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Testimony on "Strategic and Critical Minerals Policy: Domestic Minerals Supplies and Demands in a Time of Foreign Supply Disruptions"
Subcommittee on Energy and Mineral Resources
Committee on Natural Resources
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Good morning, Mr. Chairman, members of the Committee, ladies and gentlemen. My name is Rod Eggert. I am Professor of Economics and Business at Colorado School of Mines. My area of expertise is the economics of mineral resources. I participated in two activities relevant for today's hearing. I chaired the committee of the U.S. National Research Council (NRC) that prepared the 2008 report *Minerals, Critical Minerals, and the U.S. Economy*. I served as a member of the committee of the American Physical Society and the Materials Research Society (APS/MRS) that prepared the 2011 report *Energy Critical Elements: Securing Materials for Emerging Technologies*.

I organize my remarks into three sections. First, I describe the context for current concerns about strategic and critical minerals. Second, I summarize the 2008 NRC report on critical minerals identified above. Third, I present my personal views on strategic and critical minerals, which are significantly shaped by the NRC and APS/MRS studies.

Context

Mineral-based materials are becoming increasingly complex. In its computer chips, Intel used 11 mineral-derived elements in the 1980s and 15 elements in the 1990s; it may use up to 60 elements in the future. General Electric uses some 70 of the first 83 elements of the periodic table in its products. In contrast, as recently as two or three decades ago, a typical household owned products containing perhaps 20 elements.

Moreover, new technologies and engineered materials create the potential for rapid increases in demand for some elements used previously and even now in relatively small quantities. The most prominent—although by no means only—examples are gallium, indium and tellurium in photovoltaic solar cells; lithium in automotive batteries; and rare-earth elements in wind turbines, hybrid vehicles, compact-fluorescent light bulbs, and a number of defense and military applications.

These technological developments raise two concerns. First, there are fears that supply will not keep up with the explosion of demand due to the time lags involved in bringing new production capacity online or more fundamentally the basic geologic scarcity of certain elements. Second, and more-directly relevant to today's hearing, there are fears that supplies of some elements are insecure due to, for example, import dependence, export restrictions on primary raw materials by some nations, industry concentration, or the reliance on byproduct production that characterizes the supply of some strategic and critical minerals. In both cases, mineral availability—or more precisely, unavailability—has emerged as a potential constraint on the development and deployment of emerging and important technologies, especially in the clean-energy and defense sectors.

Minerals, Critical Minerals, and the U.S. Economy

It was in this light that the standing Committee on Earth Resources of the National Research Council initiated a study and established an ad hoc committee, which I chaired, to examine the evolving role of nonfuel minerals in the U.S. economy and the potential impediments to the supplies of these minerals to domestic users. The U.S. Geological Survey (USGS) and the National Mining Association sponsored the study, the findings of which appear in the volume *Minerals, Critical Minerals, and the U.S. Economy* (NRC 2008).

The report provides a broad context for current discussions and concerns. It defines a 'critical' mineral as one that is both essential in use (difficult to substitute away from) and subject to some degree of supply risk. Under this definition, 'strategic' minerals are the subset of critical minerals essential in military applications.

The degree to which a specific mineral is critical or strategic can be illustrated with the help of a figure (Figure 1). The vertical axis represents the impact of a supply restriction should it occur, which increases from bottom to top. The impact of a restriction relates directly to the ease or difficulty of substituting away from the mineral in question. The more difficult substitution is, the greater the impact of a restriction (and vice versa). The impact of a supply restriction can take two possible forms: higher costs for users (and potentially lower profitability), or physical unavailability (and a "no-build" situation for users).[1]

The horizontal axis represents supply risk, which increases from left to right. Supply risk reflects a variety of factors including: concentration of production in a small number of mines, companies, or nations; market size (the smaller the existing market, the more vulnerable a market is to being overwhelmed by a rapid increase in demand); and reliance on byproduct production of a mineral (the supply of a byproduct is determined largely by the economic attractiveness of the associated main product). Import dependence, by itself, is a poor indicator of supply risk; rather it is import dependence combined with concentrated production that leads to supply risk. In Figure 1, the hypothetical Mineral A is more critical than Mineral B.

