Access to Critical Raw Materials: A U.S. Perspective

Statement of

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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, Golden, Colorado, USA. My area of expertise is the economics of mineral resources. I organize my remarks into four sections. First, I describe the context for current concerns about critical mineral raw materials. Second, I explain the way I view and analyze these issues—my personal conceptual lens, if you will, or alternatively the biases I bring to this topic. Third, I describe recent developments in U.S. public policy. Finally, I re-cast my statement in the form of answers to the specific questions you asked me to address.

Let me emphasize at the outset that I am presenting a U.S. perspective and *not* a U.S.-government perspective. Although I am knowledgeable about current policy discussions in the United States, I do not represent the U.S. government.

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—although by no means only—examples are gallium, indium and tellurium in photovoltaic solar cells; lithium in automotive batteries; and rare-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, 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 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.

Four Propositions

In a 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.[1]

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 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

[1] Roderick G. Eggert, "Critical Minerals and Emerging Technologies," *Issues in Science and Technology*, volume XXVI, number 4, 2010, pp. 49-58.

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 governments of 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*. 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 recommendations of a 2008 report of the U.S. National Research Council (described in the appendix to this testimony), 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 National Research Council 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. At present, the markets for most of the so-called 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 research and development*. Again echoing the 2008 National Research Council report, I recommend that national governments 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 recommend funding scientific, technical, and social-scientific research on the entire mineral life cycle, as well as 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 United States will be in crisis anytime soon. But I also am aware that without a sense of panic, we may not undertake these sensible actions.

<u>Recent Developments in U.S. Public Policy</u>

The 2008 publication of a U.S. National Research Council report, *Minerals, Critical Minerals, and the U.S. Economy*, coincided with the beginning of recent U.S. interest in critical raw materials.[2] This report examines the evolving role of nonfuel minerals in the U.S. economy and the potential impediments to the supplies of these minerals to domestic users. Although not directly focused on public policy, it provides a broad context for current discussions and concerns. The appendix to this testimony describes this study of the National Research Council.

The United States does not have a comprehensive, integrated policy on access to critical minerals and materials. Nevertheless, a number of developments in 2010 reflect growing U.S. interest in access to raw materials:

- *Subcommittee on Critical and Strategic Mineral Supply Chains*. Late in the year, the President's National Science and Technology Council (NSTC) Committee on Environment, Natural Resources, and Sustainability established this subcommittee. Its purpose is to coordinate federal science-and-technology activities across the various cabinet-level agencies, including but not limited to

[2] U.S. National Research Council, *Minerals, Critical Minerals, and the U.S. Economy* (Washington, D.C., National Academies Press, 2008). I chaired the committee that wrote this report.

the departments of Commerce, Defense, Energy, and the Interior, as well as the Environmental Protection Agency and the National Science Foundation. Its activities will include: identifying and monitoring specific critical and strategic minerals of concern; identifying, evaluating, and recommending federal activities to enhance minerals-data collection and economic analysis, to stimulate scientific and technological innovation, to strengthen education and training, and to review and analyze policy options; and managing the administration's strategy for critical and strategic mineral supply chains.

- *Department of Energy, Critical Materials Strategy*. In December, the Department of Energy (DOE) released its strategy for critical materials.[3] It concludes that a number of clean-energy technologies rely on mineral raw materials subject to supply disruptions, including wind turbines, elective vehicles, photovoltaic solar cells, and fluorescent lighting. The report finds that five rare-earth elements (dysprosium, neodymium, terbium, europium, and yttrium) and indium are subject to the greatest supply risks in the short term. The report identifies three strategic priorities: diversifying the global supply chain for critical materials (to alleviate supply risks caused by reliance on one or a small number of producing companies or countries), seeking substitute elements and materials, and fostering increased recycling, resource efficiency, and re-use. The DOE is developing an integrated research agenda, is working to strengthen its capacity for information gathering on critical minerals and materials, and is planning to work closely with international partners on energy-critical elements and materials. By the end of 2011, DOE plans to issue an updated strategy for critical materials.

[3] U.S. Department of Energy, *Critical Materials Strategy* (December 2010).

