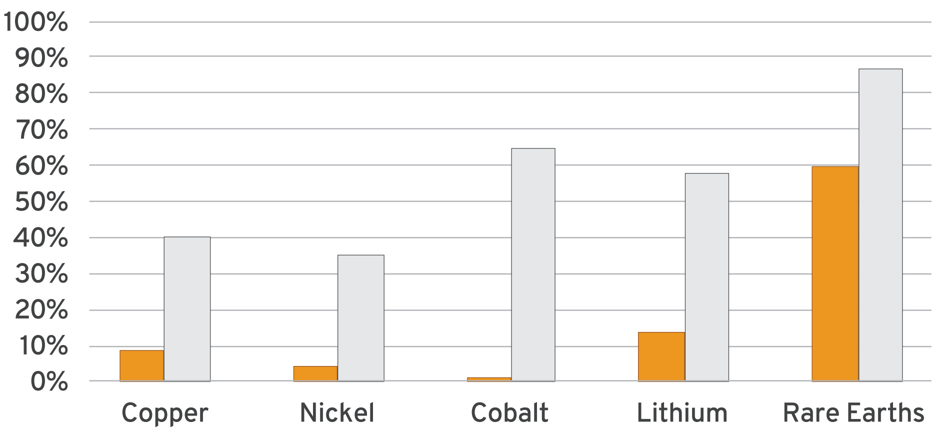
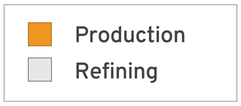


Figure 4: Chart Legend



Unlike Western nations where mineral interests are often privately owned, Chinese and Russian mineral companies are usually SOEs controlled by government.[62] From a policy perspective, there is a concern that China and Russia are using their natural resources as an extension of their foreign policy efforts, and national security scholars have suggested that Chinese SOE domination of mineral supply chains is part of a long-term strategy to influence the foreign policy of Western nations.[63]

59. U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf.
60. Alex Scott, "Challenging China's dominance in the lithium market," *Chemical & Engineering News* 100:38 (Oct. 29, 2022). https://cen.acs.org/articles/100/i38/Challenging-Chinas-dominance-lithium-market.html.
61. U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf; "Share of top producing countries in total processing of selected minerals and fossil fuels, 2019," International Energy Agency, Nov. 9, 2022. https://www.iea.org/data-and-statistics/charts/share-of-top-producing-countries-in-total-processing-of-selected-minerals-and-fossil-fuels-2019.
62. Ann Listerud, "MOR Money MOR Problems: China's Mixed-Ownership Reforms in Practice," Center for Strategic and International Studies, Oct. 1, 2019. https://www.csis.org/mor-money-mor-problems-chinas-mixed-ownership-reforms-practice.
63. Pulina, p. 19. https://cecrilouvain.be/wp-content/uploads/2019/06/Note-danalyse-62.pdf.

A key aspect of energy policy is energy security, which can be thought of as the continuity of energy supply and availability to the public. Energy insecurity creates vulnerabilities by which energy suppliers can threaten economic activity that relies on energy access. Similarly, concerns about mineral security are emerging, in which the continuity of access to critical minerals needed for domestic economic activity, especially in transportation and energy sectors, could be threatened.

Policy Implications

When policymakers speak of a U.S. clean energy transition, they often paint a picture of U.S. industrial dominance supplying technology, energy and minerals to the rest of the world.[64] Even if the United States were to become a major supplier of clean energy technology for EVs or renewable energy, the mineral intensity of these technologies would still likely significantly increase U.S. reliance on foreign mineral producers. Furthermore, although considerable opportunities exist to expand the domestic production of the minerals needed for such technology, achieving the scale of mineral production needed to meet even just U.S. requirements is extremely unlikely.

Two minerals that are an exception to this issue are copper and lithium. The United States has considerable resources of both, and—especially in the case of lithium—increased production could be key to reducing U.S. dependency on Chinese product. However, as noted above, current mining project approval processes are not well suited to increasing mining capacity. Given the increased adoption of renewable portfolio standards and even the possibility of prohibiting new fossil-fuel-powered vehicles in some states, the United States is likely to either need to reform its policies for producing new minerals domestically, or it will have to accept an increased reliance on foreign suppliers that would then have increased influence on the U.S. economy.[65]

Policies in the United States designed to increase clean energy consumption will by consequence increase the demand for related minerals, and—absent increases in their supply—will result in higher prices.