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[1] When considering security of petroleum supplies, rather than minerals, the primary concern is costs and resulting impacts on the macroeconomy (the level of economic output). The mineral and mineral-using sectors, in contrast, are much smaller, and thus we are not concerned about macroeconomic effects of restricted mineral supplies. Rather the concern is both about higher input costs for mineral users and, in some cases, physical unavailability of an important input.

Taking the perspective of the U.S. economy overall in the short to medium term (up to about a decade), the committee evaluated eleven minerals or mineral families. It did not assess the criticality of all important nonfuel minerals due to limits on time and resources. Figure 2 summarizes the committee's evaluations. Those minerals deemed most critical at the time of the study—that is, they plotted in the upper-right portion of the diagram—were indium, manganese, niobium, platinum-group metals, and rare-earth elements.

Any list of critical minerals reflects conditions at a specific point in time. Criticality is dynamic. A critical mineral today may become less critical either because substitutes or new sources of supply are developed. Conversely, a less-critical mineral today may become more critical in the future because of a new use or a change in supply risk.

Although the study did not make explicit policy recommendations, it made three policy-relevant recommendations, which I quote below:

1. The federal government should enhance the types of data and information it collects, disseminates, and analyzes on minerals and mineral products, especially as these data and information relate to minerals and mineral products that are or may become critical.

2. The federal government should continue to carry out the necessary function of collecting, disseminating, and analyzing mineral data and information. The USGS Minerals Information Team, or whatever federal unit might later be assigned these responsibilities, should have greater authority and autonomy than at present. It also should have sufficient resources to carry out its mandate, which would be broader than the Minerals Information Team's current mandate if the committee's recommendations are adopted. It should establish formal mechanisms for communicating with users, government and nongovernmental organizations or institutes, and the private sector on the types and quality of data and information it collects, disseminates, and analyzes. It should be organized to have the flexibility to collect, disseminate, and analyze additional, nonbasic data and information, in consultation with users, as specific minerals and mineral products become relatively more critical over time (and vice versa).

3. Federal agencies, including the National Science Foundation, Department of the Interior (including the USGS), Department of Defense, Department of Energy, and Department of Commerce, should develop and fund activities, including basic science and policy research, to encourage U.S. innovation in the area of critical minerals and materials and to enhance understanding of global mineral availability and use.

Four Propositions

I organize my personal views around four propositions. First, *the issues are broader than rare earths, despite the prominence of rare earths in the news over the last year*. Exactly which minerals are ‘critical’ (essential in use, subject to supply risk) varies from industry to industry, nation to nation, and over time. A number of recent studies suggest possible critical elements. Each list reflects a specific context.

In the field of energy, the U.S. Department of Energy (2010) identifies five rare earths (dysprosium, europium, terbium, neodymium, and yttrium) and indium as especially critical to wind turbines, fluorescent lighting, electric vehicles, and photovoltaic thin films. A study by the American Physical Society and Materials Research Society (APS/MRS, 2011) focusing on energy technologies identifies the same six elements as possibly critical, plus several other rare earths, the platinum-group elements, and several elements important for photovoltaics (gallium, germanium, selenium, tellurium), as well as cobalt, helium, lithium, rhenium, and silver.

For military hardware and defense systems, Parthemore (2011) identifies the following elements as critical: gallium, lithium, niobium, the rare-earth elements, rhenium, and tantalum.

For European industry, the European Commission (2010) identifies fourteen elements or families of elements as critical: antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, the platinum-group elements, rare earths, tantalum, and tungsten.

The Japan Oil, Gas and Metals National Corporation (JOGMEC) maintains joint government-industry stockpiles for seven elements (chromium, cobalt, manganese, molybdenum, nickel, tungsten, and vanadium) deemed especially important for Japanese industry and for which there are significant supply risks. JOGMEC is closely monitoring several others (gallium, indium, niobium, platinum, rare earths, strontium, and tantalum).

