**Testimony of**

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**On**
**Research and Innovation to Address the Critical Materials Challenge**

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Chairman Lamb, Ranking Member Weber, and Members of the Subcommittee, thank you for the opportunity to discuss with you today the importance of research and innovation in addressing the critical materials challenge, particularly in the context of H.R. 4481, and on the impact of such R&D in creating innovative scientists and engineers capable of ensuring an adequate supply of critical materials, now and in the future. I am Carol Handwerker, the Reinhardt Schuhmann, Jr. Professor of Materials Engineering and Environmental and Ecological Engineering at Purdue University. I am also the Program Lead for Recycling and Reuse in the DOE Critical Materials Institute. Before joining Purdue in 2005, I was at NIST for 21 years, most recently serving for nine years as Chief of the NIST Metallurgy Division where I led measurement programs for improving the manufacturing and performance of electronic, magnetic, photonic, and structural materials vital to industries across the United States. At both NIST and Purdue, I've led industry-government-university partnerships focused on solving significant industry-wide problems by translating fundamental science discoveries into new materials and technologies that industries could and did adopt.

From my vantage point, having been part of and led multi-stakeholder teams to solve significant industry-wide problems, I believe that the Critical Materials Institute is a successful model for H.R. 4481. The Critical Materials Institute has demonstrated how multi-disciplinary, multi-organization teams of innovative scientists and engineers can work together to create new technologies and supply chains for critical materials. The Critical Materials Institute, with its 4 National Laboratories, 9 universities, and 15 industrial partners, is organized, managed, and operated as a single, unified organization, setting priorities and working together on early stage R&D designed to solve the U.S. critical materials problems. The mission of CMI is echoed in the goal of H.R. 4481, "to assure the long term, secure, and sustainable supply of energy critical elements sufficient to satisfy the national security, economic well-being, and industrial production needs of the United States." Four key operating strategies of CMI are designed to accelerate early stage R&D into meaningful impact on the supply of energy critical materials: (1) identifying the most important challenges and developing effective solutions to them by marshalling the most capable research teams; (2) close collaboration with industry at the earliest possible R&D stage, even at the concept stage (TRL-1), (3) enabling new technologies that meet industry needs, explicitly quantifying economics, logistics, and environmental impact at the earliest possible stage, and (4) enlisting the help of world-leading innovative researchers and research tools within and beyond CMI to overcome roadblocks.

Every CMI technology is designed to fit into a supply chain, with industrial links at both ends. Working directly with industry partners at the earliest stage means that CMI researchers understand the quantitative characteristics of feedstocks coming into the CMI technology, the quantitative requirements for an economically viable product enabled by the CMI technology, and the economics of competing technologies, including the status quo with or without alternative sources, materials, technologies or critical materials recycling. One example from the CMI recycling and reuse research portfolio is the electrochemical recovery of Li, Co, Mn, Ni, and graphite from shredded, mixed composition Li-ion batteries. Partnerships with large-scale Li-ion battery recyclers enabled CMI R&D to be performed not on simulated shredded waste as feedstock, but on feedstock from existing commercial processes that do not currently capture all the critical materials. Techno-economic and environmental impact analyses identify bottlenecks, driving early-stage research to eliminate these potential technological barriers to economic viability and sustainability. Finally, open discussions of scientific roadblocks for individual projects across CMI have led to CMI researchers outside the projects seamlessly working with those project teams to overcome the roadblocks. These strategies are helping to create functioning, sustainable supply chains: a chain cannot exist without all the links in place and you cannot build one link without working with its neighbors.