Policies in the United States designed to increase clean energy consumption will by consequence increase the demand for related minerals, and—absent increases in their supply—will result in higher prices. Higher prices will have a deleterious economic effect, the magnitude of which is not easy to estimate, but energy prices and economic downturns are closely linked.[66] In fact, already heightened EV demand has caused an increase in lithium prices, which are now about six times higher than they were in December 2020.[67] While policymakers often tout the effect of subsidies in reducing clean energy costs, from an economic perspective, such strategies do not lower the real economic impacts but simply transfer costs from consumers to taxpayers, which introduces economic distortions and worsens economic outcomes.[68]

Higher mineral prices will economically reward suppliers and refiners of those minerals. Even though policymakers may attempt to limit the degree to which

64. Biden. https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/22/remarks-by-president-biden-at-a-virtual-event-on-securing-critical-minerals-for-a-future-made-in-america.
65. Jay Ramey, "34% of Drivers Support Ban on ICE Vehicles by 2030," Autoweek, Sept. 28, 2022. https://www.autoweek.com/news/green-cars/a41388231/internal-combustion-vehicles-ban-study; Richard Bowers, "Five states updated or adopted new clean energy standards in 2021," U.S. Energy Information Administration, Feb. 1, 2022. https://www.eia.gov/todayinenergy/detail.php?id=51118.
66. Kevin L. Kliesen, "Rising Oil Prices and Economic Turmoil: Must They Always Go Hand in Hand?" Federal Reserve Bank of St. Louis, Jan. 1, 2001. https://www.stlouisfed.org/publications/regional-economist/january-2001/rising-oil-prices-and-economic-turmoil-must-they-always-go-hand-in-hand.
67. "Lithium," Trading Economics, last accessed Dec. 22, 2022. https://tradingeconomics.com/commodity/lithium.
68. "State Fact Sheets: How the Inflation Reduction Act Lowers Energy Costs, Creates Jobs, and Tackles Climate Change Across America," The White House, Aug. 17, 2022. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/17/state-fact-sheets-how-the-inflation-reduction-act-lowers-energy-costs-create-jobs-and-tackles-climate-change-across-america; Matthew D. Mitchell et al., "The Economics of a Targeted Economic Development Subsidy," Mercatus Center George Mason University, November 2019, pp. 36-37. https://www.mercatus.org/media/72251/download?attachment.

increased U.S. mineral demands reward adversarial or unethical foreign producers, such efforts are unlikely to be successful because of the global nature of mineral commodity markets. Even if the United States does not directly import minerals from problematic producers, it remains vulnerable to price shocks induced by such producers if they have a prominent role in market supply. For example, although the United States is now less reliant on fossil fuels from the Middle East than it has been in the past, the current administration has consistently requested that Saudi Arabia increase its oil output because their large market share still affects U.S. prices.[69]

New conditions for clean energy tax credits under the IRA are designed to offer additional subsidy eligibility for products that were made using either domestic mineral content or mineral content from a nation with which the United States has a free trade agreement, and these have an effect of reducing the demand for minerals from other producers, limiting their economic gains from increased U.S. demand.[70] However, the effects of these subsidy or regulation requirements only partially offset the effects of increased demand because mineral commodities are largely homogenous. For example, although the United States no longer subsidizes cobalt produced from child labor, the increased demand for non-DRC cobalt causes those cobalt prices to rise, which then increases demand for DRC cobalt from consumers willing to buy it at a lower price than on the open market. Even though the demand for DRC cobalt is not as high as it would be absent content requirements in EV subsidies in the United States, the overall heightened demand for cobalt and the fact that there are still buyers willing to purchase DRC cobalt means that policies that increase cobalt consumption in the United States still have an economically beneficial effect on all cobalt suppliers. Policymakers should therefore avoid falling into central planning biases where they may—mistakenly—believe that regulations or subsidy regimes would undo the effects of increased product demand in nations from which the United States may not want to source minerals.

A key solution to avoiding the unintended consequences of clean energy policy is significantly increasing recycling capacity. The recycling of minerals and metals is advantageous because these commodities do not lose their utility after recycling.