Over time, which materials are critical changes—with advances in materials science and engineering that reduce reliance on specific elements, and with advances on the supply side that relax supply constraints.

Second, *each element has its own story, and import dependence by itself need not be risky*. From all the attention rare earths have received, one might think that geopolitical risks and import dependence are the only cause for concern about availability and supply risk. Geopolitical risks and import dependence certainly are important for those elements with geographically concentrated production, where one or a small number of companies or governments might act opportunistically or unpredictably to the disadvantage of users. But import dependence by itself need not be risky if foreign sources are numerous and diversified, and if the associated foreign governments believe in undistorted international trade.

Different elements have different constraints on availability, as APS/MRS (2011) illustrates. Although essentially no element is in danger of being used up (or depleted) in a geologic sense, some elements are not significantly concentrated by geologic process above their average crustal abundance. Germanium—used in fiber optics, infrared optics, and photovoltaic cells—is an example. Germanium is not especially rare on average in the earth’s crust but rarely is present as the main component in minerals.

In other cases, technical limitations constrain the availability of an element. Rare-earth elements actually are not very rare geologically. They exist in a number of minerals, such as eudialyte, that at present are not a source of supply because existing methods of mineral processing and extractive metallurgy are inadequate (both technically and commercially) to remove the rare earths from other elements and, in turn, separate the specific rare-earth elements from one another.

Byproduct supply is another source of supply risk. Indium, for example, is produced as a byproduct of zinc production. Tellurium is a byproduct of copper refining. The key insight here is that the availability of indium, tellurium, and other byproducts is strongly influenced by the commercial attractiveness of the byproduct’s associated main product (zinc in the case of indium, copper for tellurium). A significant increase in the price of a byproduct may not result in a significant increase in the production of the byproduct, once the available byproduct is recovered from a main-product ore.

Environmental and social concerns are factors influencing the availability of an element. The point is not to dispute that mineral production can have negative consequences for the natural environment or local communities; it can and does in some circumstances. Rather the point is: processes to ensure that mineral production occurs in ways that are consistent with standards for environmental protection and respect for society can (a) increase the time lag between an unexpected increase in demand and new production capacity to meet this demand and (b) redirect the location of production away from nations with stricter (or less-predictable) environmental and social rules to nations with less-strict (or more-predictable) rules.

Third, *markets are responding, but time lags can be significant*. Markets provide powerful incentives for investments that re-invigorate supply and reduce supply risk. There are minor manias now in exploration for mineral deposits containing rare-earth elements and, separately, lithium. Over the next five to ten years, a number of non-Chinese rare-earth mines are likely to begin production. However, given the long lead times between initial exploration and mining (which can range anywhere from five to fifteen years or more), only those rare-earth projects in advanced exploration or development prior to the rare-earths crisis of the last year will be producing rare earths in the next few years.

Increased recycling also can be an important response to constraints on supply. Recycling comes in two forms. The most obvious comes from recycling of products at the ends of their lives—for example, recovering ferrous and nonferrous metals from junked automobiles. Less obvious but very important is the recycling of manufacturing scrap or waste.

On the demand side, markets encourage users of mineral-based elements to obtain “insurance” against mineral supply risks. In the short to medium term users can, for example, maintain stockpiles, diversify sources of supply, develop joint-sharing arrangements with other users, or develop tighter relations with producers. Over the longer term, users might invest in new mines in exchange for secure supplies or, undertake research and development to substitute away from those elements subject to supply risks.

Fourth, *there are essential roles for government*. To ensure mineral availability over the longer term and reliability of supplies over the short to medium term, I recommend that government activities focus on:

- *Encouraging undistorted international trade*. The governments of raw-material-importing nations should fight policies of exporting nations that restrict raw-material exports to the detriment of users of these materials.

