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Subcommittee on Energy and Mineral Resources

"*Examining the Methodology and Structure of the U.S. Geological Survey's Critical Minerals List*"

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Chairman Stauber, Ranking Member Ocasio-Cortez, and other Members of the Subcommittee, thank you for the opportunity to provide testimony on the U.S. Geological Survey's Critical Minerals List. I am a research professor in the Department of Economics and Business at Colorado School of Mines and hold the Coulter Foundation Chair in Mineral Economics. As part of my university responsibilities, I am deputy director of the Critical Materials Institute, an Energy Innovation Hub established by the U.S. Department of Energy in 2013, to accelerate innovation in energy materials and led by the Ames National Laboratory.

Of relevance for this hearing, I have been involved in the topic of critical minerals and materials for more than fifteen years. In 2007-2008, I chaired the committee of the National Research Council that developed a conceptual framework for criticality assessment that is reflected in many of the criticality assessments since the committee's report was published (National Research Council, 2008).

My testimony represents my personal views, although these views reflect work I have done and opportunities I have had at Colorado School of Mines and with the Critical Materials Institute.

I organize my testimony around four topics: the concept of a critical mineral or material; a review of selected other (non-U.S. Geological Survey) assessments of mineral and material criticality; a comparison of the U.S. Geological Survey's 2022 assessment with the 2023 assessment by the U.S. Department of Energy; and consideration of the question, why have a list?

Concepts

A critical mineral or material provides essential functionality to a modern engineered material, component or system; has few if any easy substitutes; and is subject to supply-chain risks or longer-term concerns about availability. It is the combination all three of these characteristics that makes a mineral or material 'critical' in the specialized sense of the concept – not simply that a mineral or material is indispensable or essential, the common meaning of the word.

Five key aspects of critical minerals and materials are:

First, *risks come in two basic forms: physical unavailability and price*. Physical-unavailability risk reflects the probability and consequences of not being able to obtain a needed mineral or material. Price risk reflects the probability and consequences of unexpected fluctuations in price.

Second, the consequences of lack of physical availability or unexpected price changes differ from circumstance to circumstance. In other words, *something important is at risk but exactly what is at risk depends on the circumstance*. For a company, profits and growth are at risk if a supply disruption leads to physical unavailability of a material or to unexpected increases in input costs. For a nation's manufacturing sector, at risk are the viability of the sector and jobs in the sector. For national security, at risk is the ability of a nation's military and associated civilian infrastructure to respond during and immediately following a national emergency. For the energy transition, at risk is the transition itself if input minerals and materials are not available in sufficient quantities and at affordable costs from sources that are secure, environmentally sustainable and socially responsible.

Third, *the sources of risk vary from one mineral and material to another and differ between the short term and long term*. In the short term (one or a few years, up to about a decade), the principal sources of risk relate to the fragility of the geography of existing production, processing and use of minerals and the materials. More specifically, these risks include:

- Geographically concentrated production in a small number of mines, companies or countries;
- Geopolitical risks in important producing countries;
- The small, opaque markets that exist for many of the minor metals included in most assessments of critical minerals and materials, which leaves market participants vulnerable to unexpected disruptions and, moreover, discourages investment in the sector because investors do not sufficient knowledge about a sector to make them comfortable investing in the sector; and
- Reliance on byproduct production of a mineral or metal, in which case the availability of the byproduct is a function not just of market conditions for the byproduct but also conditions facing the main product.

In the long term (a decade or more into the future), the principal sources of risk relate to more fundamental determinants of mineral availability:

- How abundant is a mineral in the earth's crust?
- Is there a technology proven at scale that can recover the mineral at prices customers are willing to pay, with environmental impacts that are acceptable to society?
- Can companies and local communities work together to effectively manage the environmental and social impacts that often accompany mining and processing?
- Given the long lead times in developing new mines, will there be sufficient investment today to ensure that a decade or two from now we have sufficient and affordable quantities of minerals to meet the growing demands of society?

Fourth, *criticality is dynamic*. Which specific minerals and materials are 'critical' changes over time. As technologies evolve and change, so too do material requirements. As we transition from lead-acid batteries in internal-combustion engines to lithium-ion batteries in electric vehicles, lead becomes less critical, while lithium and other associated battery materials (such as nickel and cobalt) become more critical. Another example comes from lighting. As society moved from compact-fluorescent bulbs to light-emitting diode (LED) bulbs, the demand and prices for the rare-earth element europium fell considerably as did europium's criticality.

Fifth, *it's about processing, not just mining*. While mining is the essential starting point for mineral-derived materials, in many cases what is missing in the United States or represents a choke point elsewhere in the world is processing and the production of intermediate products that occur after mining.

Selected Assessments of Critical Minerals and Materials

Many entities have conducted formal assessments. For a recent paper that reviews criticality studies and methods, see Schrijvers and others (2020). For an earlier and detailed discussion of methodology from the perspective of corporations, nations and the world, see Graedel and others (2012).

