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before the

House Committee on Science, Space, and Technology

The Role of Federal Research in Establishing a Robust U.S. Supply Chain of Critical Minerals and Materials

November 30, 2023

Chairman Lucas, Ranking Member Lofgren, and esteemed Members of the Committee, thank you for the opportunity to testify before you today. My name is Ryan Peay, and I am the Deputy Assistant Secretary for Resource Sustainability in the Office of Fossil Energy and Carbon Management (FECM) at the Department of Energy (DOE). I appreciate the opportunity to be here today and discuss with you DOE's work to advance technologies and approaches to ensure secure domestic critical minerals and materials (CMM) supply chains.

The U.S. Geological Survey (USGS) has identified 50 critical minerals for multiple economic sectors.[1] Critical minerals are defined in the Energy Act of 2020 as "any mineral, element, substance, or material designated as critical by the Secretary [of the Interior]."[2] Under the Act, critical minerals are essential to U.S. economic or national security; vulnerable to supply chain disruptions; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States.[3] Congress specifically excluded "fuel minerals" from the definition of critical minerals.[4] For 31 of these critical minerals, the U.S. relies on other countries for more than 50 percent of our requirements, and we rely entirely on foreign sources for more than a dozen of these minerals.[5] Our current reliance on foreign sources for critical minerals is made more challenging as the world transitions to a clean energy and industrial economy.

In response to these challenges, President Biden signed Executive Order 14017, *America's Supply Chains*, on February 24, 2021, directing each department in the administration to assess potential supply-chain risks within their jurisdiction and develop strategies to mitigate and

[1] U.S. Geological Survey. 2022 Final List of Critical Minerals. Federal Register. February 24, 2022. Available at https://www.federalregister.gov/documents/2022/02/24/2022-04027/2022-final-list-of-critical-minerals
[2] 30 U.S.C. 1606(a)(3)(A).
[3] 30 U.S.C. 1606(c)(4)(A).
[4] 30 U.S.C. 1606(a)(3)(B)(i).
[5] U.S. Geological Survey. Mineral Commodity Summaries 2023. 2023. Available at https://pubs.usgs.gov/publication/mcs2023

overcome these deficiencies.[6] This Executive Order expands work previously directed in EO 13953, *Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries* from September 30, 2020.[7] In addition, in October of 2022, President Biden announced the new American Battery Materials Initiative. The ABMI is a DOE-coordinated interagency effort to secure the minerals and materials needed for everything from batteries to defense systems. It works to coordinate federal investment across the interagency to meet the Administration's short- and long-term critical minerals goals; support policies and solutions to solve the biggest critical mineral supply chain chokepoint—minerals processing; and align responsible mining and processing standards.

In February of 2022, DOE released a report titled *America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition*, followed by a Critical Materials Assessment in July of this year.[8] DOE designated our Critical Materials List based on the definition in the Energy Act of 2020 and the results of the Assessment, which determined criticality based on the potential for supply risk and importance to energy supply chains in the short (2020-2025) and medium (2025-2035) terms. The Critical Materials List includes all of the critical minerals on the 2020 USGS list and because of differences in mandate and methodology, includes four additional critical materials that were identified based on projected future needs for energy applications. These additional materials include copper, electrical steel, silicon, and silicon carbide. It is expected that DOE's list will be updated every few years, as well as the USGS list which will be updated every three years, as requirements for critical minerals and materials are inherently dynamic.

To meet the projected demand for CMMs, the U.S. must develop multiple sources (upstream) for critical materials. However, that alone will not be sufficient to establish resilient supply chains. A lack of processing and refining capabilities (midstream), as well as manufacturing (downstream), often poses a greater risk to supply chain robustness than the sources themselves. For example, the U.S. mines the largest amount of rare earth elements (REEs) of any country other than the People's Republic of China (PRC), but we ship much of our REE concentrate to the PRC for future processing and refining.[9] For most critical materials, midstream processing represents the greatest U.S. challenge.

The PRC maintains a dominant position in the midstream processing capabilities for several different critical materials, including REEs, graphite, and cobalt. By intervening in each stage of the supply chain for over three decades, PRC non-market policies and practices and resulting market distortions have made it very difficult for midstream processing capabilities to be built in the U.S. or other countries. Dependence on a single source for these materials leaves the U.S.

