



# INVESTIGATION OF RARE EARTH ELEMENT EXTRACTION FROM NORTH DAKOTA COAL-RELATED FEEDSTOCKS

Steve Benson, Dan Laudal, and Mike Mann, University of North Dakota  
Dan Palo, Barr Engineering and Shane Addleman, PNLL



## Goals and Objectives

### Goal:

- To develop a high performance, economically viable, and environmentally benign technology to recover rare earth elements from North Dakota lignite coal, associated sediments, and a lignite drying system reject stream.

### Objectives:

- Determine the abundance and forms of rare earth elements in lignite, associated roof and floor materials, and coal drying reject streams,
- Determine the potential to concentrate REEs through traditional and augmented physical beneficiation methods.
- Identify the optimum methods to separate and concentrate the REEs to 2 percent by weight,
- Perform a technical and economic analysis of the optimum concentrating scheme,
- Conduct lab-scale test work to validate the separation methodology selected.

## Workplan

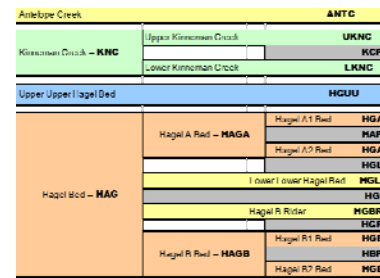
- Task 1.0 – Project Management and Planning
- Task 2.0 – Sampling and Characterization of Proposed Feedstocks
- Task 3.0 - Technical and Economic Feasibility
- Task 4.0 – Laboratory-scale Testing for Determination of Bench-scale Design Parameters
- Task 5.0 – Bench-scale System Design
- Task 6.0 – Final Report

## Sampling

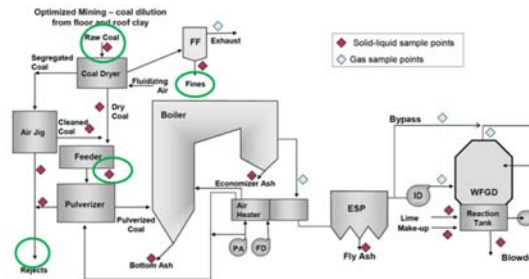
- Mine Sampling - Lignite coal, roof, parting and floor materials from the Falkirk mine.
- Plant Sampling: GRE DryFining™ inlet coal, air jig outlet, feeder outlet and fabric filter fines from the Coal Creek station.

## Sampling

### Falkirk Mine Sampling



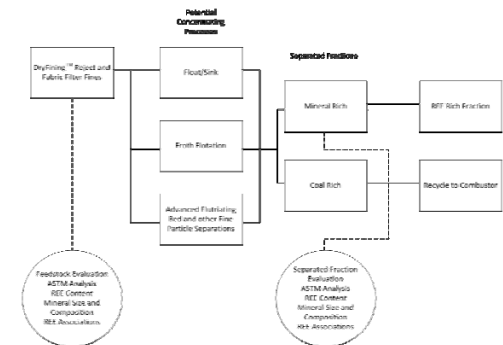
### Coal Creek Station Sampling



## Characterization

Category	Equipment	Function
Bulk chemical composition	ASTM standard analysis	Proximate analysis; Ultimate analysis; Ash composition
	X-ray fluorescence	Bulk chemistry; major, minor and trace elements including RFF
	Inductively coupled plasma-mass spectrometry	Reactive fraction followed by digestion; Abundance of trace elements including REE
Forms of REE	Neutron activation analysis	Level of trace element and REE in solid samples
	X ray diffraction	Bulk mineralogy; major and minor crystalline phases
	Scanning electron microscopy/A-ray microanalysis	Morphological analysis – imaging and chemical composition of minerals
Chemical fractionation	CCSEM – chemical composition, size and associations of mineral grains (Included or excluded relative to coal particles)	Quantitatively determine the modes of occurrence of the inorganic elements based on solubility in water, ammonium acetate, and HCl

## Separation and Concentration



## Technical and Economic Analysis

Develop several potential processing schemes for concentrating REEs from the chosen feedstock(s), followed by process modeling and technical and economic evaluation.

## Bench-scale System Design

- Basis of the bench-scale design will be the process flow diagrams for a commercial scale facility, with a scaled-down throughput of 5-10 kg/hr of the proposed feedstock.

Steven A. Benson, Ph.D.  
Institute for Energy Studies &  
Energy & Environmental Research Center,  
University of North Dakota  
(701) 777-5177; Mobile: (701) 213-7070  
steve.benson@enr.und.edu