

WRITTEN TESTIMONY

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Hearing on “Powering the 21st Century with American Copper”

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Chair Stauber, Ranking Member Ansari, Members of the Committee, and Committee staff – thank you for inviting me to participate in today’s hearing. It is an honor to be able to share my expertise today on an area of great focus throughout my research career: mineral supply chains, and specifically, copper.

WITNESS BACKGROUND & SUMMARY OF RELEVANT EXPERTISE

My name is Dr. Michele Bustamante, and I am a Staff Scientist with the Natural Resources Defense Council (NRDC). NRDC is an international non-profit, based in the U.S., that uses science, law, and advocacy to protect the earth — its people, its plants and animals, and the natural systems on which all life depends. Over the past six years in my role as part of NRDC’s Landscape Conservation team, I have leveraged my multidisciplinary background from training as an environmental engineer, materials engineer, and sustainability scientist to contribute substantively to this mission. My work focuses on conducting research and analysis, developing decision support tools, and providing science-based strategic guidance on a variety of issues at the intersections of energy, climate, and natural resources policy; most commonly, focusing on fossil fuels and critical minerals.

My professional experiences studying mineral supply chains, and copper in particular, however, far predate my time at NRDC. Immediately prior to joining NRDC, I was awarded a Congressional Science & Engineering Fellowship, jointly sponsored by the Materials Research Society (MRS) and the Metals, Minerals, and Materials Society (TMS)). Among other things, the work that earned me this fellowship focused on modeling copper and copper byproducts at systems level as well as mine-level detail, under a variety of demand scenario futures, in two university settings between the period of 2012-2018; first, during my PhD at Rochester Institute of Technology, and then later as a postdoctoral research associate in the Materials Systems Lab at Massachusetts Institute of Technology (MIT).

Supply dynamics for copper, and its frequent byproduct, tellurium, played a central role in my doctoral dissertation studies on energy critical minerals.¹ In that work, I used tellurium

¹ Michele L. Bustamante, *Criticality of Byproduct Materials: Assessing Supply Risk, Environmental Impact, and Strategic Policy Response for Tellurium* (Rochester Institute of Technology, 2016), <https://core.ac.uk/download/pdf/232140593.pdf>.

as a case study to advance novel approaches to better assess supply risk,² environmental impact,³ and potential efficacy of different risk mitigation strategies (with a special focus on non-mining solutions)⁴ for other similar materials also facing challenges unique to their byproduct-dominant supply chains. Then for my postdoc, I joined a team of research scientists and professors at MIT who specialized in copper market modeling as part of a portfolio of material systems research. Multiple research projects throughout my appointment were funded by mining industry majors, and, in off hours, I also occasionally joined the team in consulting for a smaller copper developer directly who trusted these models to inform real-world decision-making.

Currently, I lead critical and/or clean energy transition minerals research efforts at NRDC. I track and translate existing research on energy transition mineral supply and demand projections as well as promising solutions to supply risk (recycling, recovery from unconventional sources,⁵ substitution and innovation, increased efficiency through supply chain, etc.). I also work to support development of relevant policy publications,⁶ advise on contemporary policy discussions, and direct novel systems-level research (supply/demand modeling, and/or geospatial mapping), most often in collaboration with external partners at leading universities.

Although this work has focused primarily on battery cathode and anode materials, we have often included copper among the metals of interest in our research due to its central role in electrification across sectors. I continue to engage meaningfully with recent copper modeling literature and bring that perspective to this testimony, alongside my prior years of research.

² This work required deeply understanding the main supply streams used for producing and refining copper (i.e., primary electrolytic, primary hydrometallurgical (SX-EW), and secondary recycled), and their trends over time because only one produces the tellurium-yielding byproduct. Michele L. Bustamante and Gabrielle Gaustad, “Challenges in Assessment of Clean Energy Supply-Chains Based on Byproduct Minerals: A Case Study of Tellurium Use in Thin Film Photovoltaics,” *Applied Energy* 123 (2014): 397–414.

<https://doi.org/10.1016/j.apenergy.2014.01.065>. Full text accessible at: <https://tinyurl.com/RG-Bustamante-AppEn-2014>

³ Michele L. Bustamante et al., “Life Cycle Assessment of Jointly Produced Solar Energy Materials: Challenges and Best Practices,” *Solar Energy Materials and Solar Cells* 156 (2016): 11–26.