- *International trade*. The Obama administration is investigating whether China violated World Trade Organization (WTO) rules in supporting (subsidizing) its export of clean-energy goods and technologies. A part of this investigation involves Chinese export restrictions on rare-earth elements, important inputs for a number of clean-energy technologies. This investigation is the result of a petition filed by the United Steelworkers under Section 301 of the Trade Act of 1974, which allows businesses and unions to request that the government initiate dispute-settlement proceedings with the WTO.
- *Legislation*. A number of bills were introduced in 2010 in the Senate and House of Representatives. One bill passed the House but died in the Senate. Some proposed legislation focused narrowly on rare-earth elements, whereas other bills were broader and looked at critical minerals and materials more generally. The range of provisions in the proposed legislation included stockpiling, loan guarantees for private domestic investments in critical minerals and materials, streamlining the process of environmental permitting for domestic mineral development, information gathering and analysis (market transparency), research and development, and education and training. Discussion of the proposed legislation served as a sort of vetting process for provisions of new legislation likely to be introduced in the new session of Congress that began earlier this month. It remains to be seen whether any legislation passes this year, especially legislation with funding, given the priority that the new Congress is likely to give to controlling federal spending. Even if no legislation passes this year, action is likely to be taken by agencies in the executive branch of the federal government.

Your Questions

How does the United States view the current situation with regards to resource security?

The issue of access to critical mineral raw materials has captured the attention of federal officials, primarily because of concerns about how supply disruptions might affect the military and the development and deployment of clean-energy technologies. Whether and how public policy should respond are the subjects of discussion within the executive and legislative branches of the federal government.

What policies is the United States undertaking in order to ensure resource security?

As I noted earlier in this testimony, the United States does not have a comprehensive strategy for access to mineral raw materials. But the executive and legislative branches are considering a number of policy options. The key developments in 2010 were: the establishment of the Subcommittee on Critical and Strategic Mineral Supply Chains within the President's National Science and Technology Council, with responsibility for coordinating federal actions across the executive agencies of government; the release of the Department of Energy's *Critical Materials Strategy*; the Section 301 petition of the United Steelworkers that led to an ongoing investigation by the Obama administration into possible Chinese violation of WTO rules; and various pieces of legislation, none of which became law but rather served as mechanisms for gauging support for possible future legislation, including stockpiling, loan guarantees for private domestic investments in critical minerals and materials, streamlining the process of environmental permitting for domestic mineral development, information gathering and analysis, research and development, and education and training.

What is the role of technology and innovation in promoting resource security?

Over the longer term, technology and innovation are the keys to promoting resource security. Governments, in turn, have key roles to play in fostering research and innovation, especially in pre-competitive activities that are likely to be underfunded by the private sector acting alone. Research is critical on both the supply (geology, mineral extraction and processing, recycling) and demand (substitution) sides of critical raw-material markets.

How could the United States and European Union cooperate in this field?

Cooperative programs involving academic organizations, industry and government have the potential to contribute significantly to education and applied research in this field. I recommend cooperative programs in two areas: information and analysis, and technical research and development. In both areas, the scope of activity should include the entire material lifecycle.

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

<u>Note</u>

This testimony is a revised, updated, and expanded version of testimony presented originally before 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. I revised and updated this testimony to include recent policy developments in the United States and to respond to the specific questions the European Parliament asked me to address.

