Hearing to examine the United States' increasing dependence on foreign sources of minerals and opportunities to rebuild and improve the supply chain in the United states

Statement of

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<u>Introduction</u>

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for the opportunity to speak today. I am Rod Eggert, Viola Vestal Coulter Foundation Chair in Mineral Economics at Colorado School of Mines. As part of my university responsibilities, I am deputy director of the Critical Materials Institute, an energy innovation hub (multi-institutional research consortium) funded by the U.S. Department of Energy and led by the Ames Laboratory. My area of expertise is the economics of mineral resources and materials.

I organize my remarks into three sections. First, I describe the context for current concerns about dependence on foreign sources of minerals and improving U.S. supply chains. Second, I present my views on appropriate roles for government in light of these concerns. Third, in the bulk of my testimony, I comment on the roles of research and education in fostering innovation and domestic supply chains for mineral resources and materials.

<u>Context</u>

First, it is not import dependence itself but rather *risky* import sources that are threats to U.S. users of mineral resources and the technologies that these resources underpin. In fact, import reliance is good if foreign sources are available at lower costs or are of higher quality than alternative domestic sources. In many cases, imports are simply intra-company transfers within a vertically integrated company; import reliance reflects an efficiently organized supply chain in which each step takes place in the location best suited to undertake this step. Approximately 62% of all U.S. imports, not just mineral resources, are intermediate products that U.S. entities use as inputs into the production of goods produced within the United States.[i]

Import dependence is a problem, however, when it puts supply chains and U.S. companies and material users at risk. Such is the case when imports come from one or a small number of production facilities, companies or countries – especially countries in which political decisions, restrictions on international trade, civil disruptions, or other developments may restrict access to materials for U.S. users.

Second, import dependence is one aspect of the broader and more-fundamental issue of supply-chain risk and raw-material availability. Short-term supply-chain risks may be due to: a limited number of mines, production facilities or companies (whether domestic or foreign); rapid, unanticipated demand growth for a material with small, existing markets; or reliance on by-product production of a material. Over the longer term, raw-material availability reflects: fundamental geochemical abundance or scarcity of chemical elements; investments in basic science, mineral exploration, mine development and process engineering to enable extraction and recovery of elements from rocks and minerals, manufacturing wastes and end-of-life products; environmental and social issues associated with mining lower-grade raw materials in more-remote locations; and availability of scientists, engineers and other professionals in the disciplines necessary for assuring material supply chains.

Third, the overall need for mineral resources will grow over time. Thus, existing sources and recycling will be insufficient to satisfy future demands (Ali, et al., 2017).

Government's Role[ii]

We appropriately rely primarily on private initiative to develop the mineral resources, materials and technologies that underpin today's society – technologies that encompass energy, health care, electronics and communications, transportation, environmental protection and national defense, among others.

But government plays essential roles in both establishing the institutional framework in which private activities occur and acting when markets do not work well. With respect to mineral resources and raw-material supply chains, government plays essential roles in:

- Facilitating undistorted international trade,
- Establishing a framework for efficient development of domestic natural resources that appropriately protects the natural environment and considers not only national needs but also the interests of the communities in which resource development occurs,
- Collecting and disseminating information, as well as carrying out strategic analysis, on which both private and public decisions can be made, and
- Fostering innovation and domestic supply chains through research and education.

The first role is outside the scope of this hearing. The second and third roles are the subject of other testimony at this hearing. Thus, I focus the rest of my testimony on the fourth role, fostering innovation and domestic supply chains through research and education.

Fostering Innovation and Domestic Supply Chains Through Research and Education

Although not a panacea, innovation is key to improving human living standards, environmental quality and even social well-being. Research and education are the means through which innovation occurs.

Private companies and individuals certainly have incentives to, and do, invest in research and education because of the benefits they bring to companies and individuals. But from society's perspective, private companies and individuals by themselves underinvest in research and education because the benefits are uncertain, often far in the future and often difficult for companies and individuals to fully capture.

Research. Over the longer term, there are three fundamental ways to manage supply-chain risks and assure resource availability: (1) enhance and diversify production, (2) waste less, and (3) use less. Research creates knowledge and technological options in all three areas.

Innovation to enhance and diversify production is the domain of research in basic geoscience, mineral processing and extractive metallurgy.

Innovation to waste less is the domain of research in improving manufacturing efficiency and increasing recycling of both manufacturing wastes and end-of-life products.

Innovation to use less, especially of those materials that are subject to the greatest short-term supply chain risks and long-term constraints on availability, is the domain of materials science and engineering.

Among the grand research challenges central both to enhancing and diversifying production and to reducing wastes are:

- Chemical separations, as highlighted by a 2016 paper in *Nature*, which identifies improving the separation of rare-earth elements as potentially revolutionary in terms of unlocking new and greater quantities of resources using less energy and with less environmental damage (Sholl and Lively, 2016), and
- Resource efficiency, enhancing the degree to which we recover multiple elements and materials that exist in a mineral deposit, manufacturing waste or end-of-life product (Söderholm and Tilton, 2012; Eggert, 2016). In practice, mining and recycling operations appropriately are driven by commercial considerations. These operations optimize the recovery of the most-valuable element or elements, which typically comes by not recovering any or all of the less-valuable elements that might be recovered. Innovation has the potential to improve the technical efficiency of recovery and to lower processing costs.