One of the early studies in the modern era of concern about critical minerals and materials (beginning in about 2005) was National Research Council (2008), which I referred to earlier in my testimony. The major contribution of this study was a conceptual framework for assessing material criticality emphasizing two criticality dimensions: likelihood of a supply disruption, and the consequence of the disruption should it occur. Indicators of a supply disruption include those listed in the previous section of this testimony, which differ depending on whether one is concerned about the short term or long term. Many subsequent studies use modified versions of this conceptual framework, customizing the assessment around those factors that are important in a particular circumstance.

Corporate assessments: A number of companies evaluate their raw material risks through assessments of materials criticality. For example, Ku and Hung (2014) describe General Electric's approach that, at the time, evaluated the materials used in its manufacturing and commercial operations, scoring each material in two dimensions: supply and price risk, and impact on General Electric operations.

National or regional assessments: A number of countries or regions, other than the United States, have assessed the raw material risks faced by their economies or that threaten national security. Notably, the European Union assessed critical raw materials and published lists in 2011, 2014, 2017, 2020 and 2023 (European Commission, 2023). All these assessments are organized around two determinants of criticality: supply risk, and economic importance. Hatayama and Tahari (2015) evaluated critical minerals and materials from the perspective of Japan. Lusty and others (2021) assessed minerals and materials critical for technology applications in the United Kingdom (UK), based on two considerations: global supply risk, and UK economic vulnerability. The Indian Ministry of Mines (2023) identifies 30 minerals critical to India's economy.

Nearly all assessments of critical minerals and materials, including the national assessments listed above, reflect the perspective of mineral and material consumers. However, two nations, Australia and Canada, have assessed critical minerals and established lists of critical minerals that reflect opportunities for these nations to produce and export minerals to customers in countries facing supply-chain risks (Australian Government Department of Industry, Science and Resources 2023, Natural Resources Canada 2023).

Energy-transitions assessments: The International Energy Agency (2021) and the International Renewable Energy Agency (Gielen 2021) published assessments of minerals essential for low-carbon energy technologies subject to supply-chain risks and uncertainties about long-term availability.

World: For an evaluation of material criticality for the world as a whole, see Graedel and others (2015), which assesses criticality in three dimensions: supply risk, vulnerability to a supply restriction, and environmental implications of mineral and material production.

Comparing U.S. Assessments

We in the United States have three current, public and published assessments and lists of critical minerals and materials: the U.S. Geological Survey 2022 list that is the focus of this hearing, the U.S. Department of Energy's 2023 assessment and list of critical materials for energy (U.S. Department of Energy 2023), and the Defense Logistics Agency's evaluation and list of strategic materials for military and essential civilian uses (see https://www.dla.mil/Strategic-Materials/). Table 1 presents a basic comparison of the U.S. Geological Survey and U.S. Department of Energy assessments and lists. Table 2 summarizes the lists emerging from these two assessments. I have not included the assessment of the Defense Logistics Agency because I am less familiar with this assessment than the other two assessments.

Table 1. Comparing Two U.S. Assessments and Lists of Critical Minerals and Materials

	U.S. Geological Survey 2022	U.S. Department of Energy 2023
Narrow purpose	To comply with the Energy Act of 2020, and more broadly inform government and the public about critical minerals	To inform DOE strategy on critical minerals & materials research, development, demonstration, and commercialization
What or who is at risk	U.S. national security and economic development	The global development and deployment of low-carbon energy technologies
Material scope	70 nonfuel mineral commodities (usually listed as chemical elements)	Screening analysis of 37 materials, detailed evaluation of 23 materials with important uses in energy technologies
Time frame	Not explicitly forward looking, except to the extent that data on the present and recent past provide insight into the future	Explicitly forward looking (short term = 2020-2025, medium term = 2025-2035)
Key criticality indicators	Disruption potential (essentially lack of diversity in supply), international trade exposure (net import dependence), and economic vulnerability aggregated into a single supply-risk score. A single point of failure.	Importance to energy applications, supply risk
Role of data, expert judgment, forecasts and future scenarios	Draft list relies to the extent possible on objective data on the present and recent past. Final list also includes consideration of interagency feedback and public comment.	Relies on both (a) objective data on the present and recent past and (b) future demand scenarios compared to current production capacity. Preliminary list of critical and near critical materials released for public comment prior to issuance of the final report.
Number of minerals in the list	50 critical minerals, 36 on the basis of quantitative assessment, 3 based on a single point of failure, and 11 based on qualitative assessment when insufficient data were available to allow for quantitative assessment.	A number of critical materials for energy. For the short term (to 2025): 7 critical, 9 near critical. For the medium term (2025-2035): 13 critical, 6 near critical.

Sources: Nassar, N.T., and Fortier, S.M., 2021. *Methodology and technical input for the 2021 review and revision of the U.S. Critical Minerals List*: U.S. Geological Survey Open-File Report 2021–1045, 31 p., https://doi.org/10.3133/ofr20211045; U.S. Department of Energy, *Critical Materials Assessment*, July 2023, available at: https://www.energy.gov/sites/default/files/2023-07/doe-critical-material-assessment_07312023.pdf.