- *Improving regulatory approval for domestic resource development*. Foreign sources of supply are not necessarily more risky than domestic sources. But when foreign sources are risky, domestic production can help offset the risks associated with unreliable foreign sources. Developing a new mine in the United States appropriately requires a pre-production approval process that allows for public participation and consideration of the potential environmental and social effects of the proposed mine. This process is costly and time consuming—arguably excessively so, not just for mines but for developments in all sectors of the economy. I am not suggesting that mines be given preferential treatment, rather that attention be focused on developing better ways to assess and make decisions about the various commercial, environmental, and social considerations of project development.

- *Facilitating the provision of information and analysis*. I support enhancing the types of data and information the federal government collects, disseminates and analyzes. Sound decision making requires good information, and government plays an important role in ensuring that sufficient information exists. In particular, I recommend (a) enhanced focus on those parts of the mineral life cycle that are under-represented at present including: reserves and subeconomic resources, byproduct and coproduct primary production, stocks and flows of materials available for recycling, in-use stocks, material flows, and materials embodied in internationally traded goods and (b) periodic analysis of mineral criticality over a range of minerals. At present, the markets for most strategic and critical minerals are less than completely transparent, in large part because the markets are small and often involve a relatively small number of producers and users, many of which find it to their competitive advantage to keep many forms of information confidential.

- *Facilitating education and research*. I recommend that the federal government develop and fund pre-commercial activities that are likely to be underfunded by the private sector acting alone because their benefits are diffuse, difficult to capture, risky and far in the future. Over the longer term, science and technology

> are key to responding to concerns about the adequacy and reliability of mineral resources—innovation that both enhances our understanding of mineral resources and mineral-based materials and improves our ability to recycle essential, scarce elements and substitute away from these elements.
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> Education and research go hand in hand. Educational programs, especially those at the graduate level, educate and train the next generation of scientists and engineers. On the supply side, education and research in the geosciences, mining, mineral processing and extractive metallurgy, environmental science and engineering, manufacturing, and recycling can help mitigate supply risks and increase mineral availability. On the demand side, improvements in materials design—fostered by education and research in materials science and engineering—can ease the pressures imposed by those elements or minerals subject to supply risks or limited availability. Government, in addition to simply funding education and research, can play an important role in facilitating collaborations among universities, government research laboratories, and industry.

A common conclusion of almost all recent studies on strategic and critical minerals is to urge governments to improve and expand activities related to information and analysis, education, and research (for example, APS/MRS 2011, European Commission 2010, NRC 2008).

A number of other government interventions in markets have been proposed, such as military or economic stockpiles of rare earths and other critical elements; loan guarantees for investments in mines and processing facilities; and special, fast-track environmental permitting for mines that would produce rare earths or other critical minerals. These more-direct market interventions, although perhaps advisable in specific circumstances, are more controversial and less compelling in general as responses to the challenges of critical minerals.

To sum up my personal views, the current situation with strategic and critical minerals requires attention but not panic. By undertaking sensible actions today, there is no reason for crises to develop. But I also am aware that without a sense of panic, we may not undertake these actions.

Thank you for the opportunity to testify today. I would be happy to address any questions you have.

Notes

This testimony draws on the documents cited in the reference list, especially APS/MRS (2011), Eggert (2010), and NRC (2008). The testimony is a revised and modified version of related testimony I presented before (a) the Subcommittee on Energy, Committee on Energy and Natural Resources, U.S. Senate, September 30, 2010, on the role of strategic minerals in clean-energy technologies and other applications and (b) the Committee on Industry, Research, and Energy of the European Parliament, Brussels, January 26, 2011.