<https://doi.org/10.1016/j.solmat.2016.05.007>. Full text accessible at: <https://tinyurl.com/RG-Bustamante-SolMat-2016>

⁴ Michele L. Bustamante et al., “Comparative Analysis of Supply Risk-Mitigation Strategies for Critical Byproduct Minerals: A Case Study of Tellurium,” *Environmental Science & Technology* 52, no. 1 (2018): 11–21. <https://doi.org/10.1021/acs.est.7b03963>. Full text accessible at: <https://tinyurl.com/RG-Bustamante-EST-2018>

⁵ Government Accountability Office (GAO), *Critical Minerals: Status, Challenges, and Policy Options for Recovery from Nontraditional Sources*, GAO-24-106395 (2024), <https://www.gao.gov/assets/880/870385.pdf>.

⁶ Jordan Brinn, *Building Batteries Better: Doing the Best With Less* (NRDC, 2023), <https://www.nrdc.org/resources/building-batteries-better-doing-best-less>.

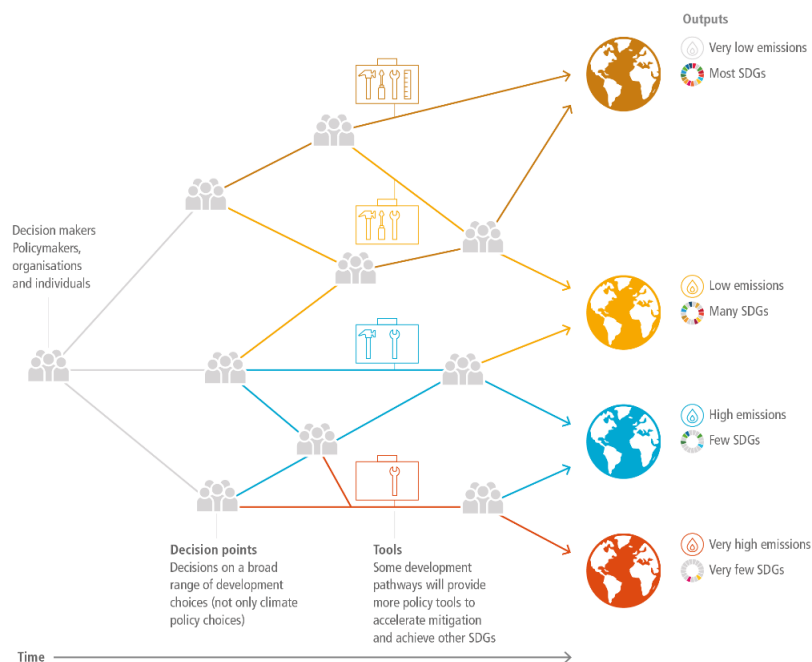
TESTIMONY

I. 21st Century Futures: Which one?

Today my fellow witnesses and I have been asked to share our expert perspectives on the subject of “Powering the 21st Century with American Copper.” But whose vision of the 21st Century are we talking about powering? And what agency are we granting ourselves – whether as public stakeholders, citizens of planet earth, or, in the case of this esteemed committee, as powerful governing body members – to consciously shape that future in ways that reflect our shared inheritance of the consequences that result from our decisions (past and present, passive and active)?

How each of us chooses to answer this underlying question, or whether we acknowledge it at all, will dramatically shape our answer about the role American copper may have in powering said future. Is it the interest of this committee to explore only what it looks like to accept the status quo, guided overwhelmingly by present market conditions and trends? Or can we be bold enough together to imagine, and focus on, a vision for the 21st century where we acknowledge Earth’s planetary boundaries⁷ and prioritize working toward realigning within them – not as an act of virtue, but of basic survival, sanity, dignity, and respect for our descendants, who cannot consent to these consequences?

