

**CRITICAL MINERALS AND EMERGING ENERGY TECHNOLOGIES**

**Statement of**

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**Before the**

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Committee on Energy and Natural Resources  
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Good morning, Madam Chairman and members of the Committee. 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 begin my testimony by describing the context for current concerns about critical minerals and clean energy technologies. I then present perspectives on these concerns from two published documents: a 2008 study of the National Research Council (NRC)<sup>1</sup> on critical minerals (I chaired the committee that prepared this report), and a 2010 paper with my personal views on critical minerals, published in the National Academies' *Issues in Science and Technology*. Finally, I briefly describe the activities of a panel on which I serve now, organized under the auspices of the American Physical Society. This panel's work focuses on critical elements for emerging energy technologies.

### 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. 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 examples are gallium, indium and tellurium in photovoltaic solar cells; lithium in automotive batteries; and rare-

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<sup>1</sup> The National Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

earth elements in permanent magnets for wind turbines and hybrid vehicles, as well as in compact-fluorescent light bulbs.

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, there are fears that supplies of some elements are insecure due to, for example, U.S. import dependence, export restrictions on primary raw materials by some nations, and industry concentration. In both cases, mineral availability—or more precisely, unavailability—has emerged as a potential constraint on the development and deployment of emerging energy technologies.

*Minerals, Critical Minerals, and the U.S. Economy*<sup>2</sup>

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* (National Academies Press, 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. The degree to which a specific mineral

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<sup>2</sup> This section of my testimony draws on testimony Steven Freiman and I prepared (and Dr. Freiman delivered) for the hearing before the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology, “Rare Earth Minerals and 21<sup>st</sup> Century Industry,” March 16, 2010.