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[6] Executive Order on America's Supply Chain. February 24, 2021. Available at https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/

[7] https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf

[8] https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition; https://www.energy.gov/sites/default/files/2023-05/2023-critical-materials-assessment.pdf

[9] https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf; https://mpmaterials.com/articles/mp-materials-reports-second-quarter-2023-results/

and our allies vulnerable. Therefore, we must ensure sufficient worldwide supplies of critical materials from responsible sources to protect U.S. national security and enable a clean energy and industrial economy.

With expected demand growth for critical materials to increase by four to six times over the next three decades, no single country will be able to satisfy global demand. This situation provides both a challenge and an opportunity to diversify critical material supply chains, improve labor and environmental standards worldwide, and create new technologies that can be deployed domestically. For the U.S. to be globally competitive, we should lead on innovation to develop sustainable approaches to our domestic critical material supply chains across the entire innovation pipeline, increasing efficiency and circularity while driving down environmental and health impacts.

DOE's Critical Materials Research, Development, Demonstration, and Deployment (RDD&D) program seeks to develop reliable, resilient, affordable, diverse, sustainable, and secure domestic critical mineral and material supply chains with a strategy consisting of five pillars: (1) diversify and expand supply; (2) develop alternatives; (3) materials and manufacturing efficiency; (4) circular economy; and (5) enabling activities.

- Diversify and expand supply: Identifying new feedstocks for CMMs, including secondary sources such as wastes from coal and hard rock mining and industrial processes, as well as expanding traditional sources from existing mining and international partners.
- Develop alternatives: Developing new materials, components and systems as replacements that can reduce or eliminate dependence on critical materials.
- Material and manufacturing efficiency: Designing mining, processing, refining, and manufacturing technologies that require less energy, water, heat, and chemical inputs; produce fewer environmental impacts; and generate little to no waste containing critical materials.
- Circular economy: Reducing the need for new CMM supply by enabling reuse and recycling of materials and extending their lifetime when in use.
- Enabling activities: Continued and accelerated interagency efforts to solidify the impact of our work are key to DOE's strategy. These efforts include the development of strong international environmental and labor standards for critical material supply chains, robust life cycle and technoeconomic analyses, advanced modeling and machine learning capabilities, and mineral source traceability and verification capabilities.

To better collaborate across DOE offices and ensure effective interagency coordination, the DOE has created an institutionalized structure, the Critical Materials Collaborative (CMC).[10] The CMC was established in September 2023, from direction in the Energy Act of 2020 and the Infrastructure Investment and Jobs Act, also known as the Bipartisan Infrastructure Law (BIL). The mission of the CMC is to accelerate DOE's critical materials applied RDD&D to achieve domestic clean energy manufacturing, climate, and national security goals by building a robust innovation ecosystem; training the critical materials workforce across multiple sectors; enabling

[10] https://www.energy.gov/cmm/critical-materials-collaborative

industry adoption of novel, cutting-edge technology; and laying the scientific and technological groundwork needed to address emerging challenges.

The CMC serves to help better plan critical minerals and materials RDD&D efforts and ensure DOE's larger interagency coordination through the NSTC Critical Minerals Subcommittee. FECM's Office of Resource Sustainability and the Office of Energy Efficiency and Renewable Energy's (EERE) Advanced Materials & Manufacturing Technologies Office are co-leading the CMC, while all DOE offices involved in critical minerals and materials RDD&D form a CMC Executive Committee. The aim of the CMC is to integrate critical minerals and materials applied RDD&D across DOE and improve coordination with the rest of the federal government to accelerate the development of transformational technologies that will be foundational to securing critical material supply chains. The CMC will work closely with the interagency to expand project performers' access to the Department's world-class expertise, capabilities, and facilities.

As part of its coordination and planning efforts, the CMC is engaging with its members to develop a research roadmap, share up-to-date information, support NSTC coordination, and share resources. The Collaborative will be a focal point for developing an innovation ecosystem around critical minerals and materials to include other agencies, laboratories, academia, industry, and others.

There are four main methods to diversify supplies of critical materials: recycling, recovery from secondary and unconventional feedstocks, responsible domestic mining, and accessing a broader range of international sources.