As a sustainability scientist, I consider it my job to center the latter vision in my testimony responsive to the hearing topic today. But do not confuse this intentional focus for ignorance or naivety to the 21st century as it is currently unfolding before our eyes. Training in my field strongly embraces the importance of envisioning many futures and considering broad ranges when informing decision makers about what *could* be coming – whether in terms of climate impacts, or the subject of this hearing, potential copper demand. Being clear-eyed about the world as it is while preparing for that to change, assessing risks, and navigating tradeoffs are all at the heart of sustainability science techniques. However, it is equally important to consider what it would *mean* to traverse



The importance of decisionmakers in shifting development pathways to increased sustainability (Credit: IPCC AR6 WGIII Box TS.3, Figure 1)

⁷ Johan Rockström et al., “Planetary Boundaries Guide Humanity’s Future on Earth,” *Nature Reviews Earth & Environment* 5, no. 11 (2024): 773–88; Detlef P. van Vuuren et al., “Exploring Pathways for World Development within Planetary Boundaries,” *Nature* 641, no. 8064 (2025): 910–16, <https://doi.org/10.1038/s41586-025-08928-w>.

different scenario futures, and then weigh that evidence to decide which ones we would actually *want* to aim for when decision times arise. Because, unless it happens to be the reference case “status quo” scenario, your preferred future almost certainly won’t come about by accident. And it is precisely the role of policymakers, who uniquely hold the power to shape economic conditions from the top down, to guide society toward conditions most conducive to bringing about that desired future.

In practice, decision making is an unavoidably subjective process, especially when dealing with complex issues. Beyond unavoidable limitations in what can be measured at any given time, even the best data driven foundation will virtually always come up against some degree of subjectivity while weighing multiple, sometimes competing, interests. In other words, it is not just a matter of what is known, but also of what is valued. I, and the organization I represent, lay out clearly what values we hold closest in our mission, and they inform the kinds of scenario futures I highlight in this testimony. As a special class of decisionmakers, empowered through democratic election, it is my hope that you all will share in the core value that I believe is at the heart of your role in this representative system of governance by definition, and that is the public interest. I hope my testimony will help you consider how caring for natural systems is an essential part of that duty to hold close the public interest in deciding what to do about the issues we discuss today.

a. On Sustainable 21st Century Futures: Emissions and Energy

The Intergovernmental Panel on Climate Change (IPCC) produces perhaps the most comprehensive resources for exploring sustainable futures in production of its Assessment Reports (ARs) synthesizing the growing body of literature. According to these authors, “[a]mbitious mitigation can be considered a precondition for achieving the Sustainable Development Goals (SDGs).” Given its far-reaching effects, climate change mitigation is an essential component of any sustainable future. However, it is far from sufficient because different technology choices and consumption patterns can create tradeoffs, or synergies, between different aspects of human and natural systems. It is therefore valuable within an overall sustainability approach to explore a range of scenario futures, even within the desired climate action paradigm, that are capable of showcasing those differences, or their driving factors (e.g., primary energy mix, overall energy demand and demand per capita, degree of circularity or recycling, etc.).

IPCC AR6 showcased this range by drawing upon over 1000 modeled scenarios, to put forward five illustrative mitigation pathways (IMPs) limiting warming to 1.5-2C, alongside two higher emission scenarios – a status quo “Current Policies” (CurPol) scenario and a lower ambition “Moderate Action” (ModAct) pathway – where warming exceeds 2C. Each IMP focuses on a different emphasis for decarbonizing. IMP-Ren places greater emphasis on renewables whereas IMP-Neg on deployment of CDR to be able to achieve significant, sustained net negative global GHG emissions. IMP-LD emphasizes efficient resource use and shifts in consumption patterns, leading to low demand for resources, while ensuring a high level of services (IMP-LD). IMP-GS pathway represents gradual strengthening of near-term mitigation whereas IMP-SP represents a strategy centering shifting global pathways towards sustainable development, including by reducing inequality.

Figure 1 below highlights two key underlying climate scenario features that are also material demand drivers – total energy demand and primary energy mix in renewables – and shows how they differ across strategies.

