



Critical Minerals

A secure and stable domestic supply of critical minerals and materials is essential to supporting U.S. energy leadership, national security, and economic growth. NETL advances innovative technologies to extract and process minerals from domestic sources, including coal-based resources, metals processing streams, and legacy mineral wastes such as mine tailings and mineral processing byproducts. Through these unconventional resources, NETL helps to reduce reliance on foreign supply chains, strengthen U.S. manufacturing, and ensure access to the materials needed for modern energy and defense systems.

R&D Applications

- Resource Discovery, Characterization, and Quantification
- Geospatial Analysis
- Critical Mineral Processing
- Alloys and Metal Making
- Extraction from Unconventional Sources
- Advanced Separation and Purification Technologies
- Technoeconomic and Life Cycle Analysis
- Development of Tools To Advance Technology Transfer



Researchers examine materials to fortify supply chains and promote research and development breakthroughs.



Experts in the Geosciences Lab accelerate domestic mineral production from unconventional feedstocks.

Targeted Rare Earth Extraction (TREE) Process

NETL's TREE process is a cost-effective, environmentally friendly method to recover rare earth elements (REE) from coal utilization byproducts. Operating at ambient temperatures and pressures, it minimizes the need for acids, solvents, and preprocessing. Tests using Powder River Basin (PRB) coal ash demonstrated that 5% or more of domestic REE demand could be met by deploying the TREE process. TREE can also be deployed in eastern states where PRB coal has been shipped and consumed for power generation, increasing the technology's impact.



Research Highlights

Unconventional Rare Earth and Critical Mineral Resource Assessment Tool (URC Tool)

To reduce U.S. reliance on foreign REE imports, NETL developed the URC Tool. This artificial intelligence-driven platform uses geologic and environmental criteria to predict where REE and critical minerals are likely to occur across the U.S. The initial PRB test shows promise due to the region's data availability and geologic simplicity. This tool marks a paradigm shift in how we identify unconventional mineral resources. The URC method is scalable and adaptable for broader application.

Lithium in Marcellus Shale-Produced Water

Produced water from hydraulic fracturing operations in the Marcellus Shale may represent a substantial domestic lithium source. By analyzing public datasets, NETL estimates that Pennsylvania's produced water could yield roughly 1,160 metric tons of lithium annually. Assuming full recovery, this could represent up to 40% of the current U.S. lithium consumption. Using NETL's ProMMiS (Process Optimization and Modeling for Mineral Sustainability) platform, part of the IDAES (Institute for the Design of Advanced Energy Systems) tool suite, researchers conduct technoeconomic evaluations to determine the most viable recovery technologies and product pathways.

METALLIC: The Minerals to Materials Supply Chain Research Facility

METALLIC is a multilaboratory initiative that NETL leads to accelerate research, development, demonstration, and deployment (RD3) across the entire minerals and materials supply chain. The consortium consists of nine national laboratories and supports four key RD3 centers: feedstock beneficiation, extraction and separation, refining, and alloy development and advanced manufacturing. By offering technical expertise, facilities, and coordination, METALLIC enables faster transition of technologies from lab to market.

Domestic Prospectivity and Geospatial Modeling

Researchers at NETL have conducted extensive field prospecting to locate potential critical mineral-containing coal-based materials. By developing a systematic method and understanding how minerals are present within various materials, they can identify promising resources that can be separated and recovered. Researchers use X-ray diffraction, scanning electron microscopy, microprobe analyses, and analytical characterization techniques to identify potential materials and develop extraction techniques.

Publications

- Creason, C. G., Justman, D., Rose, K., Montross, S., Bean, A., Mark Moser, M., Wingo, P., Sabbatino, M., & Thomas, R. B. (2023). A geo-data science method for assessing unconventional rare-earth element resources in sedimentary systems. *Natural Resources Research*, 32(3), 855-878. <https://www.osti.gov/pages/biblio/1959388>.
- Fritz, A. G., Tarka, T. J., & Mauter, M. S. (2023). Assessing the economic viability of unconventional rare earth element feedstocks. *Nature Sustainability*, 6, 1103-1112. <https://www.osti.gov/pages/biblio/2328134>.
- Gao, Y., Pham, V. H., Weidman, K. J., Spaulding, R. E., Wang, C., & Matranga, C. (2024). High-performance cementitious composites containing nanostructured carbon additives made from charred coal fines. *Scientific Reports*, 14(1), 8912. <https://www.nature.com/articles/s41598-024-59046-y>.
- Mackey, J., Bain, D.J., Lackey, G., Gardiner, J., Gulliver, D., & Kutchko, B. (2024). Estimates of lithium mass yields from produced water sourced from the Devonian-aged Marcellus Shale. *Scientific Reports*, 14, 8813. <https://doi.org/10.1038/s41598-024-58887-x>.
- Montross, S. N., Bagdonas, N. D., Paronish, T., Bean, A., Gordon, A., Creason, C. G., Thomas, B., Phillips, E., Britton, J., Quillian, S., & Rose, K. (2022). On a unified core characterization methodology to support the systematic assessment of rare earth elements and critical minerals bearing unconventional carbon ores and sedimentary strata. *Minerals*, 12(9). <https://www.mdpi.com/2075-163X/12/9/1159>.

NETL is a U.S. Department of Energy (DOE) national laboratory dedicated to innovating and accelerating the nation's energy solutions in hydrocarbons, geothermal energy, and critical minerals production. The Lab further strengthens its impact by engaging with industry, academia, and other stakeholders through four strategically located Centers of Excellence: Coal, Critical Minerals & Advanced Alloys, Oil & Gas, and Geothermal. With research sites in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL operates as one laboratory to create advanced energy technologies that support DOE's mission and enable affordable, reliable and, secure energy to fuel human prosperity.



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