Table 2. The Priorities Identified by the U.S. Geological Survey and the U.S. Department of Energy

Element or Material	**U.S. Geological Survey, 2022, Critical Minerals**	**U.S. Department of Energy, 2023, Critical Materials for Energy, Near Critical or Critical**	
		Short Term (2020-2025)	**Medium Term (2025-2035**
Aluminum	X		X
Antimony	X		
Arsenic	X		
Barite	X		
Beryllium	X		
Bismuth	X		
Cerium	X		
Cesium	X		
Chromium	X		
Cobalt	X	X	X
Copper			X
Dysprosium	X	X	X
Electrical steel		X	X
Erbium	X		
Europium	X		
Fluorspar	X	X (fluorine)	X (fluorine)
Gadolinium	X		
Gallium	X	X	X
Germanium	X		
Graphite	X	X (natural)	X (natural)
Hafnium	X		
Holmium	X		
Indium	X		
Iridium	X	X	X
Lanthanum	X		
Lithium	X	X	X
Lutetium	X		
Magnesium	X	X	X
Manganese	X		
Neodymium	X	X	X
Nickel	X	X	X
Niobium	X		
Palladium	X		
Platinum	X	X	X
Praseodymium	X	X	X
Rhodium	X		
Rubidium	X		
Ruthenium	X		
Samarium	X		
Scandium	X		
Silicon			X
Silicon carbide		X	X
Tantalum	X		
Tellurium	X		
Terbium	X	X	X
Thulium	X		
Tin	X		
Titanium	X		
Tungsten	X		

Uranium		X	X
Vanadium	X		
Ytterbium	X		
Yttrium	X		
Zinc	X		

Sources: U.S. Geological Survey, Department of the Interior, 2022, "2022 Final List of Critical Minerals," *Federal Register*, 87 FR 10381, pp.10381-10382. February 24; U.S. Department of Energy, *Critical Materials Assessment*, July 2023, available at: https://www.energy.gov/sites/default/files/2023-07/doe-critical-material-assessment_07312023.pdf.

The U.S. Geological Survey list consists of 50 minerals that meet the threshold for designation as critical minerals. But this assessment presents much more detail than implied by the single list. Fifty-four minerals are ranked from most to least risky when sufficient data were available to allow for quantitative assessment. Eleven additional minerals were evaluated qualitatively. Three minerals were designated critical on the basis of a single point of failure in the domestic (U.S.) supply chain even though they did not qualify as critical on the basis of the quantitative assessment.

The U.S. Department of Energy designates materials as critical, near critical and not critical and makes these determinations over two time periods – the short term (2020-2025) and the medium term (2025-2035). A larger number of materials are critical or near critical for the medium term compared to the short term – 19 for the medium term, 16 for the short term. Aluminum, copper and silicon are critical or near critical in the medium term but not in the short term.

Overall, *the U.S. Geological Survey assessment is broad and U.S.-centric, focusing on minerals important for U.S. national security and economic activity; and is based on data from the present and recent past, and thus is forward-looking only to the extent that these data provide insight into the future. The U.S. Department of Energy assessment is energy-centric and takes a global perspective, focusing on materials important for energy technologies, and is explicitly forward looking with perspectives on the short term (2020-2025) and medium term (2025-2035).* Both assessments are described in sufficient detail that others can easily see the basis for a material's designation as critical. Others also could replicate the analysis or modify the approach if they wish.

Why Have a List?

Broad considerations: An evaluation of mineral and material criticality can be indispensable in setting priorities and informing private-sector decisions and government policies. A list is simply the most basic of the outputs of an evaluation.

A list is most useful when it is viewed as an intermediate product rather than the final word - the result of an initial screening and identification of minerals and materials deemed important for further, more-detailed evaluation.

The danger of a simple list of minerals and materials as either critical or not critical is that it obscures the complexity of criticality, suggesting that criticality is "yes/no" rather than a continuum of risk and importance.

The longer a list is, the less it represents a prioritization and the less useful the designation 'critical' is. If everything is critical, then is anything really critical?

The broader the scope of analysis is, the less useful it is for specific decisions and policies. A narrow focus, for example, on military preparedness or energy technologies is potentially more useful for policy making than an assessment and list based on all economic sectors of an economy, especially for a large economy such as the United States.

The U.S. Geological Survey list: The list is long (50 minerals), and the scope is broad (national security, national economic activity). Thus, the primary uses of the list should be (1) to signal to government officials and the broader public that minerals are essential and subject to supply-chain risks and (2) to identify specific supply chains for further analysis. Designation as 'critical' should not by itself qualify a mineral for special treatment, which should require this more in-depth analysis of particular supply chains.

In other words, the U.S. Geological Survey list should inform but not determine public policy. A list should simply be one of several inputs to the formulation of public policy.

Thank you for the opportunity to testify today. I am happy to address any questions the Committee Members have.

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