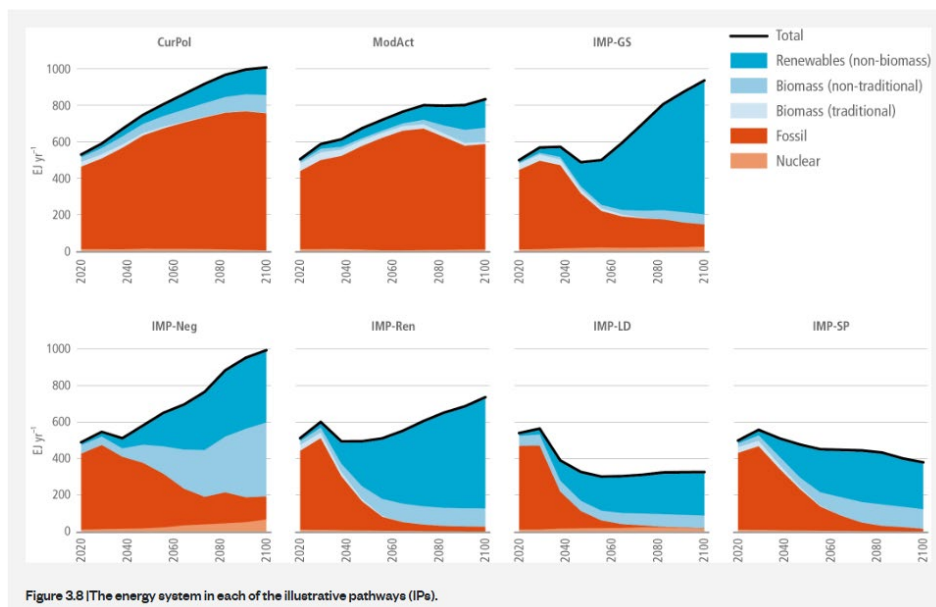


Figure 3.8 | The energy system in each of the illustrative pathways (IPs).

Figure 1. Illustrative 21st century future scenario pathways, emphasizing different strategies for mitigation and different levels of ambition – spanning status quo (CurPol), Moderate Action (ModAct), as well as Paris-consistent 1.5-2C mitigation (IMP-*) pathways, where *=shorthand description of its unique strategy. Reproduced from IPCC AR6 WGIII Chapter 3, Figure 3.8.⁸

There are areas of broad agreement in certain aspects across these scenarios. For example, in IPCC AR6, 1.5–2 °C pathways require rapid declines in fossil generation while expanding electricity supply, largely from clean sources. Pathways limiting warming to 1.5 °C with no or limited overshoot project global electricity systems almost fully decarbonizing by around mid-century, with low- or zero-emission sources supplying roughly 95–100% of electricity and renewables constituting the biggest share across models. Similarly, pathways limiting warming to 2 °C showcase low-carbon sources dominating electricity supply by mid-century, at slightly lower rates of 90–97%. However, despite renewables remaining the largest component in these pathways, the higher warming scenarios have greater contributions from nuclear power and fossil fuels with carbon capture and storage than in 1.5 °C pathways. Further, across these 1.5-2C scenarios, the amount electricity supply expands varies widely from 30–60% by 2050, which can mean very different upstream material demand requirements.

⁸ IPCC AR6 Chapter 3. [Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren, 2022: Mitigation pathways compatible with long-term goals. In IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*[P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.005]

Generally speaking, the most resource-efficient way to navigate transition is to manage overall energy demand through the process because – whether it is used for climatizing and lighting buildings, manufacturing products, producing food and agricultural goods, transporting people, or producing power itself – energy demand is one of the most central drivers of all other impacts. AR6 notes, for example, that a stronger emphasis on demand-side mitigation implies less dependence on CDR and, consequently, reduced pressure on land and biodiversity compared to higher consumption, higher emission scenarios that compensate with high use of BECCS.⁹

Ambitious low-emissions demand-side scenarios suggest that well-being could be maintained or improved while reducing global final energy demand, and some current literature estimates that it is possible to meet decent living standards for all within the 2°C warming window.¹⁰ Strategies for reducing energy and material demand without sacrificing quality of life improvement potential include policies incentivizing use of energy efficient technologies and alternative ways of meeting demand for a particular service (such as transportation) with lower per capita energy, emissions, and/or upstream raw material requirements.

II. What does a 21st century vision imply for copper?

Even within the common frame of sustainably oriented pathways, there can be a wide range of scenario futures with variable impacts on demand for important materials, like copper. Despite this hearing’s appropriate focus on our own nation’s role in long-term future outlooks for copper, the copper market, like so many other commodities, is ultimately a global one. As such, I will start with a discussion of the more readily available global demand and recycling picture for copper before zooming into the more limited domestic US outlooks for sustainable development.

a. Global status & outlook

Currently, around 27 million metric tons (Mt) of refined copper are consumed worldwide each year, 17% of which is met by recycled or reused copper¹¹ (recovering about 45% of what is available each year)¹². Contemporary demand is split between major demand sectors, including building construction (26%), consumer and general products, cooling, and electronics (23%); power and telecom infrastructure (17%); transportation (13%); industrial equipment (12%); and others (9%).¹³ The International Energy Agency (IEA) provides helpful additional insight on copper’s end uses. IEA suggests nearly one-third (29%) of 2024 demand comes from “clean tech” applications, comprised of over 18% from

⁹ IPCC AR6 Chapter 3.

