Written Statement of

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An examination of the domestic critical minerals supply and demand chain"

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Chairman Lamborn, Ranking Member Holt, and Members of the Subcommittee, thank you for inviting me to testify on the important issue relating to recycling and reuse of critical minerals.

My name is Eric Peterson. I am the Efficient Use and Recycling Focus Area Lead for the Critical Materials Institute, a Department of Energy (DOE) Energy Innovation Hub. I also lead the Academic Outreach and Strategy Development work at Idaho National Laboratory's Center for Advanced Energy Studies. I am an inorganic chemist by training and have worked with developing new separations methods and fundamental understanding of structure and bonding of the highly valued rarer elements throughout the past 32 years.

My testimony will address the following:

- Clean Energy technologies today.
- The critical materials challenges.
- Establishment of the Critical Materials Institute (CMI).
- CMI's improving efficient use and recycling Focus Area.
- The supply chain and economic analysis component of CMI.

Introduction

Many domestically-manufactured products rely on critical materials, or materials that are important in their use and subject to supply restrictions. In particular, the energy industry is heavily reliant on critical materials and could be significantly affected by supply disruptions and resulting price increases and fluctuations. These critical materials are found in many traditional, new, and emerging energy applications and are key components in energy technologies such as lighting, solar photovoltaics, batteries, and wind turbines. Technologies using critical materials are poised to make even more significant contributions to national energy, environmental, and economic goals.

Our nation stands at a critical time regarding the competitive opportunity for clean energy. In 2013, $254 billion were invested globally in clean energy, just over 360 percent increase since 2004; trillions more will be invested in the years ahead.(1) In the transition to a clean energy economy, the United States faces a stark choice: the clean energy technologies of today and tomorrow can be invented and manufactured domestically, or America can surrender global leadership and import these technologies from other countries.

Clean energy technologies today

Many of today's clean energy technologies rely on the use of materials with certain essential properties, such as efficient light emission or strong magnetism. Many of those critical materials are essential to producing products that DOE's Office of Energy Efficiency and Renewable Energy (EERE) is also investing in. In 2010, DOE issued a

Critical Materials Strategy ("Strategy") to address this reliance.(2) Due to rapidly changing conditions, DOE updated the Strategy in 2011.(3) These reports defined and assessed critical materials by analyzing two dimensions: 1) importance to the clean energy industry, and 2) supply risk. The Strategy identified five rare earth elements – neodymium, europium, terbium, dysprosium, and yttrium – as critical materials currently essential for America's transition to cost-competitive clean energy technologies like wind turbines, electric vehicles, and energy efficient lighting. The Strategy also identified two additional elements, lithium and tellurium, as "near-critical" materials. Identifying and addressing near-critical element challenges is crucial as both the clean energy industry and critical materials market dynamics change. These particular non-rare earth elements play an indispensable role in batteries for hybrid and electric vehicles and commercial photovoltaic thin films, and represent the next highest criticality in terms of importance to the clean energy industry and risk of supply disruption. Even in the short time since the Strategy was issued, the outlook has dramatically changed. Lithium's importance has increased due to electric/hybrid automotive needs and tellurium's importance has dropped in response to industry's decision not to build photovoltaic solar systems because of lower cost silicon-based systems entering the marketplace.

The critical materials challenges

DOE's Strategy identified three pillars to address critical materials challenges:

1) diversifying supply of critical materials,
2) developing alternatives to critical materials,
3) driving recycling, reuse, and more efficient use of critical materials.

First, diversified global supply chains are essential. To manage supply risk, multiple sources of materials are required. This means taking steps to facilitate the extraction, processing, and manufacturing of critical materials here in the United States, as well as encouraging other nations to expedite alternative supplies. In all cases, extraction, separation, processing, and manufacturing must be done in an environmentally sound manner. Second, substitutes need to be developed. Research leading to material and technology substitutes will improve flexibility, decrease demand for critical materials, and provide the materials needed for the clean energy economy. Third, recycling, reuse and more efficient use of critical materials could significantly lower world demand for newly extracted materials. Research into recycling processes coupled with well-designed policies will help make recycling economically viable over time. Simply put, the United States cannot mine, substitute, or recycle the way out of this crisis – it requires a carefully orchestrated balance of all three approaches.