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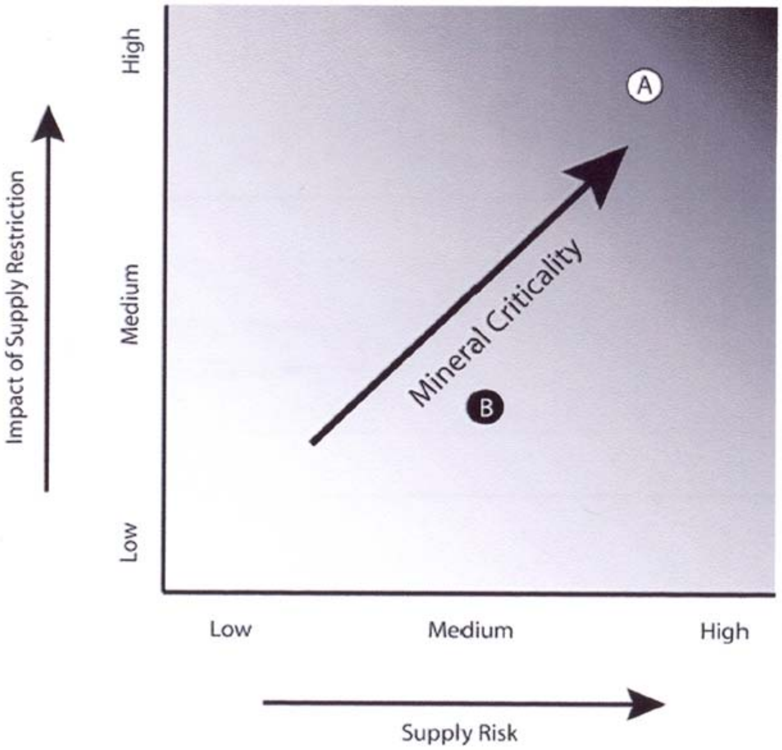

Figure 1. The Criticality Matrix. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

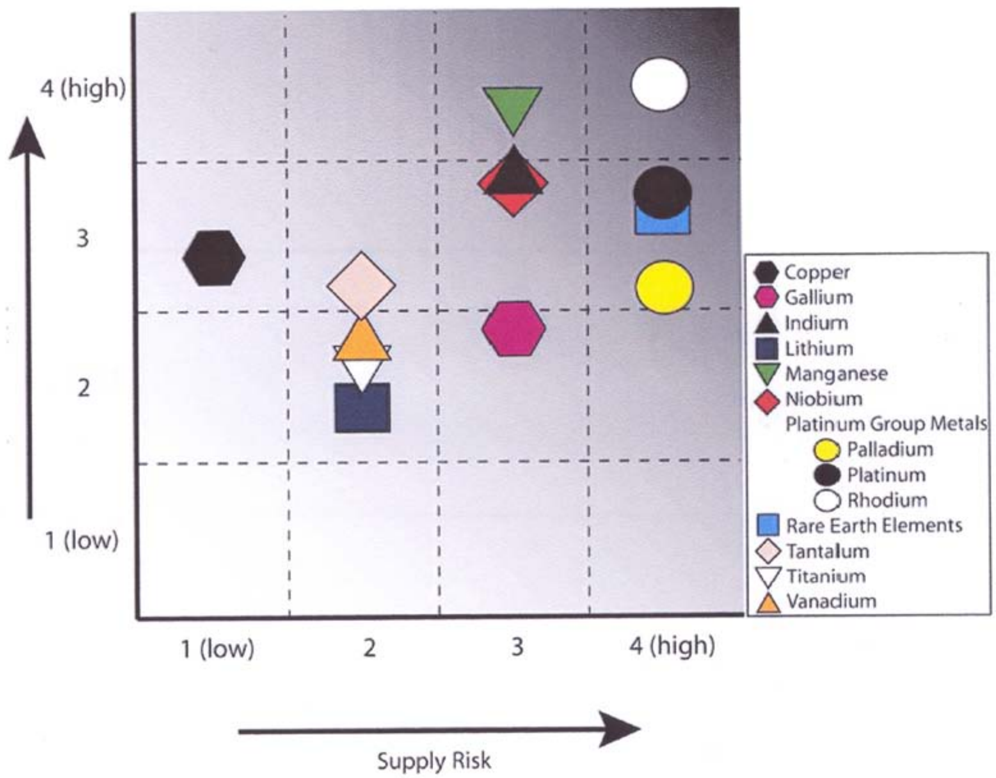

Figure 2. Criticality Evaluations for Selected Minerals or Mineral Families. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).