Recycling from end-of-life systems like electric vehicles and offshore wind turbines could eventually be able to produce a significant percentage of the Nation's critical material requirement. DOE's review of large-capacity batteries indicated that 20 percent to 40 percent of nickel and cobalt needs for new batteries could be met with cobalt recovered from recycling batteries as soon as 2030.[11] Recycling can dramatically decrease the cost, energy and water use compared to conventional mining. One ton of battery-grade cobalt can be recovered from 5 to 15 tons of spent lithium-ion batteries, which requires the equivalent of 300 tons of ore.[12] RDD&D can enable competitive recycling technology in the future. In the near term, sourcing 10 percent of material needs from recycling can support stressed supply chains and reduce the threat of supply shocks.

EERE is advancing technologies to recover critical materials from components at end-of-life, including through the Critical Materials Innovation Hub (CMI Hub), led by Ames National Laboratory, and the ReCell Center, led by Argonne National Laboratory. EERE's Wind Energy Technologies Office also launched the BIL-funded Wind Turbine Materials Recycling Prize this year, which will develop cost-effective and sustainable recycling industry for two material categories, including rare earth elements. EERE's Solar Energy Technologies Office announced the partially BIL-funded Materials, Operation, and Recycling of Photovoltaics (MORE PV)

[11] https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf
[12] https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf

funding opportunity, which will optimize critical material requirements in PV systems and develop advanced low-cost pathways for PV recycling.[13]

Secondary and unconventional feedstocks encompass many potential sources, including coal and coal byproducts, coal wastes, produced water from oil and gas production, ionic clays, hard rock mine tailings, acid mine drainage, bauxite residue, and phosphate sludge. Together, these sources have the theoretical potential to provide enough REEs to meet the nation's needs for decades, as well as significant quantities of other CMM resources.[14] For most secondary and unconventional resources, there is an opportunity for remediating the environmental impacts and reducing the waste from mining and other extraction activities. RDD&D in this area is geared toward commercial scale development, with a BIL funded DOE REE demonstration facility being built this decade.

FECM's Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Initiative supports regional coalitions of academia, industry, States, NGOs, and Tribal entities, that assess the potential for developing domestic supply chains using secondary and unconventional feedstocks. Billions of tons of coal waste and coal ash have been generated over the past two centuries and remain in waste piles or impoundments.[15] These and similar feedstocks represent a significant opportunity to diversify the supply of CMM resources while remediating longstanding environmental degradation and creating good jobs in mining and energy communities.

Current conventional mining practices use large amounts of energy, water, and other resources, and produce substantial greenhouse gas (GHG) emissions. Additionally, the success rate for finding new mines is very low (1000:1), taking almost a decade or more and hundreds of millions of dollars to identify and prove a resource.[16] The Administration's Interagency Working Group on Mining Laws, Regulations, and Permitting led by the Department of the Interior recently produced a report that outlined the need for mining organizations to build more robust engagements with local communities, as well as potential methods to improve the permitting process for mineral development, especially on Federal lands.[17] Ultimately, new and innovative approaches would help extract resources in a responsible and sustainable manner.

To that end, DOE is evaluating the potential for additional RDD&D investments to advance technological solutions and revolutionize mining into a more targeted enterprise that uses

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[13] https://www.ameslab.gov/cmi;
https://recellcenter.org/;
https://americanmadechallenges.org/challenges/wind-turbine-materials-recycling;
https://www.energy.gov/eere/solar/articles/funding-notice-materials-operation-and-recycling-photovoltaics-more-pv

[14] Report to Congress on Recovery of Rare Earth Elements and Critical Minerals from Coal and Coal By-Products. Available at https://www.energy.gov/sites/default/files/2022-05/Report%20to%20Congress%20on%20Recovery%20of%20Rare%20Earth%20Elements%20and%20Critical%20Minerals%20from%20Coal%20and%20Coal%20By-Products.pdf

[15] "Domestic Wastes and Byproducts: A Resource for Critical Material Supply Chains." Evan J. Granite, Grant Bromhal, Jennifer Wilcox, and Mary Anne Alvin, National Academy of Engineering, The Bridge, 53(3), 59-66, Fall 2023.

[16] "Geological data for mineral exploration." Eldosouky, et al. Geospatial Analysis Applied to Mineral Exploration. 2023. Available at https://www.sciencedirect.com/science/article/abs/pii/B9780323956086000068

[17] https://www.doi.gov/sites/doi.gov/files/mriwg-report-final-508.pdf

"surgical" approaches to extract minerals from ever deeper sources, minimize surface and environmental impacts, and improve public confidence in responsible mining techniques. Technology development areas for future mining research would likely include advanced drilling technologies, digital subsurface applications (autonomous operations, robotics, real-time extraction), *in situ* mineral extraction, novel processing, and tailings management. Data collection and management capabilities will also be critical in such an effort, as well as the building of a traceability capability with verification for all major critical materials.

