

## Feasibility of Recovering Rare Earth Elements Program

## Program Background

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) and the National Energy Technology Laboratory's (NETL) Feasibility of Recovering Rare Earth Elements program develops extraction, separation, and recovery technologies for the production of rare earth elements (REEs) and critical materials (CMs) from coal and coal-based resources.

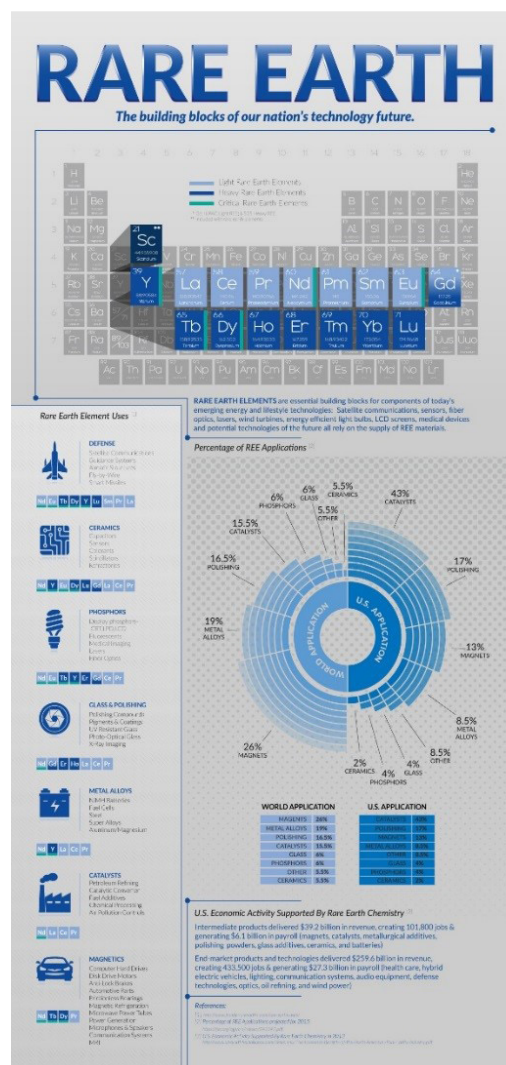
This research, design, and development (RD&D) program is working on process and production technologies, environmental management, and field materials sampling and characterization. Additionally, the program uses systems integration, optimization, and efficiency improvements to produce REEs and CMs from coal and coal by-products, such as coal and coal refuse, clay/sandstone over/under-burden coal seam materials, power generation ash, and aqueous effluents in acid mine drainage (AMD) sludge.

Our Nation’s vast coal reserves contain quantities of REEs. They offer the potential to reduce our dependency on other countries for these CMs and to create new industries in regions where coal plays an important economic role. The DOE-NETL REE-CM program offers a way to improve the economics of a domestic coal-based value chain and to reduce its environmental impact. The development of an economically competitive supply of REEs and CMs will help maintain our Nation’s economic growth and national security.

## Reserve Estimates

An initial assessment of the quantity of REEs likely to be found in coal deposits and associated mineral matter was performed by DOE-NETL in 2014–15. This assessment indicated that approximately 6 million metric tons (MTs) of REEs could potentially be recovered from known coal reserves. Those reserves are found in select western state coal basins in Montana, Wyoming, Colorado, Utah, New Mexico, and Arizona. Similar estimates indicated that nearly 5 million MTs were potentially available in coal deposits in Pennsylvania, West Virginia, Kentucky, and Virginia.

In addition, separate estimates were made for the total tonnage of REEs that might be available in coal ash and coal mine refuse. Those estimates suggested several additional million MTs of REEs could be found in these sources as well. The actual amounts that can be recovered would ultimately be a function of mining practices, the ease of extraction of REEs from the base feedstock material; and the overall economics of the process.



## Recovery Opportunities

Long-term opportunities to economically recover REEs from coal and coal-based resources depend not only on RD&D that is focused on near-term technical and economic feasibility, but also on leveraging the knowledge

of novel recovery concepts that apply to low REE concentration feedstock materials.

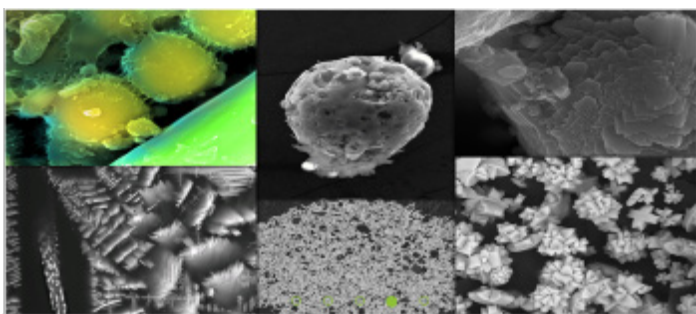
These new processes and systems must incorporate steps to recover, separate, and refine REEs without generating additional unwanted products. These advances may facilitate recovery of REEs from large volumes of fly ash and bottom ash, as well as other low REE-containing materials such as AMD effluents and/or sludges. Moreover, co-production of REEs with other useful materials present in coal-based resources makes REE recovery more economically favorable.

## Program Structure

The REE program portfolio currently consists of both intramural and extramural projects, ranging from concept definition and development—Technology Readiness Level (TRL 1–3), through laboratory and bench-scale testing (TRL 3–5), and additionally, small pilot-scale testing (TRL 4–6). Those steps are necessary to validate the design, construction, and operation of functional prototype coal-based facilities that can produce salable, high-purity REEs.

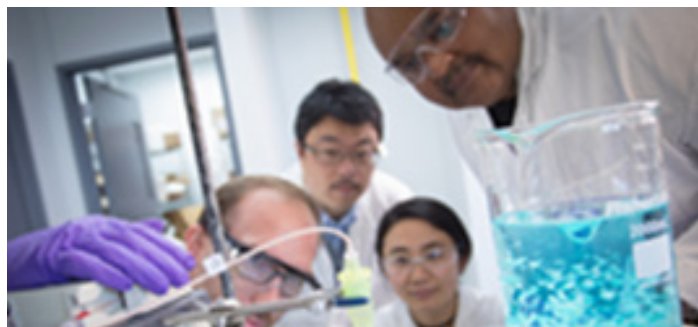
The program's core technology areas include:

- **Enabling Technologies** – Develop technology knowledge bases through resource identification, field sampling and characterization, techno-economic analysis development, and field and/or process sensor development.



- **Separations Technologies** – Address the viability of utilizing commercially available extraction and separation equipment and/or systems developed for alternate technologies. Demonstrate their capability for the extraction and separation of REEs from coal-based

materials by technology transfer. In parallel, develop new transformational REE extraction and separation concepts.



- **Process Systems** – Design, construct, and operate bench-scale and/or small, pilot-scale systems to validate the capability of producing REEs from coal-based resources.



## Program Summary

- **Prospecting** – Field sampling, characterization, and identification of 'best' materials for obtaining REEs and their reserves.
- **Processing** – REE extraction, separation, and recovery projects, as well as demonstration of concept feasibility from bench-scale through pilot-scale integrated process system testing.
- **Production** – Generation of market-ready REEs.

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