A key solution to avoiding the unintended consequences of clean energy policy (i.e., rewarding unethical practices in mineral procurement, increasing environmental destruction from mining expansion, increasing China's influence on the economics of mineral supply) is significantly increasing recycling capacity. The recycling of minerals and metals is advantageous because these commodities do not lose their utility after recycling.[71] An analysis of global mineral needs for clean energy found that if a 95 percent recycling rate were achieved for cobalt, lithium and nickel, their total cumulative mineral demand could roughly be cut in half.[72] Of note, although improved recycling policy may end up being key to reducing U.S. reliance on the foreign extraction and refining of minerals, current recycling behavior is largely driven by material reclamation profitability rather than foreign policy paradigms.

Past R Street research has noted that economic interest in recycling is largely dependent on the value of the recycled materials after processing.[73] The high

69. Alex Marquardt et al., "Inside the White House's failed effort to dissuade OPEC from cutting oil production to avoid a 'total disaster,'" CNN, Oct. 5, 2022. https://www.cnn.com/2022/10/04/politics/white-house-lobby-opec-oil-production-cuts-gasoline-prices-midterms/index.html.
70. H.R. 5376, Inflation Reduction Act, 117th Congress.
71. "Is Metal Infinitely Recyclable?" Federal Metals, Nov. 3, 2022. https://federalmetals.ca/is-metal-infinitely-recyclable.
72. Dominish et al., pp. 22-23. https://earthworks.org/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf.
73. Philip Rossetti, "Can the recycling industry achieve a circular economy?" R Street Institute, Dec. 15, 2020. https://www.rstreet.org/2020/12/15/can-the-recycling-industry-achieve-a-circular-economy.

utility of recycled minerals means that private sector interest in recycling is likely to flourish even without public support. If policymakers seek to ensure high levels of recycling to address policy concerns of foreign dependence, though, research has noted that market-based policies tend to yield better results than mandates.[74] While the potential scale of industrial recycling needed for clean energy minerals is not something that currently exists in the United States, policymakers should consider how important recycling policies will be to mitigating mineral scarcity concerns.

Above all, policymakers should understand that they are unlikely to achieve ambitious climate efforts such as net-zero emissions without either reforms to expand domestic mineral production or a substantial increase in foreign production supplying U.S. consumption.

Conclusion

The domestic production levels of key minerals used in clean energy in this country currently fall well below what would be needed for an energy transition as outlined in the NZE. Although the United States has the potential to become a major supplier of copper and lithium for clean energy technology domestically—even potentially abroad—virtually every significant effort to expand that supply has encountered significant barriers to market entry. For minerals such as nickel and cobalt, it is unlikely that the United States will ever be able to produce enough to satisfy its own potential clean energy demand, which underscores the importance of robust and open international trade that provides consumer access to mineral commodities. This necessary reliance on the international trade of mineral commodities, however, means that policymakers cannot ignore the Chinese influence on both the production and refining elements of mineral supply chains. Policymakers should recognize that the United States will be under additional influence from China and its ability to interfere in natural market activities via its SOEs should the United States increase its economic dependence on select minerals. Additionally, domestic policies that raise demand for clean energy and its associated minerals are certain to enrich foreign suppliers, some of which use unethical practices such as child labor.

Policymakers should understand that there is a wide gulf between the popular rhetoric of a clean energy transition and the realities of mineral scarcity that are likely to exacerbate clean energy costs and increase reliance on foreign suppliers.

Overall, policymakers should understand that there is a wide gulf between the popular rhetoric of a clean energy transition and the realities of mineral scarcity that are likely to exacerbate clean energy costs and increase reliance on foreign suppliers. Policies such as permitting reform, especially for copper and lithium, and a renewed focus on recycling could mitigate these issues but will not entirely resolve them due to the physical limitations of mineral availability within the United States.

74. Philip Rossetti, "Deposit Refund Systems Are More Effective than Mandates," R Street Shorts No. 112, March 2022, p. 3. https://www.rstreet.org/wp-content/uploads/2022/03/update_RSTREETSHORT112-5-1.pdf.

About the Author

Philip Rossetti is a senior fellow for Energy and Environmental Policy at the R Street Institute. He has worked extensively on issues related to energy policy, environmental issues and climate change. Prior to joining the R Street Institute, Rossetti supported the minority staff of the Select Committee on the Climate Crisis in the U.S. House of Representatives, and before that he was the Director of Energy Policy at the American Action Forum.