¹⁰ IPCC AR6 WGIII Chapter 5

¹¹ Values for the year 2024 from IEA Global Critical Minerals Outlook 2025.

¹² IEA cites 45.5% end-of-life recycling rate <https://www.iea.org/data-and-statistics/charts/end-of-life-recycling-rates-for-selected-metals>

¹³ Percentages from UNCTAD report 2025, figure 4 <https://unctad.org/system/files/official-document/ditcinf2025d2.pdf>; based on International Copper Study Group (ICSG) (2024). The World Copper Factbook 2024. Lisbon: ICSG. Available at: <https://icsg.org/copper-factbook/>

power grids, 6% from solar, 2% from wind and EVs, respectively, and <1% from grid battery storage and other low emission power generation. In the near term, copper scrap availability is expected to grow alongside consumption until 2030, then outpace demand growth.¹⁴

Unfortunately, IPCC does not yet include a quantitative review of critical mineral demand associated with its climate mitigation scenarios or illustrative pathways.¹⁵ This limits rigorous multi-model-based insights for demand consistent with standardized sustainable pathways, as possible with features like emissions and energy demand data. However, several relevant individual studies have been produced in recent years providing a range of estimates for what climate action-aligned global copper demand may look like.

IEA was an early high visibility contributor, producing an initial set of model results in 2021 based on decarbonization benchmarks originating from the IPCC’s Special Report on limiting warming to 1.5C: net-zero carbon dioxide emissions by 2050 (NZE). In the latest version of IEA’s Global Critical Minerals Outlook (2025), NZE copper demand grows most rapidly in the short-term to 2030, reaching just shy of 35 Mt/yr, then slowing down between 2035 and 2050, breaking 40 Mt/yr in 2045 and ending at 41Mt/yr in 2050. Clean technologies’ share of demand grows rapidly to 44% by 2030, peaking at over half (51%) in 2035 before dipping back down to 48% and staying there 2045-2050. By contrast, under its status quo scenario (Stated Policies or STEPS), IEA anticipates lower levels of copper demand, which stay below 40Mt/yr through 2050, growing steadily from 31Mt/yr in 2030 to over 37Mt/yr in 2050. Clean technology share is predictably lower throughout, holding steady above current levels at ~35% from 2030-2050.

What do other recent studies show? Comparing results across multiple studies would be a step forward toward enabling insights beyond any one author’s, model’s, or scenario’s assumptions about what might be needed. Figure 2¹⁶ presents preliminary analysis from such a review of copper demand scenario data, collected by a doctoral summer fellow at NRDC during the summer of 2024. Because we applied a recency screen, only demand modeling studies published between 2020 and the end of the summer term (August 2024) were collected. The results displayed above represent data from eight unique modeling studies, featuring 22 scenario projections¹⁷ of total global copper demand, and spanning a wide range of climate scenario alignment – from 1.5C-inspired net-zero by 2050 (NZE) up through 2C warming and

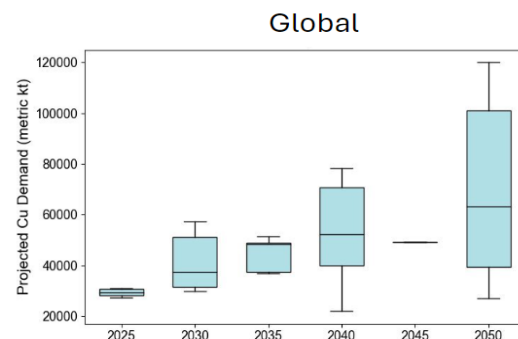


Figure 2. Spread in global copper demand projections for available studies published 2020-2024 (Aug). Demand sector = all/total. Climate scenario alignment varies.

¹⁴ IEA, *Recycling of Critical Minerals* (International Energy Agency, 2024), <https://www.iea.org/reports/recycling-of-critical-minerals>.

¹⁵ This is largely due to limited, but actively emerging, representation of material demand in the standard integrated assessment models.

¹⁶ Figure credit: Dr. Swati Narasimhan, Schneider Fellow Summer 2024.