This effort would build on and incorporate work initiated by the Advanced Research Projects Agency-Energy's (ARPA-E) Mining Innovations for Negative Emissions Resources (MINER) program which seeks to identify novel technologies that can substantially reduce waste, resource use, and GHG emissions from new mining.

In the meantime, domestic sources are not sufficient in the near-term to satisfy the Nation's critical material needs. Even in the long-term, it is important to develop a diverse critical materials supply network to maintain supplies needed by our allies and keep market prices for critical materials affordable in international and domestic markets. Therefore, U.S. collaboration with other countries could expand the sources and quantities of responsible supplies of critical materials. As part of this process, it is important to build capabilities for tracing and verifying the mineral origin for advanced batteries, magnets, and other manufactured products. Currently, countries such as the PRC that hold monopolies on the midstream and downstream processing of these critical minerals are investing heavily internationally to ensure a diverse feedstock that will feed their supply chains for years to come.

The Department is proactively engaging with our international partners. This includes the G7 and the International Energy Agency, where we are working with allies to promote secure and diversified supplies, market transparency, and responsible practices across the supply chain. The Department is also working closely with Australia through the recently signed Australia-United States Climate, Critical Minerals, and Clean Energy Transformation Compact. Canada, Japan, the UK, and the European Union are also key partners in advancing resilient critical material supply chains.

The Department has identified a tiered approach to help build new domestic commercial infrastructure in the near-term and bring new technologies to market in the next decade. This approach has allowed the Department to coordinate efforts across various technology readiness levels and exploit the exceptional expertise that resides across multiple DOE offices. These three technology development tracks are: (1) demonstration and commercial application; (2) advanced technology development; and (3) transformational technology development. The first track focuses on getting current or near-ready technologies to the marketplace to help stand up critical pieces of domestic supply chains as soon as possible. The second track is focused on technologies that advance the current state of the art in terms of cost, equitable social and environmental performance, but which remain three to ten years away from commercialization. The third track includes potentially transformational technologies that have the potential to revolutionize the critical materials industry in terms of environmental and equitable social performance as well as cost, but which are probably at least a decade from commercialization.

All of these development pipelines are important to accelerate the deployment of robust domestic supply chains for critical materials.

It is urgent to get new commercial midstream technology in place in the U.S. to establish domestic supply chains this decade. With funding from the BIL and the Inflation Reduction Act (IRA), the Department's Office of Manufacturing and Energy Supply Chains (MESC) and the Loan Programs Office (LPO) are leading these efforts, with LPO committing more than $3 billion for several critical materials production and recycling project, and MESC targeting over $6 billion in BIL funding to support battery materials processing, manufacturing, and recycling.[18]

MESC works to strengthen and secure energy supply chains and manufacturing to modernize U.S. energy infrastructure and support the clean energy transition. To this end, MESC is implementing provisions in the BIL, the Defense Production Act, and the IRA. Two important efforts include the Battery Materials Processing and Battery Manufacturing Recycling Supply Chain Facilities to separate and process critical battery materials and the Rare Earth Element Demonstration Facilities that will extract from unconventional feedstock materials, such as lignite coal and acid mine drainage.

At the same time, FECM, EERE, and other DOE applied research offices are working to develop technologies that improve on the current commercially available state of the art technologies that have reduced costs and adverse impacts while demonstrating optimal performance through their lifecycles. As these technologies are shown to be effective at lower Technology Readiness Levels, DOE's applied science and technology offices will work to advance them toward commercialization.

FECM is also advancing an RDD&D portfolio geared toward increasing the domestic production of critical materials in the United States. Research is focused on extracting, separating, and recovering rare earth elements and critical materials from unconventional and secondary sources. We have had success in this area, including the design, construction, and operation of five first-of-a-kind bench and small pilot-scale facilities that are producing high-purity mixed rare earth oxides/salts from coal-based resources using conventional beneficiation and separation processes. FECM has released several BIL-related FOAs this year to help accelerate these efforts.[19][20][21] We are also developing more energy efficient synthetic graphite, graphene and carbon anode materials from coal, coal waste, and coal byproducts.

