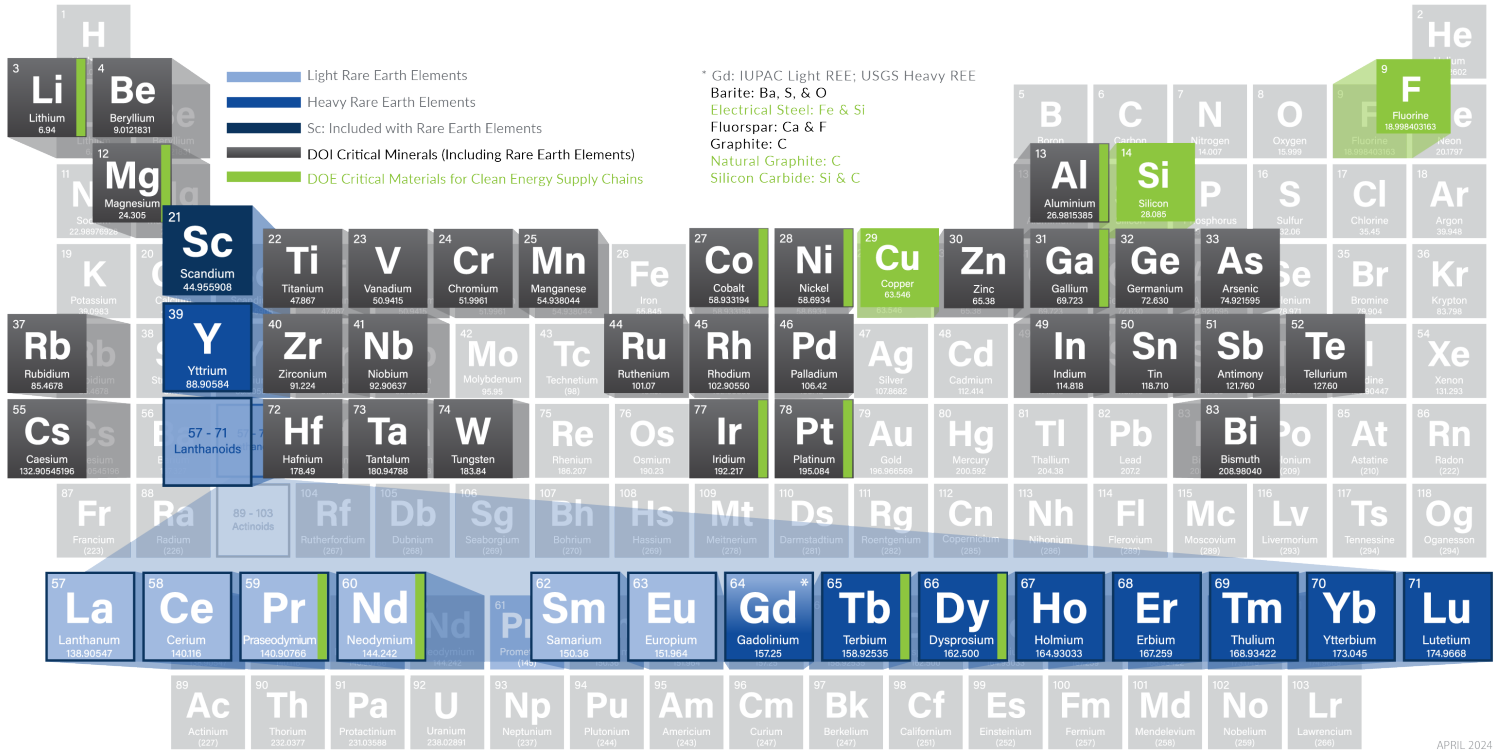


CRITICAL MINERALS AND MATERIALS PROGRAM



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The Critical Minerals and Materials Program aims to rebuild U.S. leadership in extraction and processing technologies to support an economically, environmentally benign and geopolitically sustainable U.S. domestic supply chain for critical minerals and materials (CMM)^{1, 2}—which includes rare earth elements (REEs) and a host of other critical elements—from secondary and unconventional resources.

Secondary and unconventional CMM resources include any resource from a secondary byproduct of anthropogenic processes or in situ geologic deposits that are distinctive from conventional CMM ore deposits. These secondary and unconventional CMM resources require revised or new methods and models for characterization, assessment and recovery.

Examples of secondary byproduct and unconventional CMM resources include:

- Secondary byproducts derived from mining and fossil-energy related waste streams, e.g., coal fly ash, acid mine drainage, mine tailings and reject waste, oil and gas produced water and alloy production residues.
- Sedimentary deposits, e.g., coal, black shale, tonsteins, coal underclays and marine phosphates.

PROGRAM GOALS

The CMM Program approach is centered on the crucial challenge of developing and demonstrating economically feasible extraction processes that are also environmentally benign and economically beneficial to U.S. communities, focusing on the following goals:

- Validation of the technical and economic feasibility of domestic small pilot-scale facilities to produce high-purity CMM from carbon ore and coal-based resources
- Production of 1–3 tonnes/day of high-purity mixed rare earth oxides/salts in domestic demonstration-scale facilities and refining to metals or alternate user-specified products as required for use in the CMM supply chain using coal-based and alternate resources as feedstock materials
- Production of a National CMM Prospectus based on regional assessments of secondary and unconventional CMM resources including an estimate of potential U.S. production of CMM

KEY TECHNOLOGY AREAS

The CMM Program portfolio includes detailed cutting-edge characterization of secondary and unconventional CMM resources, prospectivity modeling of these resources, and the application of novel technologies to extract CMM from diverse geological materials, sediments, and waste materials.