¹⁷ Not equally distributed across studies, or time period reporting intervals (e.g., only 1 in 2045)

beyond via business as usual and even <4C scenarios. For illustration's sake only, median demand collected from these studies for 2030 was estimated at 37 Mt/yr (min-max: 30-57 Mt/yr) across the study data as currently reflected in our database, which is equal to the 2050 demand in IEA's STEPS scenario but aligned with its NZE scenario demand for between 2030 and 2035. By 2040, median demand grows to 52 Mt/yr (22-78 Mt/yr), exceeding even NZE's 2050 demand by over 25% but 10 years sooner. And by 2050, median demand hits 63 Mt/yr (27-120 Mt/yr). Given the wide range of features, it is not surprising that we would find a larger spread among studies than within one (IEA 2025) alone; however, it is less intuitive that more recent NZE modeling would be on the lower end overall, and appears to reflect artificial influence of one study with more scenarios. While far from complete or comprehensive (requiring updating, further harmonization to ensure useful comparison, and review of more underlying quantitative features), this exercise indicates the kind of useful resource that, if transparently available and interactive, could help inform policymakers by providing a common information on spread, central tendencies, and drivers of difference from best available scientific estimates.

More individual studies continue emerging than can be effectively summarized here: expanding capabilities, improving sector details, modernizing assumptions and potential solutions. One recent example, Deux et al.¹⁸ published a copper-adapted version of their team's BATTMIND model, which was designed to center around trends in transportation sector electrification and explore potential upstream implications for number and location of new mine openings. This study uses a long-run cost curve, built around known mines, deposits and resource characteristics, to predict response to demand, focused around Net-Zero by 2050 scenario pathways. Despite using IEA sourced drivers of demand for non-EV sectors, I observe results to ultimately project lower levels of demand globally than IEA under all of its 8 illustrative scenarios, most likely because of differences in how its transportation sector need is represented. A noteworthy finding the team's model enables is that while dozens of new mine openings will be needed (at least 87 globally through 2050), aggressive recycling economy-wide can enable a 31% reduction in number of new mines compared to their net-zero aligned reference scenario and a 77% reduction from the count needed to meet demand under large battery size and low recycling rate scenario. Studies from Diersen et al.¹⁹ and Ryter et al.²⁰ also show promising outlooks for enhancing copper recycling, especially if implemented in enduring ways; specifically, potential to meet ~50-60% of copper demand for countries outside China before 2030, and displace on average 50% of mined demand for every unit of secondary supply added.

¹⁸ S. Deux et al., "The Electric Vehicle Transition: Effects on Copper Supply Dynamics in a Net-Zero Future," *Resources, Conservation and Recycling* 228 (March 2026): 108798, <https://doi.org/10.1016/j.resconrec.2026.108798>.

¹⁹ Isabel Diersen et al., "The Opportunity for Utilizing End-of-Life Scrap to Meet Growing Copper Demand," *Journal of Advanced Manufacturing and Processing* 7, no. 3 (2025): e70031, <https://doi.org/10.1002/amp2.70031>.

²⁰ John Ryter et al., "Assessing Recycling, Displacement, and Environmental Impacts Using an Economics-Informed Material System Model," *Journal of Industrial Ecology* 26, no. 3 (2022): 1010–24, <https://doi.org/10.1111/jiec.13239>.

b. United States Status & Outlook

Currently, around 2.3 Mt of refined copper are consumed in the United States each year, 25% of which is met by recycled copper.²¹ According to USGS, citing the Copper Development Association, demand is split similarly along lines led by building construction (42%), electrical and electronic products (23%), transportation equipment (18%), consumer and general products (10%) and industrial machinery and equipment (7%).²²

US-specific outlook studies are harder to come by because, in recognition of the global market, country level demand is not typically reported as transparently. During the earlier referenced 2024 review, my team found only 5 unique studies where demand for copper in the US was published in studies where the data were accessible, either via supplemental data files or manual data extraction from figures. Across these 5 studies, we collected a total of 11 scenario projections, where 60% of the studies only provided one scenario, and the top two provide the rest. Grouping by demand scope, only 2 studies provided industry wide estimates, as opposed to a subsector (EVs, or transport + grid), limiting parity with global insights further; however, they found 2030 demand to be about 3 Mt/y (ranging from a low of 2.6Mt/y – through behavior change driven dematerialization, lowering consumer demand and increasing shared infrastructure via urbanization and increased substitution – to a high of 3.2Mt/y from clean energy and electrification focus)²³ and 2050 demand to be 3.6Mt/y (ranging as low as 3Mt/y, for a scenario where product lifetimes are extended, to a high of 3.9Mt/y according to the He and colleagues study dominating scenario count, or 5.1Mt/y in the systematically high Seck and colleagues study²⁴). This limitation underscores the value of more open science and geographically explicit modeling because different countries will have different needs, and clearer pictures of that can inform policy and development decisions that may be better aligned with preventing speculative overdevelopment and aligning with our nation’s needs as the measure of supply security.