I am pleased to be here today representing Purdue University, a public land-grant university with 44,500 undergrad and grad students, 2/3 of which are in STEM disciplines. Purdue is one of the major engineering universities in the United States: 5th in the number of undergraduate engineering degrees awarded at 1771 in 2019; 5th in the number of women awarded undergraduate engineering degrees at 412 in 2019; and 5th in doctoral engineering degrees awarded at 280 in 2019. One of Purdue's areas of expertise is advanced manufacturing, from developing new materials and processes for additive manufacturing to creating systems-level models and scenario analyses for value chains. A major contribution of Purdue faculty, graduate students, and postdocs to CMI has been their creation of tools for researchers across CMI to do preliminary self-assessments of both the economics and the environmental impacts of their early-stage technologies. These are cornerstones of advanced manufacturing research. Purdue researchers then help them refine their analyses, then identify and eliminate the economic and environmental hotspots that might limit industry adoption. Using these tools and analyses caused a cultural shift during the first five years of CMI. This has translated into further acceleration of technology development and greater industry involvement since the beginning of the sixth year. In terms of workforce development, through their experiences in multi-disciplinary CMI teams, CMI graduate students and post-docs at Purdue and across CMI have developed not only the discipline-based knowledge, skills, and abilities needed as "technically trained personnel necessary for energy critical elements research, development, and industrial production" but also have learned how to engage with industry during early-stage R&D to maximize the likelihood that the technologies they create will be economically viable and environmentally sustainable.

Finally, the CMI strategies for accelerating technology development for energy critical materials are working to bridge the "valley of death", where technologies die during the transition from early stage R&D (TRL 1-4) to pilot scale demonstrations, scale-up, and finally to commercialization. The "valley of death" occurs for many different reasons, as discussed in the 2004 National Academy of Engineering Report, **Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems**, which I co-authored. What is impressive about CMI as an organization is that its characteristics – how it is organized and manages itself, and how the researchers across CMI work on common high level goals – map almost exactly into the recommendations of the NAE Report.

A good example of how CMI is forging strong links in the supply chain is the industry-government- academia-NGO project for Value Recovery from Hard Disk Drives. Hard disk drives are one of the most widespread uses of rare earth magnets, with over 400 million of hard drives sold per year and billions still in service. Hard drives are the work horses of Cloud and data center storage, with tens of millions of hard drives retired from service each year by the hyperscale data centers alone. Through the leadership of CMI and team members Seagate and Purdue, the International Electronics Manufacturing Initiative, a consortium of more than 90 manufacturers, suppliers, industry associations, consortia, government agencies, research institutes and universities, brought together a team of individuals and organizations who not only represented the full supply chain for value recovery for HDDs, but also the wide range of expertise and creative thinking needed to address this multi-dimensional challenge of value recovery from HDDs. The primary focus of the project was to demonstrate an economically viable, environmentally sustainable circular economy for hard drives, with multiple pathways enabled by CMI research on for hard drive disassembly, magnet reuse, and recovery of rare earth oxides and metals. The electronics industry stakeholders (CMI team members and affiliates marked with *) who participated in the NEMI project included: Ames Laboratory*, Cascade Asset Management, Cisco, Critical Materials Institute*, Echo Environmental, Geodis, Google, Green Electronics Council, Idaho National Laboratory*, Microsoft, Momentum Technologies*, Oak Ridge National Laboratory*, Purdue University*, Rifer Environmental, Seagate Technology*, Teleplan, University of Arizona*, and Urban Mining Company. Based on the successful demonstration of five new pathways for value recovery, discussions of larger scale collaborations and demonstration projects are underway with multiple supply chain partners.

CMI is not simply a research program with a collection of projects focused generically on critical materials or local research interests and capabilities. CMI undertakes world-class research on specific opportunities for, and challenges to materials supply chains. It provides a comprehensive strategy for accelerating technology development to create a long term, secure, and sustainable supply chain for energy critical elements and products for the United States. Operating with a sense of urgency from the outset, CMI has used this strategy to produce striking results in a very short period of time. While government-funded R&D usually takes at least 20 years to move from discovery in the lab to success in the marketplace, CMI inventions have been adopted by industry in as little as three years from the beginning of research. This is important to keep in mind as the list of energy critical materials continues to grow, with equally difficult scientific, technological, and supply chain challenges that must be quickly overcome.  The federal government's commitment to creating a supply of energy critical elements and products for the United States through the H.R. 4481 "program of research, development, demonstration, and commercial application" will be needed to have a hope of mitigating the increasing risks to national security, economic well-being, and industrial production.