is critical 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

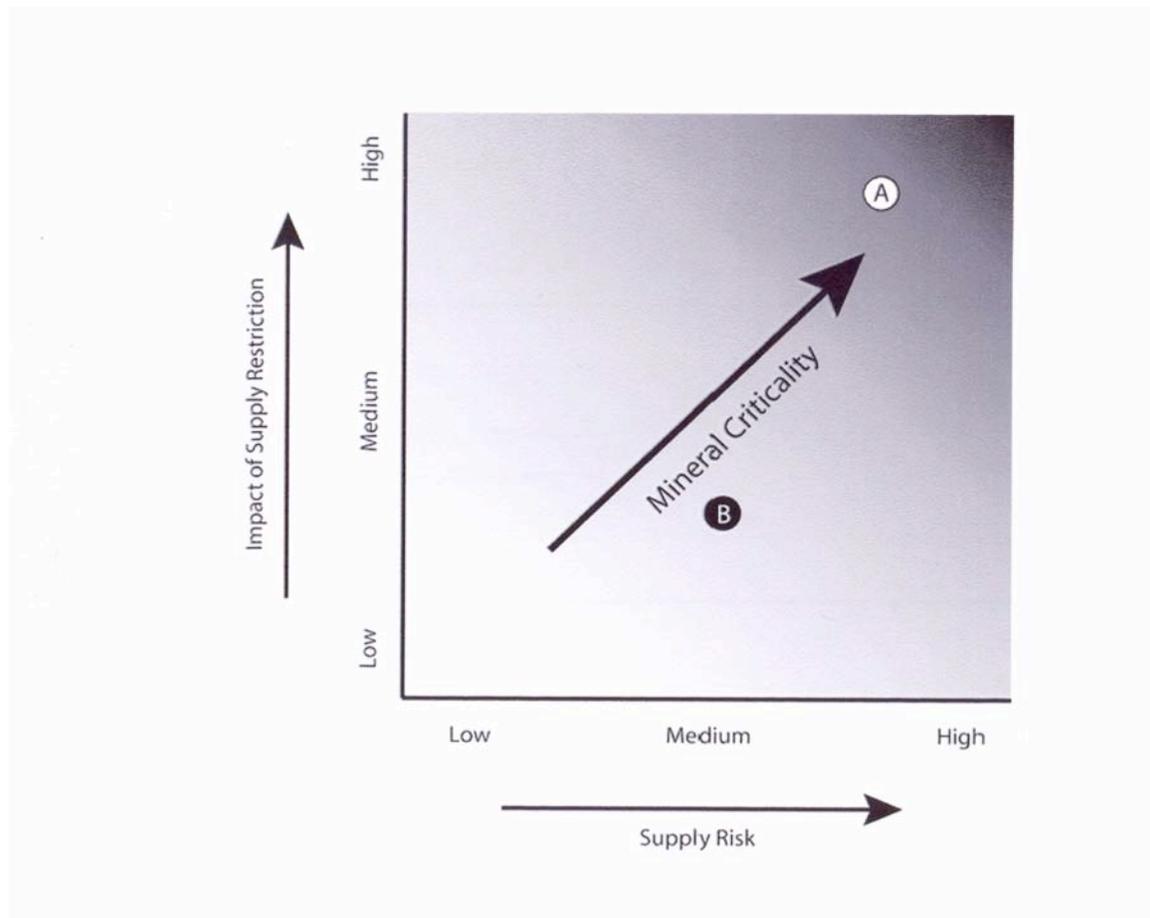


Figure 1. The Criticality Matrix. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

unavailability (and a “no-build” situation for users).<sup>3</sup>

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.

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.<sup>4</sup>

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<sup>3</sup> 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.

<sup>4</sup> Earlier this year, using a very similar analytical framework and definition of “critical” minerals, the European Commission identified fourteen critical raw materials from the perspective of European users: antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, platinum-group metals, rare earths, tantalum, and tungsten (*Critical raw materials for the EU*, report of the Ad-hoc Working Group on defining critical raw materials, Brussels, European Commission, June 2010).

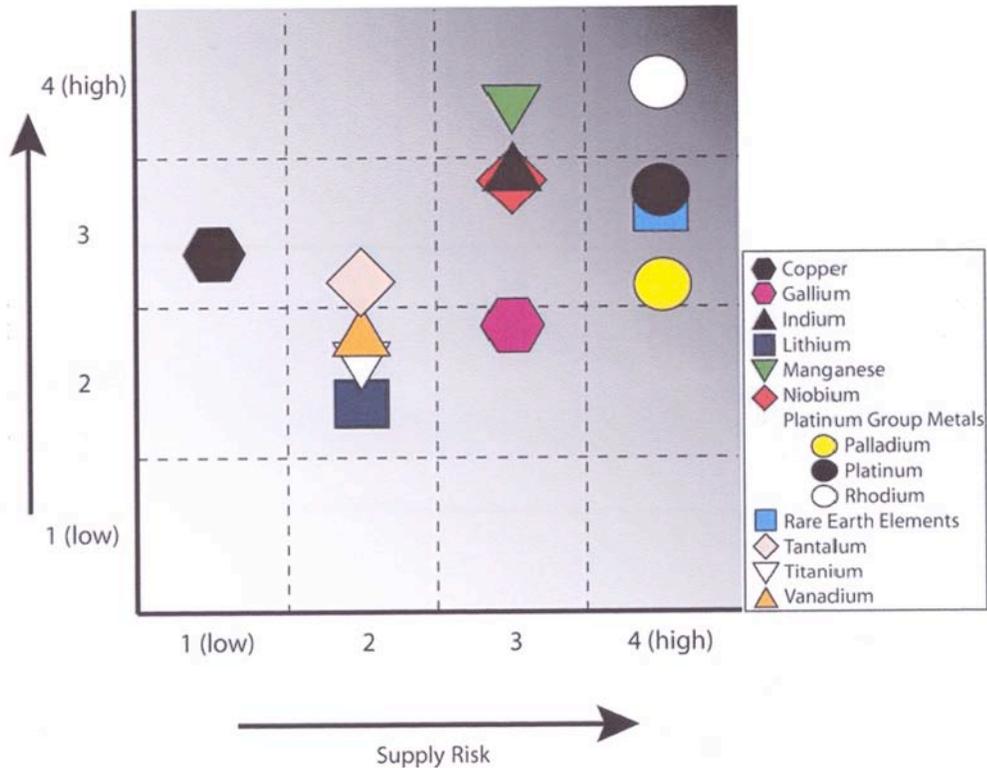


Figure 2. Criticality Evaluations for Selected Minerals or Mineral Families. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

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.

#### "Critical Minerals and Emerging Technologies"<sup>5</sup>

In this recent paper, I examine the concerns about (un)availability of mineral-derived elements as a constraint on the development and diffusion of emerging technologies. I make four major points.