III. The role of American copper in powering this 21st century vision

The role of American copper in powering a more sustainable 21st century could be a promising one; however, it requires policymakers to lean into, rather than away from, strong regulation and standards of practice that protect people and planet. This is because raw material production comes with a number of inherent risks that impact equally important resources like freshwater supplies, air pollution, and general ecosystem function. Thus, as

²¹ Value for 2025 data, calculated as ratio of total scrap (new+old) divided by total reported consumption of refined copper. USGS Mineral Commodity Summaries 2026.

<https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-copper.pdf>

²² USGS MCS 2026. <https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-copper.pdf>

²³ Rui He and Mitchell J. Small, “Forecast of the U.S. Copper Demand: A Framework Based on Scenario Analysis and Stock Dynamics,” *Environmental Science & Technology* 56, no. 4 (2022): 2709–17, <https://doi.org/10.1021/acs.est.1c05080>.

²⁴ Gondia Sokhna Seck et al., “Copper at the Crossroads: Assessment of the Interactions between Low-Carbon Energy Transition and Supply Limitations,” *Resources, Conservation and Recycling* 163 (December 2020): 105072, <https://doi.org/10.1016/j.resconrec.2020.105072>.

we pursue industrial policy aimed at expanding supplies of important resources like copper, we must constantly be aware of the complex economic, environmental, and cultural interests at play.

Given the United States' copper resources,²⁵ some new supply development is sure to take place here. However, the location, extent, and nature of domestic development should be dictated by weighing a variety of factors essential to the public interest, not just onshoring for onshoring's sake. For example, preservation of remaining viable fisheries or significant freshwater resources must be given significant deference due to their irreplaceable role in sustaining ecosystems that we, and other creatures, rely on for survival.

It is my view that it is possible, if challenging, to balance objectives ranging from national security to environmental quality to a robust economy that works for the people; they need not be mutually exclusive outcomes. Indeed, current U.S. copper production, refining, and import data clearly show how this balance can work effectively in practice.²⁶ The U.S. is one of the world's major producers of copper ore and where we have fallen short of our domestic demand, we have turned to our closest allies (and, notably, avoided most trade with countries with whom we are not closely allied) to fill the gaps. This balanced approach allows for flexibility, creates opportunities for the U.S. to use its international finance and development tools to raise environmental and social governance standards abroad, and identify where increased domestic investments across the entire commodity value chain prepare us to sustainably and efficiently meet the 21st century demands for copper in this country.

Development that is reflective of true public need, responsibly sited, achieved through informed consent of those impacted, safely and cleanly operated cradle to grave, while providing jobs with dignity along the way should be a win-win. It's a win-win that NRDC is deeply invested in working to bring about in this country. But to get there, industry must be accountable to the public interest, which realistically requires governance as well as policies to internalize social and environmental externalities. Social license to operate – for actors throughout the supply chain – must be earned. Ways to do this include treating communities directly impacted by prospective projects as first and highest priority partners in development rather than obstacles. And at a project's end, environmental quality must be fully restored and, ideally, enhanced.

Industrial policies can help us shape which demand vectors should be prioritized within given timeframes to support sustainable growth in the near- and long-term versus other demand vectors we may want to try to manage and mitigate. Of note, none of the studies reviewed in my above sections include the new surge from AI-supporting datacenters, an emerging sector that adds new demand pressure during an already challenging period of stress on materials for existential threat of climate change. In the vision of the 21st century I am advocating for today, such prioritization would heavily feature industrial activity to support a clean energy transition needed for climate change mitigation. As I've shown

