Testimony of

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Introduction

Chairman Murkowski, Ranking Member Manchin, and Members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to testify today on behalf of the Department of Energy.

Critical minerals are used in many products important to the U.S. economy and national security. The manufacturing and deployment of these goods provides employment for American workers and contributes to U.S. economic growth. The U.S. is dependent on foreign sources of critical minerals. Of the 35 mineral commodities identified as critical in the list published in the Federal Register by the Secretary of the Interior, the U.S. lacks domestic production of 14[1] and is more than 50% import-reliant for 31.[2] For example, some mineral commodities important to energy from those identified include gallium (imported from China, the United Kingdom, Germany and the Ukraine); rare earths including dysprosium and neodymium (imported from China, Estonia, France, and Japan); lithium (imported from Argentina, Chile, China, and Russia); and cobalt (imported from Norway, China, Japan, and Finland). [3] This import dependence is a problem when it puts supply chains and U.S. companies and mineral users at risk. The dependency of the U.S. on foreign sources of critical minerals creates a strategic vulnerability for both our economy and our military with respect to adverse foreign government actions, natural disasters, and other events that could disrupt supply.

Many of the mineral commodities identified by the Department of the Interior are vital to the energy technologies of today and the future. The Department of Energy's approach to mitigate risk is in alignment with the President's Executive Order 13817 to ensure secure and reliable supplies of critical minerals. The Department's three priorities for decreasing U.S. dependence on foreign sources of critical minerals are reuse/recycling, using minerals more efficiently and developing substitutes, and increasing domestic production across the supply chain.

All stages of the supply chain are important and can impact one another. The U.S. lacks downstream domestic processing and manufacturing capabilities for some critical minerals, which results in the export of domestically produced ores and concentrates for further processing into more value-added forms. Increasing domestic production without developing the domestic processing and manufacturing capabilities will simply move the source of economic and national security risk further down the supply chain and create dependence on foreign sources for these capabilities. For example, rare earth mining has resumed in the U.S. However, the U.S. lacks the domestic capability to extract and separate the useful elements from the bastnasite ore, which can contain more than ten different rare earth elements depending on the deposit. The separation and purification of rare earth elements from bastnasite ore must instead be handled at overseas processing facilities. Because of this, the U.S. lacks the domestic capability to extract and separate neodymium from bastnasite ore, which is used in magnets.

The U.S. also lacks the domestic capability to manufacture magnets containing neodymium and relies on imported magnets crucial for both civilian and defense applications. This reliance creates potential price and demand volatility and jeopardizes U.S. jobs and national security. Addressing the full critical mineral supply chain through increasing domestic production, recycling, reprocessing, and identifying commonly available alternatives will reduce our dependence on imports, preserve our leadership in technological innovation, support job creation, and improve our national security and balance of trade. In addition, addressing the full supply chain through responsible domestic production and processing brings environmental outcomes - under American regulatory oversight, which may provide more environmental protection than other foreign producers.

Department of Energy's Approach to Critical Materials

The Department's Office of Policy has led several studies assessing material criticality across a range of energy technologies based on importance to energy and potential for supply risk. Early and on-going assessment is required to adapt the Department's priorities to changing material and energy technology markets. Over the years, some criticality levels have decreased (e.g., terbium and europium in florescent lighting phosphors); some have increased (e.g., lithium and cobalt in batteries); and some have remained prominent (e.g., neodymium and dysprosium in magnets). In addition, the Office of Policy has led several studies examining potential supply chain vulnerabilities related to market dynamics and volatility across each stage of the supply chain from mining to final product production and demand.

Within the Department, research and development (R&D) investments are coordinated among the program offices agency-wide around **three pillars** to address supply chain disruption risks: **(1) diversifying supply of critical materials – including increasing domestic production, (2) developing substitutes, and (3) driving recycling, reuse, and more efficient use of critical materials**. For example, the Department has made significant strategic investments to address rare earth permanent magnets for motors and generators. The Office of Energy Efficiency and Renewable Energy (EERE), through the Advanced Manufacturing Office (AMO), Vehicle Technologies Office (VTO) and the Wind Energy Technologies Office (WETO), and ARPA-E have made significant and complementary efforts to reduce or eliminate potential dependences on critical materials (such as rare-earth metals) that are essential to modern and clean energy technologies. The Office of Electricity (OE) is working on grid-scale battery storage technologies that use domestically sourced earth-abundant materials. The Office of International Affairs is focused on countering attempts to control or distort the critical materials markets.

While the Department has and continues to invest in R&D across the three pillars, as is described below, the Department is currently developing activities to support increased domestic production and recycling of critical materials. (A one page summary of current DOE programs involved is attached.)

R&D Across the Department

Critical Materials Institute
The Critical Materials Institute (CMI), an Energy Innovation Hub currently managed by EERE (through the Advanced Manufacturing Office), is a multi-institutional, multi-disciplinary consortium of U.S. national laboratories, universities, and companies led by the Ames Laboratory. CMI's mission is to create technological options for assured supply chains of materials critical to clean energy technologies. CMI carries out early-stage applied research in three areas: diversifying supply, developing substitutes, and reuse and recycling. These research areas are linked to industrial needs and are enabled with fundamental scientific research and

cross-cutting analysis. As a result, technologies developed by the CMI span the entire supply chain and lifecycle of materials, except geoscience and mining. While Congressional report language has continued to insist upon funding the CMI, the FY2020 Budget favors a transition away from the hub model because the mortgaging of future appropriations reduces budgetary flexibility. Instead, the Budget proposes a set of smaller and more directly managed, early-stage, R&D consortia activities.

