# U.S. Senate Committee on Energy and Natural Resources Hearing

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## The coming crunch: exponential demand growth for critical minerals

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Chairman Manchin, Ranking Member Barrasso, Distinguished Committee members,

I am grateful for the invitation to speak before you today and I look forward to engaging with you on these issues of vital importance for the future of the United States' climate change mitigation and geopolitical goals. My testimony today focuses on the exponential demand that is expected for critical minerals in the next decades as a result of the move towards a global energy transition. My research and my remarks today point towards an urgent need for action from the US government, in conjunction with allies and partners here in the US and abroad, to find ways of satisfying that demand.

My testimony is based in part on work conducted by the Wilson Center's Critical Minerals Working Group, made up of stakeholders from industry, academia and civil society, which was convened in the summer of 2021 to examine the vulnerabilities that exist in the critical minerals supply chain, and to discuss how the private sector and government can address them. In addition, I draw on reports written and published by the World Bank and the International Energy Agency.

I would like to emphasize two main points when addressing demand:

- The growth in demand for critical minerals is already impressive but will become increasingly daunting as the energy transition advances.
- Policy makers and industry must work together to find an adequate response to this daunting reality, with priority given to the development of new resources.

**A daunting reality: the pace and scale of rising demand**

With the global energy transition gathering pace, attention has recently turned to an urgent question. Renewable energy and energy storage technologies increasingly rely on the intensive use of certain critical minerals such as lithium, nickel and cobalt, manganese, and rare earth elements. In addition, the growing electrification of our energy matrix here in the US and around the world means that natural resources such as copper and aluminum are in increasingly high demand. The performance, longevity, and energy density of batteries is entirely dependent today on the availability and quality of lithium, nickel, cobalt, manganese and graphite, whereas wind turbines and EV motors depend on REEs for the permanent magnets allow them to generate power. To state the situation simply, the clean energy transition means more batteries, solar panels, wind turbines which in turn means increased demand for critical minerals.

The shift to a clean energy system is set to drive a huge increase in the requirements for these minerals, meaning that the energy sector is emerging as a major force in mineral markets. Fortunately, the earth has these minerals in abundance. Unfortunately, most of the world's reserves of critical minerals have yet to be discovered, and those that are already being exploited are unevenly distributed. To complicate matters still further, and as discussed in a recent Wilson Center publication titled *The Mosaic Approach*,[1] bringing newly discovered reserves of critical minerals to market takes many years, creating a lag between rising demand and new supplies.

The need to secure new lines of supply for the critical minerals essential for the energy transition is a fact now firmly embedded in the mindset of policy makers here in Washington and in other world capitals. However, the urgency of the situation is still not fully understood by many. This urgency stems from two inescapable realities. First, we must recognize the scale of future demand for critical minerals, which in the case of several metals is shockingly large. Second, comes the question of the pace of rising demand. Policy makers must embrace the painful truth that the highly worthy targets set for the energy transition can only be met by a combination of public policy incentives and massive investment **now** by the private sector, here in the United States and abroad, in new mining activities.

To understand the scale of demand growth, it is worthwhile turning to two recent publications by the World Bank (WB) and the International Energy Agency (IEA) respectively. In the first, titled *Minerals for Climate Action: the mineral intensity of the clean energy transition*[2], the authors examine a wide range of critical minerals and estimate their future demand as a result of the growth in renewable energies. As can be seen from the table below (taken from the World Bank report), while there is strong demand growth for all minerals associated with clean energies, in the case of minerals such as cobalt, lithium graphite and indium, annual growth rates reach stratospheric levels of several hundred percent.

[1] https://www.wilsoncenter.org/sites/default/files/media/uploads/documents/critical_minerals_supply_report.pdf

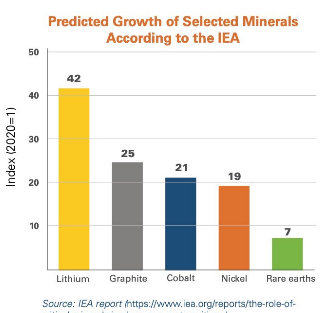
[2] https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