Addressing these three pillars is, however, a moving target, because critical materials challenges change over time due to evolving market conditions. Ongoing assessments are necessary to identify the status of current and emerging critical materials; as new technologies develop and markets respond to supply risk, the criticality of materials will also shift.

DOE's National Laboratory System is integral to this research and development (R&D) effort. The system includes the nation's historic leader in rare earth materials research, the Ames Laboratory located in Ames, Iowa. While Ames Laboratory has a core competency in rare earth materials, many other multi-program national laboratories also contribute significantly to R&D aimed at reducing the criticality of critical materials. For example, Idaho National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, Pacific Northwest National Laboratory, and Lawrence Berkeley National Laboratory have complementary efforts spanning from basic and applied research to development and demonstration.

Establishment of the Critical Materials Institute

In response to the Strategy, DOE launched a national competition for an Energy Innovation Hub to address critical material issues. Early in 2013, DOE awarded Critical Materials Institute (CMI) to the Ames Laboratory-led team. CMI is the nation's premier research, development and analysis institute dedicated to finding innovative solutions and developing creative, transformational paths to eliminating the criticality of rare earth and other materials.

CMI began operations in June of 2013. CMI is an example of a National Laboratory-Academic-Industry collaborative research partnership with seven universities, four DOE National Laboratories, and six private sector partners. CMI addresses critical materials problems by developing technologies that span the supply chain for the rare earth (plus lithium and tellurium) elements, as well as provides research infrastructure to address any emergent challenges related to materials criticality.(4)

CMI is focusing its efforts around the three pillars of the Strategy. For example, researchers are studying new, lower cost ways to extract, separate and process rare earth metals from ores and recycled materials to diversify supply. In partnership with private sector partners, CMI is searching for substitutes for rare earth phosphors to develop substitutes. Energy-efficient lighting phosphors currently need europium, terbium, and yttrium, and CMI is searching for alternative technologies that would use more abundant materials such as manganese. Lastly, CMI is conducting R&D to improve reuse and recycling of critical materials by focusing on two major areas: first, improving the cost- and energy-efficiency of separating the rare earth-containing components from end-of-life products like fluorescent light bulbs, hard disc drives and motors; and second, developing new technologies to efficiently extract rare earth elements from these end-of-life components to produce new materials. If successful, the technologies will significantly reduce loss of critical rare earths within domestic manufacturing.

In its first year of operations, the CMI team is off to a fast start. Key start-up and management operations have been put in place. About 35 CMI projects, nine of which focus on efficient use and recycling, are active. All of these projects involve multiple partners, often three or four partners collaborating to achieve the best solutions under CMI's mission. CMI researchers filed 11 intellectual property invention disclosures during our first 11 months of operation. While there is tremendous work still to be done by the Institute, this is a sign of great things to come.

CMI's Improving Reuse and Recycling Focus Area

In theory, metals are infinitely recyclable, simply by re-melting and re-casting. In practice, recycling is often inefficient or nearly nonexistent due to limits imposed by poor collection systems, human behavior, product design, low efficiency recycling technologies, and the thermodynamics of separation.(5) CMI's Improving Reuse and Recycling Focus Area (FA) seeks to enhance efficient reuse and recycling of a highly diverse set of materials that will further diversify the global supply chain of critical materials by enhancing recycling technologies, improving product design, understanding recycling techno-economics and using the thermodynamics of separations.

Up to 30 percent of the rare earth element supply stream can be lost in manufacturing waste(6) and over 60 percent of the consumer product reservoir ends up in landfill or construction aggregate(7, 8). The lack of reuse and recycling is due primarily to the lack of methods that have high enough yield or low enough cost. The sources of recyclable materials are highly diverse and the matrices in which they are found are equally diverse. This diversity is one of the major challenges the FA faces and such diversity drives the ultimate determiner of technology adoption – process economics. This FA is structured around a specific set of material streams that offer the highest potential to obtain enhanced supplies of high value material including lighting phosphors, magnet materials, and electronics. CMI is examining these and other materials streams with a target of developing coupled economically viable and environmentally acceptable processing methods that apply to more than one material stream (and potentially to future critical materials) thus reducing the challenge of processing diverse source materials to manufactured products. In addition to the critical materials, there is, in some cases, an opportunity to simultaneously recover additional high value materials, such as precious metals, that may provide opportunities for improved processing economics and process adoption/utilization.