There are special roles for government to play in two specific aspects of research:

- Facilitating early-stage research and development (R&D) that is especially prone to underinvestment by the private sector acting alone, for reasons described above, and
- Facilitating the commercialization of promising ideas and new knowledge created in early-stage R&D through mechanisms such as public-private partnerships. In a perfect world, any promising new idea developed at a national laboratory or university would be picked up by the private sector. In practice, however, promising ideas often languish because of insufficient communication between basic researchers and commercial developers of new technologies.

Education. 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, who in the future will respond to concerns about newly emerging critical minerals. Education and research in the geosciences, mining, mineral processing and extractive metallurgy, environmental science and engineering, manufacturing, and recycling can mitigate supply risks and increase material availability. Improvements in materials design—fostered by education and research in materials science and engineering—can ease the pressures imposed by those elements and materials subject to supply risks or limited availability.

Part of the educational challenge today is broad and relates to study of science, technology, engineering and mathematics, as highlighted in a number of National Research Council studies (for example, U.S. National Research Council 2007 and 2012).

Part of the educational challenge is narrower and relates to discipline-specific issues and the dearth of professionals in economic geology, mining, mineral processing and extractive metallurgy. A 2013 study of the National Research Council highlights these issues (U.S. National Research Council, 2013). Without well-educated professionals in the necessary disciplines, it will be difficult to rebuild and improve raw-material supply chains in the United States.

Critical Materials Institute. One example of an existing federal activity in the area of innovation and raw-material supply chains is the Critical Materials Institute (CMI), an energy innovation hub funded by the Department of Energy (http://cmi.ameslab.gov). The special focus of this research initiative is developing technological options for assuring supply chains of materials that provide essential properties to emerging clean-energy technologies, including high-efficiency motors, batteries, advanced lighting and solar materials.

CMI conducts early-stage research in all three areas identified above: to diversify and expand the availability of materials throughout their supply chains, to reduce wastes by increasing efficiency of manufacturing and recycling, and to reduce demand by identifying substitutes for materials subject to supply-chain risks. CMI also facilitates the commercialization of the new knowledge it creates through the active participation of its industry members.

Among CMI's current priorities is demonstrating the production of NdFeB magnets, essential in high-efficiency motors and at present produced almost entirely in China, using materials and technologies located entirely in the United States.

Recycling. Domestic supply chains already are well established for recycling manufacturing wastes and end-of-life products containing the major metals used in construction, transportation equipment, consumer durables and capital equipment – especially steel, aluminum, copper and lead. On the other hand, relatively little recycling takes place that recovers minor and specialty metals from end-of-life products. These minor and specialty metals typically are used in small quantities but provide essential properties and functionality to modern engineered materials – for example, neodymium in permanent magnets used in high-efficiency motors, lithium and cobalt in batteries, yttrium and europium in fluorescent lighting, and germanium and indium in flat-panel displays.

Considerable research is ongoing at present, including in CMI, to develop processes that will improve the technical and commercial attractiveness of recovering these minor and specialty metals. The technical challenges of separating and recovering multiple minor elements from complex materials are considerable – the grand challenge of resource efficiency that I noted above. But we are optimistic that with time and effort these challenges can be overcome. There are two other considerations, however, that lead me to be cautious about how large recycling's role will be in supplying these minor and specialty metals.

First, products containing these elements often are widely dispersed when they no longer are used – think of old cell phones, computers, computer monitors and television sets, which often wind up in desk drawers, attics and basements. The degree to which used aluminum cans were recycled fell with the spread of single-stream recycling and the demise of reverse vending machines. Without better social systems for collecting the products that are potential sources of minor and specialty metals, recycling will be limited.

Second, and more importantly, demand is likely to grow significantly for products containing these minor and specialty elements, and these products have lifetimes that range from years to a decade or more. The faster the rate of demand growth and the longer the product lifetime, the lower the percentage of demand that can be satisfied through recycling of end-of-life products. Consider a simplistic example with the elements silver, indium, and tellurium that are minor (but essential) constituents in several types of solar materials. A typical solar panel is expected to last twenty years or more. Imagine that (a) 10 units of a minor element are contained in solar panels installed this year, (b) over the life of these solar panels, the demand for the solar panels triples and (c) as a result the demand for these elements increases to 30 units per year. Future recovery of these minor elements when today's solar panels are recycled at most could satisfy one-third of the future demand for these elements, assuming no loss of material during recycling.

I am not suggesting that recycling is not an important focus of R&D efforts; recycling R&D is essential. Rather I am urging us not to think of recycling as a major substitute for resource development and mining. Both recycling and new mines will be required to meet future demands. Innovation through research and education is key to rebuilding and improving domestic supply chains of minerals and materials.

Closing

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

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[i] Calculated with data from https://jgea.org/resources/jgea/ojs/index.php/jgea/article/view/23

[ii] See Eggert (2010) and Eggert (2011), as well as two expert-panel reports in which I participated (American Physical Society and Materials Research Society, 2011; U.S. National Research Council, 2008). My testimony today on government roles includes views I expressed in previous testimony before (a) the Subcommittee on Energy, Senate Committee on Energy and Natural Resources, September 30, 2010, (b) the Committee on Industry, Research, and Energy of the European Parliament, January 26, 2011, (c) the Subcommittee on Energy and Mineral Resources, House Committee on Natural Resources, May 24, 2011, and (d) the Senate Committee on Energy and Natural Resources, January 28, 2014.