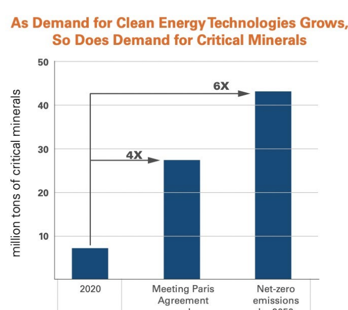
**Table: Mineral production & 2050 Projected Annual Demand from Energy Technologies**
(source World Bank, *Minerals for Climate Action: The mineral intensity of the clean energy transition*)

| Mineral | 2018 annual production (Tons, thousands) [a] | 2050 projected annual demand from energy technologies (Tons, thousands) | 2050 projected annual demand from energy technologies as percent of 2018 annual production |
|---|---|---|---|
| Aluminum | 60,000 | 5,583 | 9% |
| Chromium | 36,000 | 366 | 1% |
| Cobalt | 140 | 644 | 460% |
| Copper | 21,000 | 1,378 | 7% |
| Graphite | 930 | 4,590 | 494% |
| Indium | 0.75 | 1.73 | 231% |
| Iron | 1,200,000 | 7,584 | 1% |
| Lead | 4,400 | 781 | 18% |
| Lithium | 85 | 415 | 488% |
| Manganese | 18,000 | 694 | 4% |
| Molybdenum | 300 | 33 | 11% |
| Neodymium | 23 [b] | 8.4 | 37% |
| Nickel | 2,300 | 2,268 | 99% |
| Silver | 27 | 15 | 56% |
| Titanium | 6,100 | 3.44 | 0% |

For its part, the IEA has highlighted the mineral intensity of renewable energy technologies. In *The Role of Critical Minerals in Clean Energy Transitions*,[3] it is noted that whereas traditional hydrocarbons based energy generation systems our fuel intensive, renewable energy systems are material-, and specifically mineral-intensive. To give one example, "an onshore wind plant requires nine times more mineral resources than a gas-fired power plant." The report goes on, "Since 2010, the average amount of minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables has risen."

## Rising demand for Critical Minerals




[3] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

Basing its analysis on the implementation of the emissions reduction targets of the Paris Agreement, the IEA predicts that the share of total demand from clean energies will rise "to over 40% for copper and rare earth elements, 60- 70% for nickel and cobalt, and almost 90% for lithium. EVs and battery storage have already displaced consumer electronics to become the largest consumer of lithium and are set to take over from stainless steel as the largest end user of nickel by 2040." This stunning growth in demand for critical minerals is made even more daunting if the goal of net-zero emissions by 2050 is added. In that scenario, six times more mineral inputs would be needed in 2040 than today.

According to the IEA report, EVs and battery storage will drive a massive growth in demand for many minerals with lithium demand growing by over 40 times by 2040. In the same period, solar and wind power generation will drive a 300-700% growth in demand for the minerals used in turbines and solar panels. Although investment in these technologies has been timid until recently, as governments implement more rapid and aggressive climate change mitigation strategies, prices have risen and the incentive structure for investors has changed.

Taking a closer look at lithium, an essential element in EV battery technology, it is estimated that by 2030, "the global demand for lithium is expected to surpass two million metric tons of lithium carbonate equivalent, more than doubling the demand forecast for 2025."[4] To put this in perspective, total global production of lithium in 2020 was only 100,000 metric tons.

According to a recent report by graduate students at Georgetown University's McDonough School of Business, the demand for lithium from electric vehicle sales alone by 2030 will exceed current global production:

> "Global lithium production output in 2021 was around 90kt. By extrapolating on historical trends of personal vehicle sales in the US and considering the chemical makeup of a typical lithium-ion battery, which holds about 8kg of lithium, we have calculated that the US will require 68kt of lithium in the year 2030 alone if half of all its vehicles sold are EVs. The pioneering EV and clean energy company Tesla Inc. announced its ambition to sell 20 million EVs per year by 2030, a feat that will require Tesla alone to have access to 160kt of lithium for just one single year of sales by 2030. Demand for other critical minerals is also soaring, and EV batteries reflect just one application of these widely-applied resources."[5]

As we noted in *The Mosaic Approach*:

> "While these predictions take place over the course of decades, exponential increases in demand for lithium are already happening. In a 2021 quarterly earnings report SQM, the second largest lithium producing company in the world, predicted global lithium demand to increase by nearly 50% in 2021. Already unable to keep pace, considering lag time,

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[4] https://www.statista.com/statistics/452025/projected-total-demand-for-lithium-globally/

[5] *Securing Critical Mineral Access for America*, Georgetown University, McDonough School of Business, February 2022, https://static1.squarespace.com/static/62044a6be422b4487fe49cfa/t/6218b42a6ed0fb71648ee002/1645786170126/Report_+Securing+Critical+Mineral+Access+for+America.pdf

> permitting challenges and underinvestment in infrastructure, technological innovation, and human capital, this issue will continue to compound."[6]

The scale of the challenge must therefore not be underestimated. One way to grasp that scale has been put forward by Guillaume Pitron in *The Rare Metals War*,[7] who notes that, with a doubling of demand for REEs every 15 years: "At this rate, over the next 30 years we… will need to mine more mineral ores than humans have extracted over the last 70,000 years."[8]

**Addressing rising demand: the need for an integrated approach.**
Given the scale of demand growth, it should be clear that mere tinkering around with critical minerals policy is unlikely to make a sufficient impact. What is needed today is a "whole of society" approach that incorporates all levels of government, the private sector, research and educational institutions, and end-users of critical minerals. This means adopting a holistic, open-minded approach to the issue, embracing (in order of priority):

- the development of new resources;
- new forms of extraction and processing;
- new technologies both in extraction and applications;
- energy efficiency models; and,
- recycling and waste reduction.

