

CRITICAL MINERALS AND MATERIALS PROGRAM

Legend:

- Light Rare Earth Elements (Blue)
- Heavy Rare Earth Elements (Dark Blue)
- Sc: Included with Rare Earth Elements (Light Blue)
- DOI Critical Minerals (Including Rare Earth Elements) (Green)
- DOE Critical Materials (Yellow)

* Gd: IUPAC Light REE; USGS Heavy REE
 Barite: Ba, S, & O
 Electrical Steel: Fe & Si
 Fluorspar: Ca & F
 Graphite: C
 Natural Graphite: C
 Silicon Carbide: Si & C

MARCH 2025

Program 141, April 2025



The Critical Minerals and Materials (CMM) Program aims to rebuild U.S. leadership in extraction and processing technologies to support an economically, environmentally and geopolitically sustainable U.S. domestic supply chain for CMM^{1,2} — which include rare earth elements 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 (AMD), 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 sustainable and economically beneficial to U.S. communities, focusing on the following goals:

- Validation of the technical and economic feasibility of domestic small pilot-scale (or larger) 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, U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) 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 design and operation of large pilot-scale CMM recovery 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 Recovery Technology.**

RESOURCE CHARACTERIZATION AND TECHNOLOGY DEVELOPMENT — Current NETL-led research focuses on developing robust approaches that seamlessly integrate coal basin-scale or regional geologic data with core or borehole characterization data to predict the prospectivity and technical recoverability of CMM in secondary and unconventional 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 multiyear effort to accelerate the development of U.S. CMM supply chains while contributing to regional (Figure 1) economic growth and job creation.

METALLIC: Cross-Cutting National Laboratory Research

In spring 2024, FECM announced³ a new NETL-led project that has received \$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.

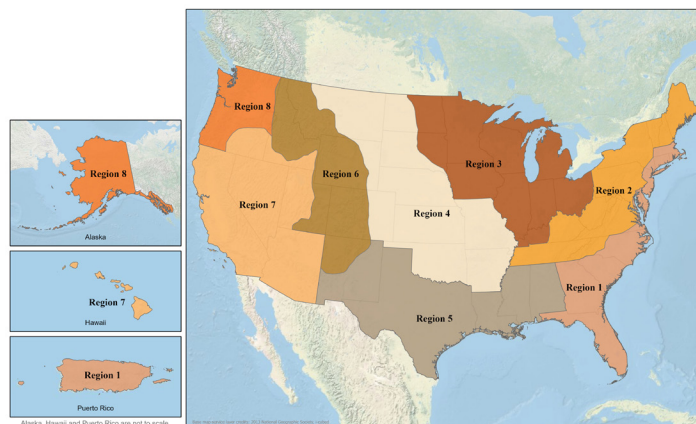
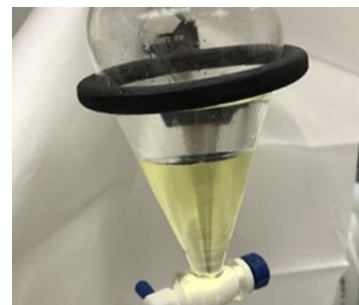


Figure 1. CORE-CM Initiative regional divisions.

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, AMD, and mineral processing streams. These processing technologies encompass both conventional and advanced extraction, separation, and refining RDD&D. The portfolio also focuses on the development of recovery methods that reduce the amount of water or chemicals 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 RECOVERY TECHNOLOGIES

— 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 goal is to reduce CMM mining footprints by eliminating large open-pit surface mines and the extensive networks of tunnels in underground mines. Major objectives include substantially reducing land, water and air impacts 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: TECHNOECONOMIC 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 technoeconomic 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 technoeconomic analysis, baseline development, market analysis, and environmental assessments to inform inhouse 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," Feb. 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 DOE national laboratory dedicated to advancing the nation's energy future by creating innovative solutions that strengthen the security, affordability and reliability of energy systems and natural resources. With laboratories and computational capabilities at research facilities in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL addresses energy challenges through implementing DOE programs across the nation and advancing energy technologies related to fossil fuels. By fostering collaborations and conducting world-class research, NETL strives to strengthen national energy security through energy technology development.

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