

# Pilot-Scale Testing of an Integrated Circuit for the Extraction of Rare Earth Minerals and Elements from Coal and Coal Byproducts Using Advance Separation Technologies



Honaker, R.Q.<sup>1</sup>, Groppo, J.<sup>1</sup>, A. Noble<sup>2</sup>, J.A. Herbst<sup>2</sup>, G.H. Luttrell<sup>3</sup>, R.H. Yoon<sup>3</sup>

- 1) Department of Mining Engineering || University of Kentucky || Lexington, KY
- 2) Department of Mining Engineering || West Virginia University || Morgantown, WV
- 3) Department of Mining & Minerals Engineering || Virginia Tech || Blacksburg, VA



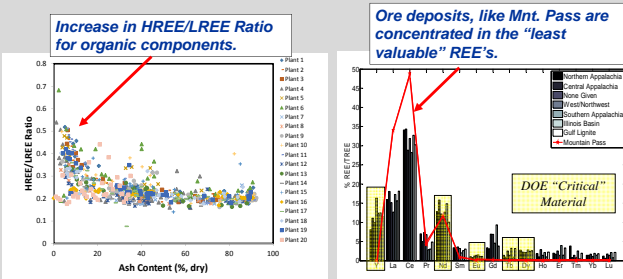
## Background

- A sustainable supply of Rare Earth Elements is crucial for several high-tech industries and defense applications.
- Current domestic sources are coming under increased pressure from poor prices.
- Byproduct recovery from coal has potential, but needs critical separation technology.
- OBJECTIVE:** Develop, design, and demonstrate a ¼ ton per hour pilot-scale system for the efficient, low-cost, and environmentally benign recovery of REEs from coal.



## Preliminary Resource/Reserve Assessment

- Examined the REE content of 20 Appalachian Preparation Plants
- Results show that REE byproducts from these plants can supply **10,000 tons per year** of REES (50% of US Demand)
- Interestingly, coal REE's are particularly enriched in "heavy" REEs

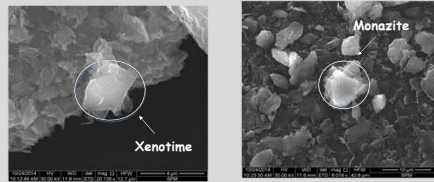


## Material Characterization

- Must first identify REE Forms to design proper processing route
- Mineral Association || Ion substitution || Organic Association

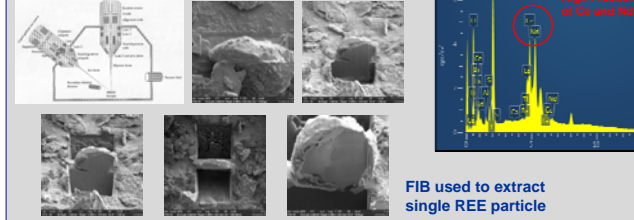
## Scanning Electron Microscopy (SEM)

- SEM was used to examine individual particles to identify minerals



EDX spectra confirm distinct mineral grains

## Focused Ion Beam Milling

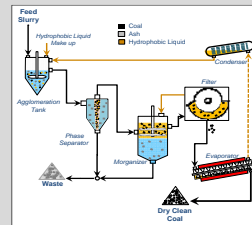


FIB used to extract single REE particle

## Advanced Separation Technologies

### Hydrophobic-Hydrophilic Separation (HHS)

- Patented process to separate ultra-fine particles (<10 micron)
- Proven success in coal (pilot-scale) and base metals (lab-scale)

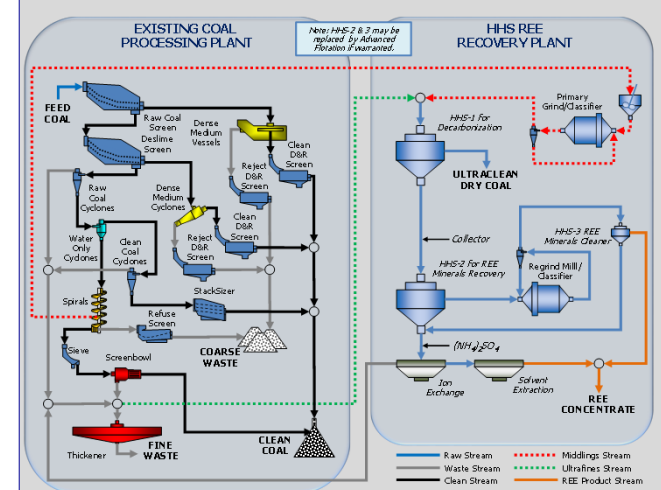


HHS Process Flow Diagram

### HHS Separation of <12 µm Chalcocopyrite

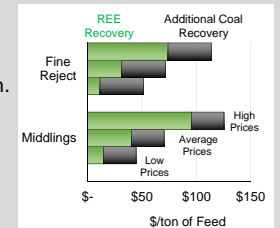
Process	Grade (%Cu)		Copper Recovery (%)	Separation Efficiency (%)
	Concentrate	Tailings		
HHS	26.7	0.13	90.6	87.3
	24.3	0.10	94.3	88.9
	24.9	0.08	92.8	90.4

## Proposed Flowsheet



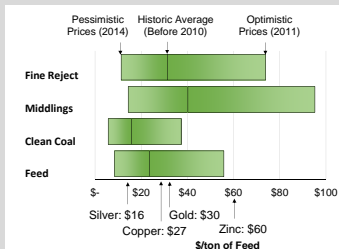
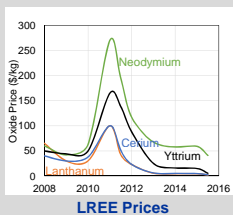
## Advantages

- Use of low-cost physical separations in the front end will reduce the need for costly chemical separation.
- Additional coal recovery will further support process economics
- Process is readily deployable for a number of pre-combustion feedstocks.



## Rare Earth Byproduct Valuation

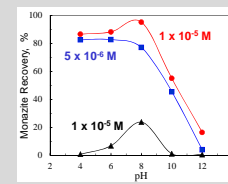
- "Rare Earths" is a plural concept.
- Rare earth prices are extremely volatile.
- Despite pessimistic trends, inherent REE content is similar to other base metals.



Valuation of a High Quality Central App Coal

## Flotation

- Conventional industrial process for fine particle separation.
- Proven success in REE concentration
- Preliminary results show that high recovery can be obtained.
- Further tests will optimize selectivity.



Flotation results for coal/monazite system

## Conclusions & Future Work

### Process Targets

- REE Concentrate Grade = 2% by weight
- Total REE Recovery > 50% by weight
- Total Production Costs <\$20 per dry Feed Ton
- Environmental: no emissions beyond those permitted

### Future Work

- Characterization and Separation Data
- Flowsheet Optimization
- Feasibility Studies
- Design and Deployment

## Contact

Rick Q. Honaker || rick.honaker@uky.edu