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[18] https://www.energy.gov/lpo/portfolio-projects;
https://www.energy.gov/mesc/battery-materials-processing-grants;
https://www.energy.gov/mesc/battery-manufacturing-and-recycling-grants

[19] September 6, 2023 Funding Opportunity Announcement: https://www.energy.gov/fecm/funding-notice-critical-materials-innovation-efficiency-and-alternatives
[20] August 21, 2023 Funding Opportunity Announcement: https://www.energy.gov/fecm/funding-notice-bipartisan-infrastructure-law-advanced-processing-critical-minerals-and
[21] July 13, 2023 Funding Opportunity Announcement: https://www.energy.gov/fecm/funding-notice-bipartisan-infrastructure-law-front-end-engineering-and-design-feed-studies

EERE is working to establish sustainable supply chains for the critical materials needed to support clean energy technologies. EERE's Advanced Materials and Manufacturing Technologies Office manages an applied RDD&D portfolio that addresses high-impact opportunities and challenges across the life cycle of critical minerals and materials for clean energy. This includes the CMI Hub, a public-private consortium of national laboratories, universities, and industry focused on technologies that make better use of materials and eliminate the need for materials that are subject to supply disruptions. Since its inception in 2013, CMI research has been awarded forty-seven U.S. patents, licensed twenty technologies, and received five Federal Laboratory Consortium awards, twelve R&D 100 Awards, and over $80 million in follow-on funding. Funding from BIL has accelerated the commercialization of CMI-developed technology to recycle critical materials from lithium-ion batteries.

Through prize competitions, EERE's Geothermal Technologies Office is incentivizing innovators to de-risk and increase market viability for direct lithium extraction from geothermal brines, while the Vehicle Technologies Office is spurring innovative solutions to collect, sort, store, and transport spent and discarded lithium-ion batteries for eventual recycling and materials recovery. The Hydrogen and Fuel Cell Technologies Office (HFTO) is advancing research on substitutes for and reducing the amount of platinum and iridium in electrolyzers needed for clean hydrogen production, as well as addressing critical material recovery and recycling, with a target for increasing the efficiency and cost effectiveness of raw materials for hydrogen technologies by 2028. The Vehicle Technologies Office continues to drive research and development on next-generation battery chemistries as alternatives to commercial lithium-ion batteries and the critical materials like cobalt, nickel, graphite, manganese, and lithium that they currently contain.

Additionally, several DOE offices help to identify discoveries and inventions that show promise at very low Technology Readiness Levels and work on advancing technologies toward commercial deployment. ARPA-E and the Office of Science are investing in game changing breakthroughs that can lead to transformational technologies that will be part of a next generation of critical minerals and materials supply chains. ARPA-E's MINER program seeks to increase U.S. domestic supplies of copper, nickel, lithium, cobalt, and other rare earth elements. And the Office of Science supports foundational science on understanding the role of rare earth elements, platinum group elements, other critical elements to determine the properties of materials and molecules and science that will enhance the extraction and chemical processing of these elements, including engaging in the Material Genome Initiative.[22]

DOE has over $8 billion in funding dedicated to critical materials and minerals advancement. Additionally, the IRA provides 48C tax credits to re-equip, expand, or establish industrial facilities for the processing, refining, or recycling of CMM.

Mr. Chairman, critical minerals and materials are crucial to the way we live our lives every day. They are required in a wide range of strategic industries, including aerospace, medicine, and defense. They are also indispensable components in clean energy technologies, such as batteries, electric vehicles, wind turbines, and solar panels.

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[22] The Materials Genome Initiative (MGI) is a U.S. Federal government multi-stakeholder initiative to develop an infrastructure to accelerate and sustain domestic materials discovery and deployment in the United States

U.S. reliance on foreign sources for these materials is neither sustainable nor secure. That is why the DOE is taking robust and wide-ranging actions to address this challenge and secure domestic and allied supply chains for critical minerals and materials.

For over a decade, DOE has invested in basic and applied research and development related to critical minerals and materials to address the scientific and technological challenges that underpin supply chain vulnerabilities as demand for CMMs increase worldwide. RDD&D has the potential to help create the transformational technologies to ensure that the U.S. has the material resources needed for economic, energy and national security.

DOE appreciates the Committee on Science, Space, and Technology for its bipartisan support of critical materials research, development, and demonstration over many years, and we look forward to continuing our work with the Committee on additional critical materials policy going forward.