As previously described, CMI's R&D in this area is focused on two major thrust areas. First, improving the cost- and energy-efficiency of separating the rare earth-containing components from end-of-life products; second, developing new technologies to efficiently extract rare earth elements from end-of-life components to produce new materials. In the area of improving the economics and efficiency of the separation process, CMI has made significant progress in developing new technology for processing lighting phosphors, disc drive voice coil magnets and selective extraction of intact magnets from those disc drives.

The second thrust area of developing new technologies to efficiently extract and separate rare earth elements from the end-of-life components naturally follows from the first thrust because once one has the components, they are still in configurations that are not useful for new products. They have formulations that do not necessarily serve the needs of new products, thus making it difficult to make new products. Generally elements must be separated to some level of purity before manufacturing new products. CMI's efforts include developing environmentally sound methodologies for elemental extraction utilizing supercritical fluids and membranes that involve significant energy savings and environmental footprint reductions. A couple of other examples include developing a system known as electro-recycling in which CMI reduces the amount of acid needed to dissolve a component by electrochemically generating the acids in tiny quantities right at the site where it is needed. Once the element is dissolved away from the surface, it can be collected either electrochemically (electrowinned) or by membrane-supported solvent extraction (a process under development in the first focus area of the Hub). This approach saves using large amounts of acids to dissolve the elements away from its matrix. In yet another example, CMI is studying ways in which large magnets can be recovered, such as those found in wind turbines, and essentially repurpose them by cutting them up and machining them into new smaller units. Finally, CMI is looking for and developing a set of biological extractors – using living, naturally-occurring bacteria that essentially live off of the materials that contain the rare earth elements and liberate them from those materials so that they can be collected with solvent extraction or simple precipitation, a process known as bio-hydrometallurgy. Additionally, CMI is creating engineered bacteria that have the ability to selectively absorb the elements from solution - thus concentrating the elements. Both approaches are showing excellent progress toward their goals.

Supply Chain and Economic Analysis Crosscut

The fourth leg of CMI is the Supply Chain and Economic Analysis Crosscut in which CMI is investigating fundamental scientific and economic processes to support the other three legs of the Hub. One segment of this work includes analyzing critical material market conditions such as projected supply and demand. In the recycling function, cross-cutting science research will develop a set of models to provide insight into increasing the efficiency of materials collection and processing. Since collection is one of the largest problems for getting materials into recycling streams, these models will identify economically viable collection and processing systems across North America. Furthermore, as supply and demand for critical materials changes over CMI's lifetime, the Supply Chain and Economic Analysis Crosscut will provide some of the tools to accelerate responsiveness to meet such future needs.

Summary

To summarize, the work being done across the Critical Materials Institute, and especially in the efficient use and recycling area, highlights DOE's commitment to address the global demand for critical materials that underpin clean energy technologies. If the United States intends to be a global leader in clean energy technologies, a sustainable domestic supply chain for a clean energy economy must be ensured.

Mr. Chairman and members of the Subcommittee, thank you once again for the opportunity to testify and I am pleased to answer any questions you have.

References:

1) See: Bloomberg, “Global Trends in Renewable Energy Investment, Fact Pack as of Q4 2013” (Jan. 2014): http://about.bnef.com/files/2014/01/BNEF_PR_FactPack_Q4_CleanEnergyInvestment_2014-01-15.pdf
2) U.S. Department of Energy, "Critical Materials Strategy," 2010. http://energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf
3) U.S. Department of Energy, "Critical Materials Strategy," 2011. http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf
4) https://cmi.ameslab.gov/
5) B. Reck and T. Graedel, "Challenges in Metal Recycling," *Science,* vol. 337, pp. 690-695, 2012.
6) U.S. Geological Survey, "Mineral Commodity Summaries 2012," [Online]. Available: http://minerals.usgs.gov/minerals/pubs/mcs/2012/mcs2012.pdf.
7) A. Saguchi, K. Asabe, T. Fukuda, W. Takahashi and R. Suzuki, "Recycling of Rare Earth Magnet Scraps: Carbon and Oxygen Removal from Nd Magnet Scraps," *Journal of Alloys and Compounds,* Vols. 408-412, pp. 1377-1381, 2006.
8) S. Constantinides, Interviewee, *Arnold Magnetic Supplies, private communication.* [Interview].