Appendix: *Minerals, Critical Minerals, and the U.S. Economy*

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

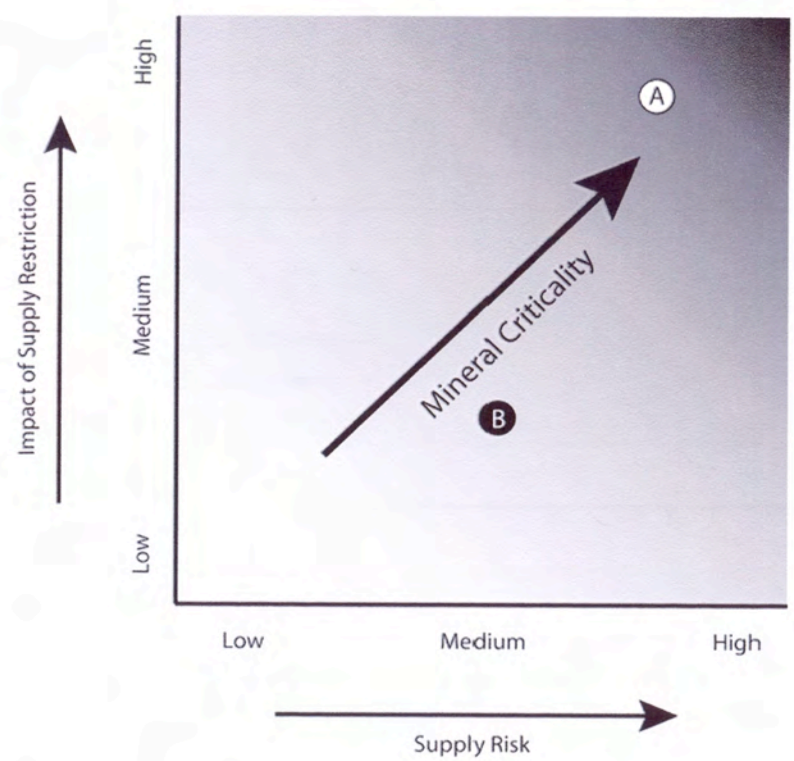

Figure 1. The Criticality Matrix. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

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).[4]

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.[5]

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[4] 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.

[5] In 2010, 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

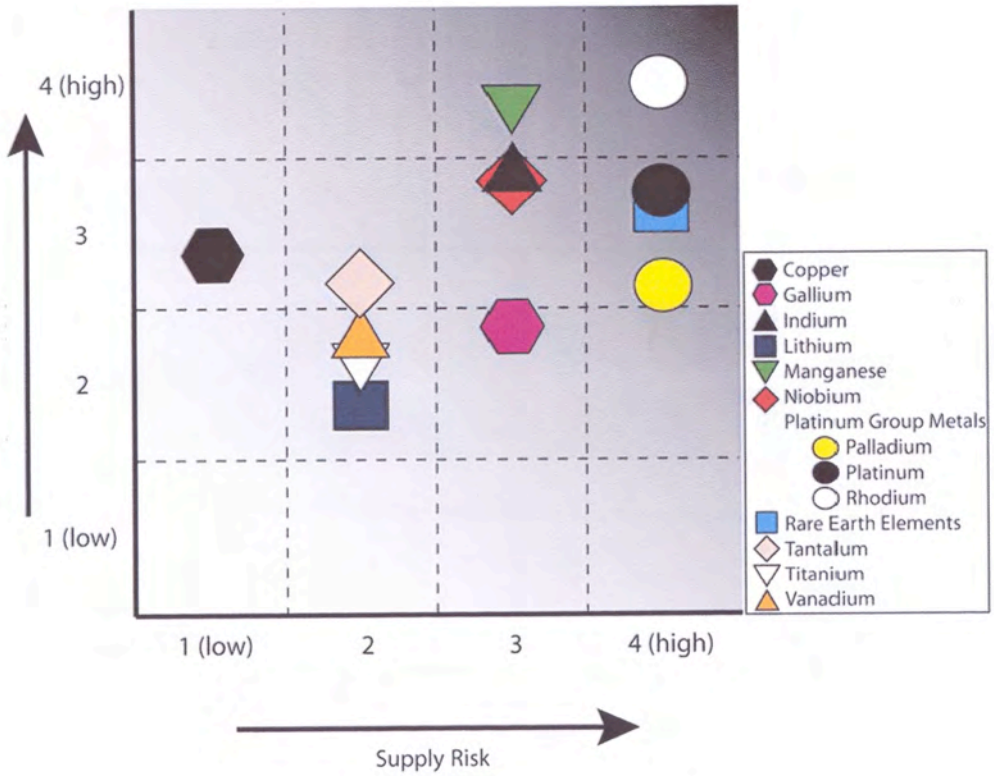

Figure 2. Criticality Evaluations for Selected Minerals or Mineral Families. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

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:

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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).

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.