For this fully integrated research, development, demonstration, and deployment (RDD&D) program, DOE-NETL's efforts uniquely span basic and applied science and technology development (e.g., technology readiness level (TRL) 1–3), through engineering design, construction, and operation of bench- and small pilot-scale separation facilities (TRL 3–5), to development of process designs and operation of near-future engineering-scale prototype separation facilities (TRL 6–8).

The research and development efforts of the CMM Program apply to three key technology areas: **Resource Characterization and Technology Development, Critical Mineral Processing, and Advanced Critical Material Extraction Technology.**

RESOURCE CHARACTERIZATION AND TECHNOLOGY DEVELOPMENT – Current NETL-led research focuses on developing robust approaches that seamlessly integrate basin-scale geologic data with core or borehole characterization data to predict the prospectivity and technical recoverability of CMM in unconventional and secondary sources.

Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Initiative

The DOE Office of Fossil Energy and Carbon Management (FECM) CORE-CM Initiative funds coalition teams focused on repurposing secondary and unconventional resources to address the upstream and midstream CMM supply chain and

downstream manufacturing of high-value, nonfuel, carbon-based products. This initiative is designed as a multi-year effort to accelerate the development of U.S. CMM supply chains while contributing to regional (Figure 1) economic growth and job creation.

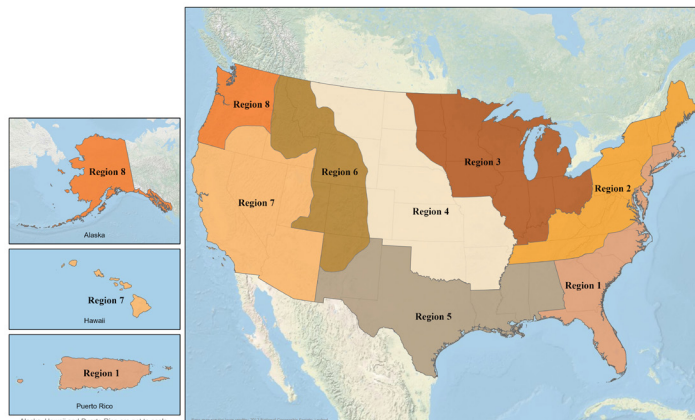


Figure 1. CORE-CM Initiative regional divisions

METALLIC: Cross-Cutting National Laboratory Research

In Spring 2024, FECM announced³ a new NETL-led project that will receive \$75 million in funding to develop the Critical Materials Supply Chain Research Facility (METALLIC) focused on accelerating and de-risking CMM technology development and commercialization. METALLIC will leverage capabilities of nine national laboratories, including NETL, to tackle the nation's CMM challenges.

CRITICAL MINERAL PROCESSING – NETL's focus on CMM processing includes developing novel materials and processes to concentrate CMM streams from dilute sources. These include oil and gas produced waters, acid mine drainage (AMD), and mineral processing streams. These processing technologies encompass both conventional and advanced recovery RDD&D. The portfolio also focuses effort on the development of processing methods that reduce the amount of water required for processing and science that targets overall environmental performance of CMM operations.



To date, these efforts have resulted in the design, construction, and operation of three first-of-a-kind, small pilot-scale facilities producing small quantities (e.g., ~100 gm/day) of greater than 90% high-purity mixed rare earth oxides/salts from coal-based resources using conventional physical beneficiation and hydrometallurgical processes.

ADVANCED CRITICAL MATERIAL EXTRACTION TECHNOLOGY

– This technology area focuses on RDD&D to develop technologies that support innovation needs for responsible and transformational mining of CMM in the United States. The major goals are to eliminate large open pit surface mines and the extensive networks of tunnels in underground mines to reduce CMM mining footprints. Major objectives include substantially reducing waste, water use, and greenhouse gas emissions currently associated with conventional mining practices. Key RDD&D areas of interest include advanced drilling technologies, deployment of novel geophysical tools, autonomous subsurface operations, in-situ mining and processing, mine waste and tailing management, and mineral traceability.



SYSTEMS ANALYSIS: TECHNO-ECONOMIC AND LIFE CYCLE ANALYSIS

The CMM Program has an important focus on the analysis of systems related to CMM supply chains, such as improving understanding of the techno-economic factors that determine the potential success of new technologies, conducting life cycle analysis of proposed processes, and coalescing the data required to inform an understanding of CMM markets. NETL uses its knowledge and experience with techno-economic analysis, baseline development, market analysis, and environmental assessments to inform in-house research and evaluate externally proposed projects while developing independent baseline analyses to recover CMM from secondary and unconventional resources.



¹ DOE EERE, "U.S. Department of Energy Releases 2023 Critical Materials Assessment to Evaluate Supply Chain Security for Clean Energy Technologies," July 31, 2023, <https://www.energy.gov/eere/articles/us-department-energy-releases-2023-critical-materials-assessment-evaluate-supply>

² USGS, "U.S. Geological Survey Releases 2022 List of Critical Minerals," February 22, 2022, <https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals>

³ NETL, "NETL To Lead Multi-National Lab Collaboration To Rapidly Advance Critical Minerals and Materials Technologies," April 2, 2024, <https://netl.doe.gov/node/13549>



NETL is a U.S. Department of Energy national laboratory that drives innovation and delivers solutions for a clean and secure energy future by advancing carbon management and resource sustainability technologies. Through its expertise and research facilities, NETL is advancing innovations to enable environmental sustainability for all Americans. Using the power of workforce inclusivity and diversity, innovators at NETL's research laboratories in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, conduct a broad range of research activities that support DOE's mission to ensure America's security and prosperity by addressing its energy and environmental challenges through science and technology solutions.

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