In its first five years (using FY12-16 appropriations), CMI issued 78 invention disclosures, filed 50 patent applications, received six patents, created two open-source software packages and won two R&D 100 awards. It licensed seven technologies to U.S. companies. Examples of these technologies include:

- Membrane solvent extraction for rare-earth separations, relevant for both primary production and recycling,
- 3D printing of rare-earth magnets to reduce manufacturing wastes,
- A cerium-aluminum alloy for creating lightweight, strong components for advanced vehicles and airplanes,
- A cost-effective, high-throughput system for recycling rare-earth magnets from computer hard drives, and
- Replacements for the rare earths europium and terbium in fluorescent lighting.

CMI developed capabilities to include machine learning materials design and predicted and synthesized critical material-free permanent magnets that have the potential to reduce the demand for rare earth containing neodymium-iron-boron magnets in a number of applications. CMI researchers won an additional R&D 100 Award and Gold Award for Special Recognition in Green Technology for development of an acid-free magnet recycling process.

Addressing Critical Lithium-Ion Battery Materials

The demand for the critical materials cobalt and lithium is driven by the growth in demand for lithium-ion batteries used in electric vehicles.

To mitigate critical materials supply risks for lithium-ion batteries, EERE (through VTO) aims to reduce the cost of electric vehicle battery packs to less than $150/kWh by September 2022 (from a baseline of $197/kWh in 2018).[4]

To directly address dependence of lithium-ion batteries on critical materials, VTO is funding R&D to reduce cobalt content in the battery cathode to less than 5% by weight.

EERE is also funding efforts to address the challenges of recycling lithium-ion batteries, which have more than 15 different cathode chemistries across end-use applications. EERE's VTO has established the ReCell Lithium Battery Recycling R&D Center to develop innovative, efficient recycling technologies for current and future battery chemistries. ReCell funds R&D across four research areas: design for recycling, recovery of other materials, direct recycling or cathode-to-cathode recovery, and reintroduction of recycled materials.

Getting end-of-life lithium-ion batteries to recycling centers is also a challenge to the reuse, recycling and recovery of critical materials. ReCell reports that lithium-ion batteries are currently recycling at a rate of less than 5%. In January 2019, the Department (through EERE's VTO and AMO) announced the launch of a Lithium-Ion Battery Recycling Prize to incentive American entrepreneurs to create cost-effective, disruptive solutions to collect, sort, store, and transport 90% of spent or discarded lithium-ion batteries for eventual recycling.

OE is funding efforts to develop non-lithium energy storage technologies for use on the grid. The program supports fundamental research to advance the development of batteries based on earth-abundant materials such as sodium and zinc, with a cell-level cost target below $100/kwh.

Unconventional Resources
The Office of Fossil Energy, though the National Energy Technology Laboratory (NETL) Feasibility of Recovery Rare Earth Elements Program, is currently focused on developing technologies for the recovery of rare earth elements and critical materials from coal and coal-based resources. This R&D program consists of three core areas: enabling technologies, separations technologies, and process systems. The R&D program grew to over 30 active projects in 2018, which span developing process and production technologies, environmental management, and field materials sampling and characterization, along with systems integration, optimization and efficiency improvements to produce rare earth elements and critical materials from coal and coal byproduct streams, such as coal refuse, clay/sandstone over/under-burden materials, power generation ash and aqueous effluents as acid mine drainage and sludge.

To further diversify critical materials supplies, EERE has invested and continues to invest in the recovery of critical materials, such as lithium, from geothermal brines (through the Geothermal Technologies Office (GTO) and AMO) and development of seawater mining (through the Water Power Technologies Office (WPTO)). The latter technology has the potential to use marine and hydrokinetic power to passively extract uranium, lithium, precious metals, and rare earths from seawater.[5]

Fundamental Science
In order to drive technological change, fundamental science is considered an essential input. Much of the progress by the Department's applied energy offices is underpinned by investments made by the Office of Science. These investments support fundamental research to advance understanding of critical materials at the atomic level. This research includes the development of novel synthesis techniques that control properties at the atomic level to develop unique capabilities for the preparation, purification, processing, and fabrication of well-characterized materials. The Office of Science also supports the development, validation, and application of models to theoretically and computationally identify compounds that are promising critical material substitutes. This research includes projects aimed at identifying replacements for rare earths in electronic and magnetic applications as well as alternatives to materials such as lithium and cobalt in batteries, and platinum in catalytic reactions.

Interagency Coordination
The Department also coordinates with other federal agencies, such as Department of Defense, Department of Commerce, Department of the Interior, through National Science and Technology Council (NSTC) Subcommittee on Critical Minerals. The Department has been a co-chair of the Subcommittee since 2013 and continues to provide leadership among the federal agencies to address critical minerals across the entire supply chain.

The Department and our national lab researchers and experts are committed to working in partnership with industry, academia, and other federal agencies to forge paths to critical mineral security, while also working with Congress to ensure appropriate stewardship of taxpayer investments. I appreciate the opportunity to appear before this committee to discuss the Department's efforts to increase critical mineral security.

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[1] U.S. Geological Survey, "Mineral Commodity Summaries 2018," 2018, https://doi.org/10.3133/70194932

[2] Department of the Interior, "Final List of Critical Minerals 2018," 83 Fed. Reg. 23295; 2018, https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018

[3] U.S. Geological Survey, "Mineral Commodity Summaries 2018," 2018, https://doi.org/10.3133/70194932

[4] Steven Boyd, Vehicle Electrification, Presented at DOE Vehicle Technologies, Annual Merit Review, June 2018, Washington, D.C.

[5] https://eere-exchange.energy.gov/FileContent.aspx?FileID=fcf63beb-3f9d-4e8b-9c35-aa1d746fef6d