First, *we are not running out of mineral resources*, at least any time soon. The world generally has been successful in replenishing mineral reserves in response to depletion of existing reserves and growing demand for mineral resources. Reserves are a subset of all mineral resources in the earth's crust. Reserves are known to exist and both

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<sup>5</sup> Roderick G. Eggert, "Critical Minerals and Emerging Technologies," *Issues in Science and Technology*, volume XXVI, number 4, 2010, pp. 49-58. The paper discusses minerals for national defense as well as for emerging energy technologies. In this testimony, I do not discuss military or defense issues.

technically and commercially feasible to produce. Reserves change over time. They decline as a result of mining. They increase as a result of successful mineral exploration and development and technological advancements in mineral exploration, mining, and mineral processing. Over time, reserve additions generally have at least offset depletion for essentially all mineral resources.

Second, rather than focusing on running out of mineral resources, *it is more useful to consider the constraints imposed on emerging technologies by the costs, geographic locations, and time frames associated with mineral production.* Costs are important because over time production tends to move to lower-quality mineral deposits—those that are less rich in mineral, deeper below the surface, in more remote locations, or more difficult to process. The result is higher costs for users, unless technological improvements are sufficient to offset these cost increases. Thus the constraint that mineral availability sometimes imposes on users is one of higher costs rather than physical unavailability.

Geographic location of production also is important. Other things being equal, supply risks are greater, the more concentrated production is in a small number of mines, companies, or companies. Concentrated production leaves users vulnerable to opportunistic behavior by producers, either in the form of higher prices or physical unavailability of an essential raw material. I have been careful not to say that import dependence is a risk factor. In fact, import dependence can be good if foreign sources of a mineral are available at lower costs than domestic sources. Rather it is the lack of diversified supply, domestic or foreign, that leads to supply risk, especially if a foreign source leaves us vulnerable to geopolitical risks.

Time frames are important in understanding supply risks. In the short to medium term (one or a few years, up to about a decade), supply risks are determined by the characteristics of existing sources of supply or new facilities that are sufficiently far along that they are reasonably certain of coming into production within a few years—are they diversified or concentrated, are there geopolitical risks, how important is byproduct production (which responds only weakly to changes in the price of the byproduct), is there excess or idled capacity that could be restarted quickly, is there low-grade material or scrap from which an element could be recovered?

Over the longer term (beyond a decade), mineral availability is largely a function of geologic, technical, and environmental factors. Does a resource exist in a geologic sense or in scrap that could be recycled? Do technologies exist to recover and use the resource? Can users recover a resource in ways that society considers environmentally and socially acceptable?

Third, *although markets are not panaceas, they provide effective incentives for dealing with concerns about reliability and availability of mineral resources.* Markets provide 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. Markets encourage users of mineral-based elements to obtain “insurance” against mineral supply risks. Users have the incentive to manage supply risks in the short to medium term by, for example, maintaining stockpiles, diversifying sources of supply, developing joint-sharing arrangements with other users, or developing 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, *despite the power of markets, there are useful and important roles for governments.* 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 U.S. government should fight policies of exporting nations that restrict raw-material exports to the detriment of U.S. users of these materials.
- *Improving regulatory approval for domestic resource development.* Although foreign sources of supply are not necessarily more risky than domestic sources, 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 balance the various commercial, environmental, and social considerations of project development.
- *Facilitating the provision of information and analysis.* Echoing the recommendation of the 2008 NRC report on critical minerals cited earlier, 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 (and the 2008 NRC committee) 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. In addition, we suggest that the Federal government consider the Energy Information Administration, which has status as a principal statistical agency, as a potential model for minerals information, dissemination, and analysis. Whatever agency or unit is responsible for minerals information, it needs greater autonomy and authority than at present.

- *Facilitating research and development.* Again echoing the NRC report on critical minerals, I recommend that federal agencies 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. In particular, I (and the NRC committee) recommend funding scientific, technical, and social-scientific research on the entire mineral

life cycle. We recommend cooperative programs involving academic organizations, industry, and government to enhance education and applied research.

To sum up my personal views, the current situation with critical minerals and emerging energy technologies deserves attention but not panic. By undertaking sensible actions today, there is no reason to expect that the nation will be in crisis anytime soon. But I also am aware that without a sense of panic, we may not undertake these sensible actions.

#### American Physical Society Study

Finally, the issues of interest to this Committee are also of interest to the members of the American Physical Society (APS), a leading professional society of physicists. APS, through its Panel on Public Affairs, established a panel of experts a year ago to prepare a discussion paper on Critical Elements for New Energy Technologies. The panel, on which I serve, will issue its paper and recommendations later this year. The study is a joint activity of APS and the Materials Research Society, with additional support from the Energy Initiative at the Massachusetts Institute of Technology.

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

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