²⁵ USGS MCS 2026

²⁶ USGS MCS 2026

above, for U.S. copper, this means a three-part industrial strategy that aims at a coordinated balance between (1) siting and developing new mining and processing capacity in the best locations possible, (2) managing new and growing demand drivers to focus on efficiencies and limitations, and (3) creating manufacturing and disposal standards that increase the viability and success rate of recycling to help offset virgin material demand even as overall copper demand rises. In my view, this coordinated policy approach can succeed through policymaking focused on these interconnected strategic areas:

- Manage overall energy demand by ensuring affordability for general consumers and maximized efficiency and accountability for major industrial consumers
- Manage overall goods demand, especially of high-intensity critical end use applications such that we can meet the most aggressive levels of global warming mitigation while ensure that limitations on safe extraction of raw materials are not exceeded.
- Minimize waste during goods manufacturing, through a combination of raw material recycling, reuse, and efficient use technologies with consideration of costs and possible need for government investment.
- Maximize overall system levels of end-of-life product recycling and/or reuse, within quality constraints, to supply goods manufacturers and offset primary raw material demand
- Minimize environmental impacts²⁷ during new development, operation, and end of life from mining, processing, and refining facilities; including avoiding, to the maximum extent possible habitat destruction, hydrology disruption, and toxic byproduct release while establishing gold standard and waste containment, water use, and tailings management practices, among others.

But we can't lose the forest for the trees either. If our ultimate goal in fighting climate change is to protect a future of quality for all life on earth, then we must be equally invested in the measures necessary to ensure that production of the industrial building blocks the U.S. and the rest of the world needs to meet this century's existential challenges does not inadvertently destroy the natural systems that humans and all other life on this planet require to survive.

²⁷ Grzegorz Izydorczyk et al., "Potential Environmental Pollution from Copper Metallurgy and Methods of Management," *Environmental Research* 197 (June 2021): 111050, <https://doi.org/10.1016/j.envres.2021.111050>; OAR US EPA, "TENORM: Copper Mining and Production Wastes," Overviews and Factsheets, April 22, 2015, <https://www.epa.gov/radiation/tenorm-copper-mining-and-production-wastes>; "Copper Sulfide Mining," *Earthworks*, <https://earthworks.org/issues/copper-sulfide-mining/>.

IV. Key Takeaways

Concerns over near-term shortfalls for copper are not meritless, but the degree to which we need to turn to new mining for primary production – as well as where and under what conditions we want to permit that new mining to take place – should not be treated as foregone conclusions beyond influence. Copper is a highly recyclable material, and there is potential for significant further improvement beyond current levels through enhanced collection, sorting, and investment in domestic recycling capacity. Recycling has been shown to meaningfully reduce the amount of new mines needed globally while navigating a clean energy transition – especially when combined with material intensity improvements like smaller vehicle batteries.

Nonetheless, recycling and demand avoidance alone are not likely to fully offset the need for new mining. For the U.S. specifically, addressing current midstream gaps in processing and refining capacity would be more powerful for enhancing domestic control of copper supply chains than expanding mining capacity alone and there should be concern among policymakers that several proposed copper projects rely on exporting nearly all of their mined ore outside of the U.S. for refining due to this lack of domestic processing and refining capacity.

While it is reasonable and informative to explore upper-end scenarios when facing uncertain supply and demand futures – both for energy and materials, like copper – speculative forces can create a rush to over extract and overbuild. One of the most powerful thing policymakers can do is to create the conditions for responsibly managed demand growth because this helps ensure pressures on upstream expansion are right sized for what we need to bring about the future we want and avoid unnecessary environmental, cultural, and resource impacts.

The material supply and demand research community could benefit from ensemble modeling efforts like those regularly undertaken by the climate assessment community during, for example, production of IPCC reports because they produce more reliable conclusions – based on consensus trends and ranges emerging from multiple, consistent, lines of independent, high-quality evidence – and more confidence in real world actions needed. Thus, I would urge this committee to consider working with the scientific and academic communities to determine strategic investments in this work to help inform the policy work of this subcommittee and others in government.

Where we do mine, it is essential that we take steps to ensure it is done in the safest and most responsible ways possible, for both people and the environment; certain places may simply pose too great a risk and should be permanently avoided. Further work is needed to explore where most responsible copper development – within the US and otherwise – can take place. U.S. policy that takes more of a directed development approach—the preliminary exploration of a range of geological, geographical, social, economic, and environmental values during the siting and exploration stages of project development—would greatly improve our ability to do that.