Novel Membrane and Electrodeposition-Based Separation and Recovery of Rare Earth Elements from Coal Combustion Residues (Award #DE-FE0026952)

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Summary

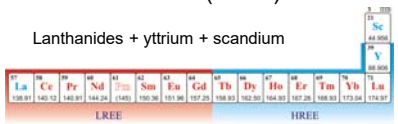
This project will develop a hydrometallurgical-based technology to extract and concentrate rare earth elements (REEs) from coal fly ash and other coal combustion residues. Specifically this project will:

- Identify and characterize a representative selection of CCR samples as candidates for REE recovery.
- Evaluate the efficiency of hydrometallurgical acid extraction techniques as a function of major CCR characteristics and extraction conditions.
- Optimize membrane filtration and carbon nanotube-enabled electrochemical deposition techniques for concentration of REEs from CCR extracts.
- Perform a technical and economic feasibility study of the proposed separation methods.
- Develop an implementation plan for a bench-scale system.

Significance and Relevance

1. Rare earth elements (REEs)

Lanthanides + yttrium + scandium

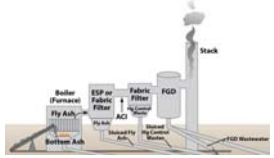


- Critical materials for electronics, energy, and defense industries

- Unstable global supply market for REEs

2. Advantages of Coal Ash as an REE Resource

- Abundant waste product: >100 million metric tons generated per year; more than 1000 ash impoundments located across the U.S.
- Coal will be an important energy source for decades



U.S. EPA

Ruhl *et al.*, 2012, *ES&T*

Project Outline

Task 1
Management Plan

Task 2 Feedstock Characterization
REE content, Mineralogy, Origin

Task 3
Technical and Economic Feasibility

Go/No-Go decision point

Task 4 Recovery Technologies
Acid Extraction
Ion Separations
Electrochemical Deposition

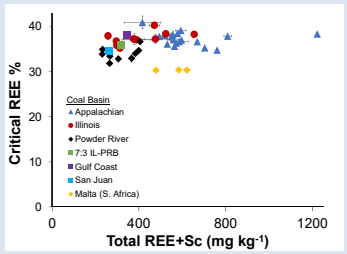
Task 5
Bench-scale implementation plan

Phase 2
Bench-scale development, testing, optimization

Task 2: Feedstock Characterization

Feedstock Selection
Goal: To select a "representative" set of ash samples

Preliminary Data: Fly ash and other types of coal ash from 22 U.S. power plants

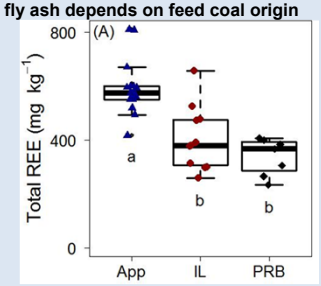


Raw REE Ores:
>1000 mg kg^{-1} (>0.1%)

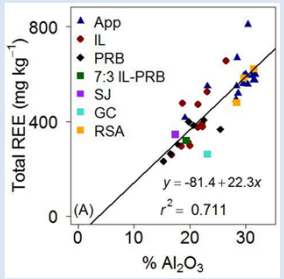
REE ores:
(10-20% critical REE)

Critical REEs: Nd, Eu, Tb, Dy, Y, Er

Total REE content in coal combustion fly ash depends on feed coal origin



Correlation between total REE and Al contents in fly ash



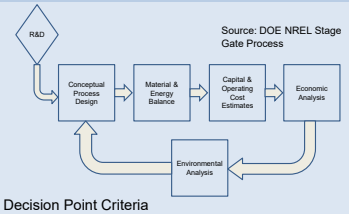
Taggart *et al.*, in review

Additional Characterization
- Major and minor element content (ICP-MS, XRF)
- Petrographic analysis
- Mineralogy (XRD)
- Specific surface area (BET)
- Particle morphology and microstructure (Electron microscopy)

Task 3: Feasibility Study

Purpose:
- To identify gaps/uncertainties in system information and weaknesses of the conceptual design
- To develop a path towards commercialization for the proposed REE separation process.

Components of the Study:
- Mass and energy balances (e.g., energy and REE recovery efficiency)
- Capital and operating cost estimations
- Lifecycle costs (transportation, waste/disposal)
- Comparison to current state-of-the art REE recovery and handling practices
- Consideration of feedstock quality and geography



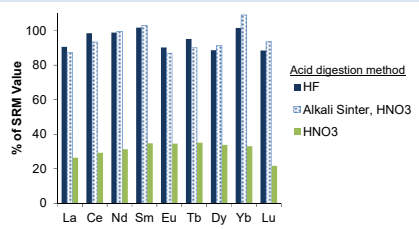
Source: DOE NREL Stage Gate Process

Decision Point Criteria
- CCR samples identified as candidates for REE recovery will be representative of a feedstock with sufficient supply under current and future production scenarios.
- The proposed separation technologies can produce a concentrated product (2% total REE on dry mass basis) upon system scale up.
- Reasonableness of the economic justification for proceeding with the remainder of the Phase 1 project.

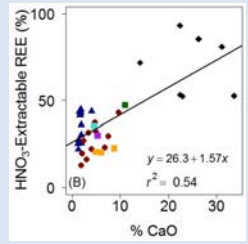
Task 4: Recovery Technologies

1. Acid Extraction

Extraction efficiencies of NIST Fly Ash standard reference material

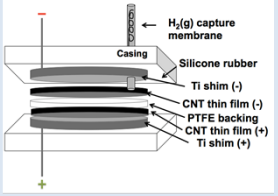


HNO_3-extractable REEs correlate with Ca content



2. REE Separations from Leachates
- Ion Exchange Resins (Pretreatment)
- Micelle-enhanced ultrafiltration
- Electrochemical deposition

Experimental Variable	Values to test
CNT filter	CNTF>BPB>BP
Flow rate	0.5-10 mL min^{-1} (Ver 2) 3-16 L min^{-1} (Ver 3)
Voltage	0.1-4 V (vs Ag/AgCl)
pH	0-6
Concentration	Above and below REE leachate concentrations



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