Ignoring any of these elements will make it impossible to build the new energy model and maintain it.

As I have argued elsewhere,[9] there are significant barriers that must be overcome to encourage higher rates of investment and production in the mining of critical minerals here in the US. Permitting remains a major concern, along with human capital shortages and price volatility, but there is a growing sense that, with the right conditions, the extractive industries can rise to the challenge. This will require close coordination between government and the mining industry, with policy makers recognizing that the energy transition in by necessity mineral-intensive, and that steps must be taken to encourage more a more secure critical mineral supply chain.

The recycling of critical minerals has been identified by many, including some in the current administration, as an essential factor in the future of critical minerals supply. And it is true that, because minerals are a component of energy infrastructure and can be recovered and recycled, recycling will play a role. However, there is a simple stark reality that must be addressed. Thus far, policy makers have largely ignored the fact that, although recycling will play an increasingly important role, materials can only be recycled once they have entered the system. This means that as demand grows exponentially, it is logically and practically impossible for recycling to satisfy that demand until there are more raw materials are in the system that current demand. This is a simple point, but one that must be stated and restated.

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[6] https://www.wilsoncenter.org/sites/default/files/media/uploads/documents/critical_minerals_supply_report.pdf, p.11
[7] Guillaume Pitron, "The Rare Metals War: the dark side of clean energy and digital technologies", Scribe, 2020.
[8] https://www.newscientist.com/article/mg24933190-400-why-using-rare-metals-to-clean-up-the-planet-is-no-cheap-fix/
[9] https://www.wilsoncenter.org/article/duncan-wood-testifies-senate-budget-committee-critical-minerals-supply-chain

The IEA estimates that "by 2040, recycled quantities of copper, lithium, nickel and cobalt from spent batteries could reduce combined primary supply requirements for these minerals by around 10%." That is not insignificant, but it is vital to recognize that 90% of future demand growth must be satisfied by newly mined resources. To give an indication of the potential and limitations of future recycling for critical minerals, under current conditions, only 35% of available copper is recycled today.[10] To make matters worse, as the vehicle fleet is electrified, the minerals that are used to produce batteries will not be recycled for at least ten years, as car owners get the maximum use out of their vehicles. This lag means that the full potential for EV battery recycling will only be realized a decade after massive electrification of the fleet begins. As we argued in *The Mosaic Approach*, "Given the expected rapidly rising demand for critical minerals, however, recycling will only ever be able to cover a modest percentage of all demand for critical minerals, and the development of new sources must be a priority."

**Uncertainty and the central place of the extractive industries**

I would like to note a final word of caution. While the predictions and analysis included in this testimony are based on current trends and realities, there is ample scope for error in estimates of demand growth. This is due to uncertainty over new uses for critical minerals, new technological breakthroughs, and of course incentives created by policy and geopolitics.

In the case of some critical minerals, specifically those that have a wide range of applications today across different clean energy technologies, such as copper, chromium, and molybdenum, it is easier to predict growth accurately by extrapolating from current conditions. To quote the World Bank, "This is because these minerals do not depend on the deployment of any one specific technology within the clean energy transition."[11] However, when it comes to minerals that are used in a more limited number of renewable energy applications such as lithium, graphite, and cobalt, there is greater uncertainty over future demand due to the potential for technological innovation. To give one clear example, battery producers are increasingly looking to manganese as a potential substitute for cobalt given its wider availability and lower price.

However, what we can safely argue is that the United States, and most of the rest of the world, find themselves spectacularly ill-prepared to meet the challenge of rising demand for critical minerals, and this must be the main take-aways from our current dilemma. To meet the challenges that we have already identified, as well as those that remain unknown at this time, it is vital that we recognize, once and for all, the central and unavoidable role played by critical minerals extraction in the clean energy transition. Mining is needed to power that transition, in the same way that the oil and gas industry was needed to drive the stunning industrial transformation of the world in the 20th century. If critical minerals stay in the ground, the transition will be insufficient. Urgent steps must be taken soon to address the severe deficit in critical minerals. To paraphrase an old adage, the best time to have done so would have been 10 years ago; the second-best time is now.

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[10] https://copperalliance.org/resource/copper-recycling/

[11] https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf