Development and Testing of an

Integrated Acid Mine Drainage (AMD) Treatment and Rare Earth/Critical Mineral Plant

DE FE 0031834

Paul Ziemkiewicz, PhD

Water Research Institute, West Virginia University

U.S. Department of Energy

National Energy Technology Laboratory
Resource Sustainability Project Review Meeting
October 25 - 27, 2022

Project Overview

- Funding
  - USDOE: $4,998,954
  - Cost Share: $1,887,250
- Project Performance Dates
  - 1 Jan 2020 to 30 Jun 2023
- Project Participants
  - West Virginia University
  - Virginia Tech
  - West Virginia Department of Environmental Protection
  - TenCate Corp.
  - Rockwell Automation

Project Overview

- Overall Project Objectives
  - design, construct, and test a pilot-scale continuous process for efficiently treating AMD while producing an enriched rare earth element/critical mineral (REE/CM) concentrate.
  - Major technology components include:
    - (1) an integrated **water treatment/pre-concentration unit** that will purify AMD to environmentally-compliant discharge standards while simultaneously producing REE/CM preconcentrates and
    - (2) a secondary **acid leaching/solvent extraction (ALSX)** process that will generate high purity rare earth oxide (REO) products.

Current Project: Integrated Acid Mine Drainage treatment and REE/CM extraction plant *USDOE Project DE FE00 31834*

Project Leadership:

West Virginia University
Paul Ziemkiewicz, Jim Constant, Harry Finklea, Lance Lin, David Hoffman, John Quaranta

Virginia Tech
Aaron Noble

State:
WVDEP-Office of Special Reclamation

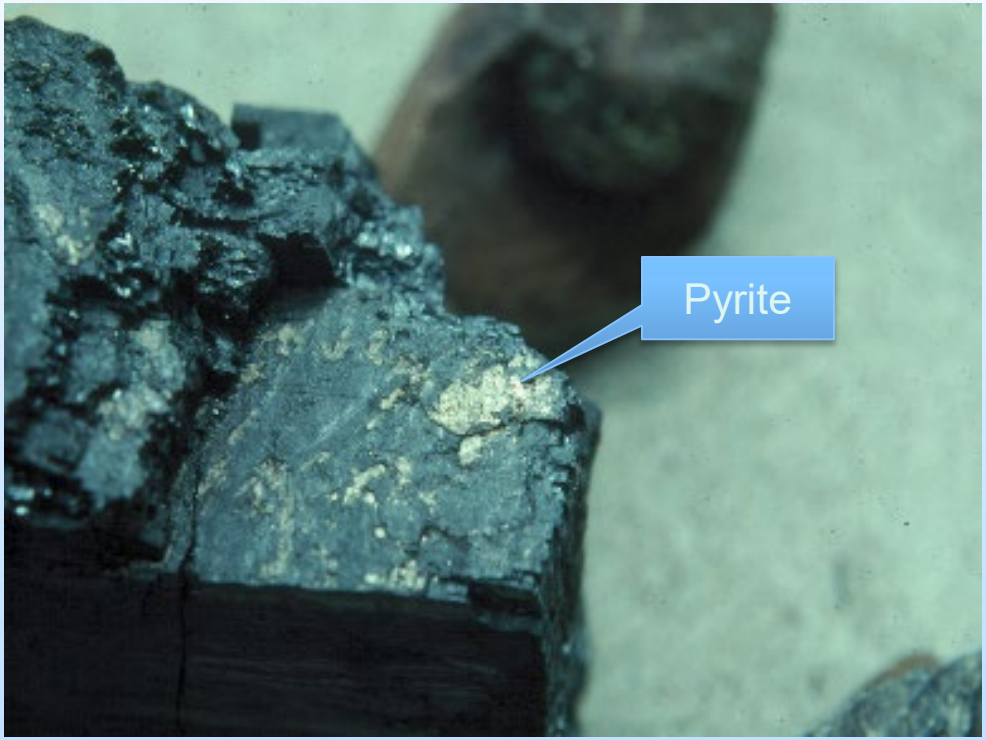
Industry:
Rockwell Automation
TenCate Corporation
L3 Eng

Acid Mine Drainage: AMD

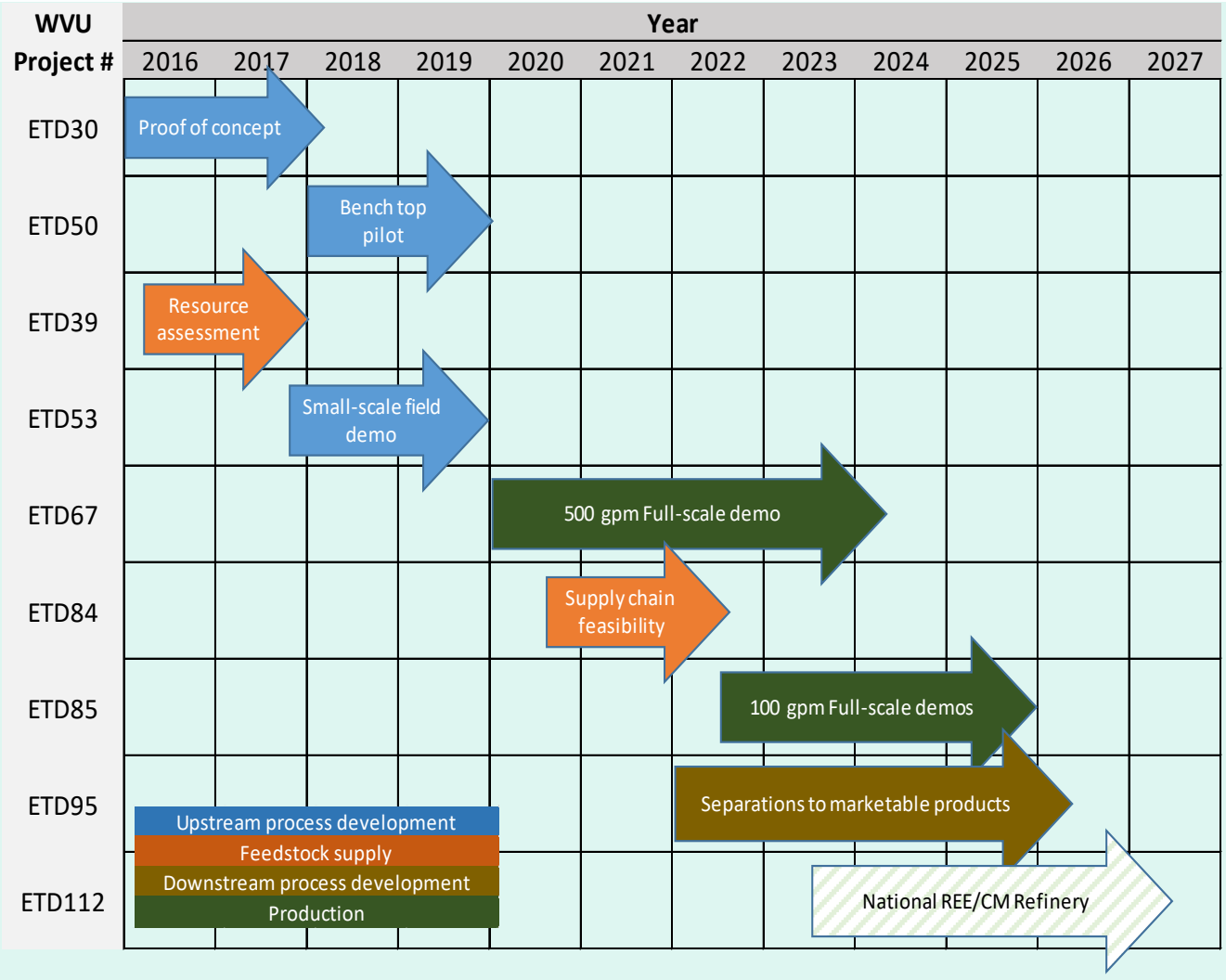
1. H_2SO_4 leaches REE from shale
2. REEs precipitate with $Fe(OH)_3$

$Fe^{2+} + O_2 + OH^- = Fe(OH)_3$

Pyrite + O_2 + H_2O= Fe^{2+} + H_2SO_4

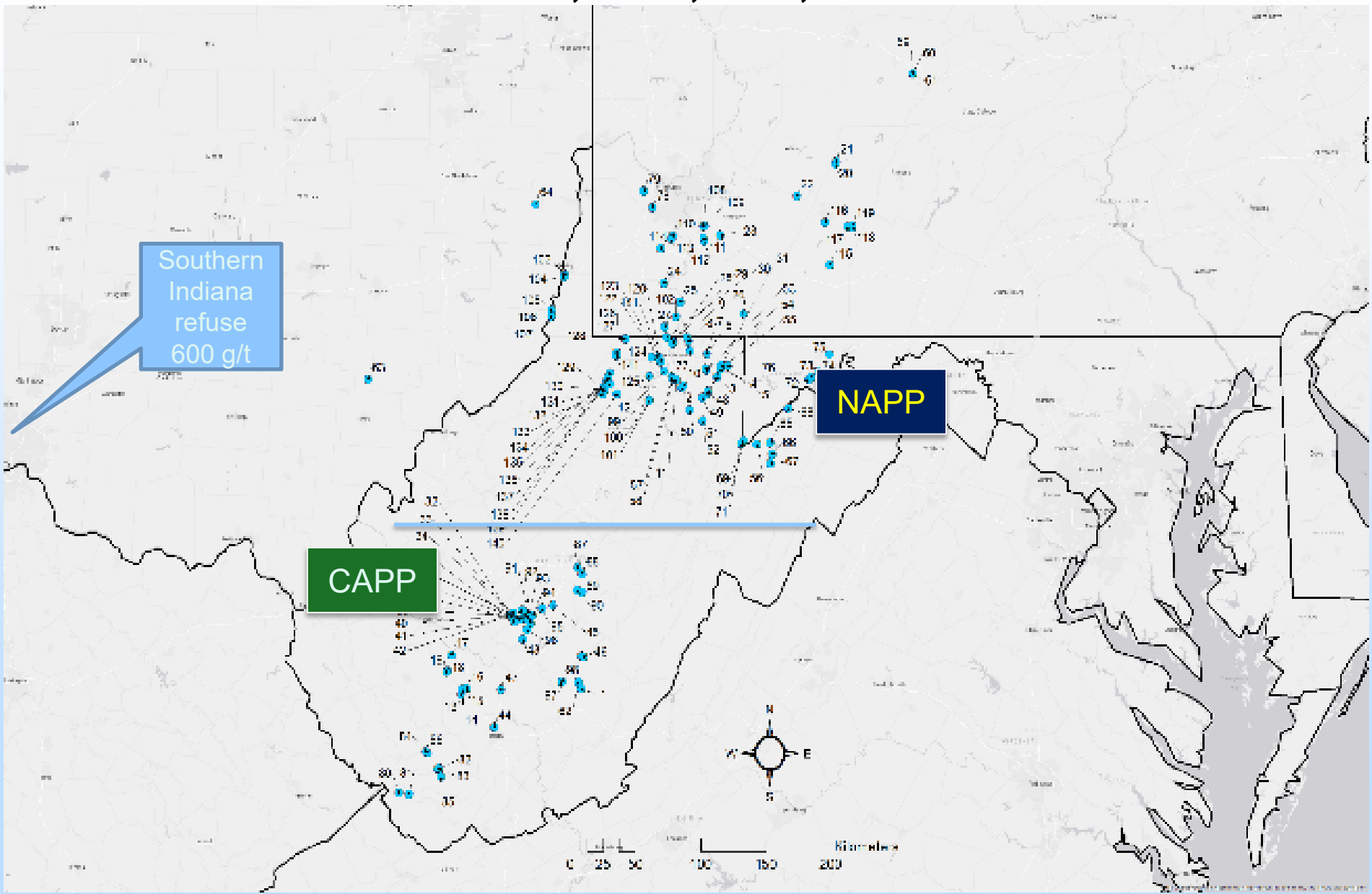


Water Research Institute: Recovering REE/CM from Acid Mine Drainage Technology Development Strategy



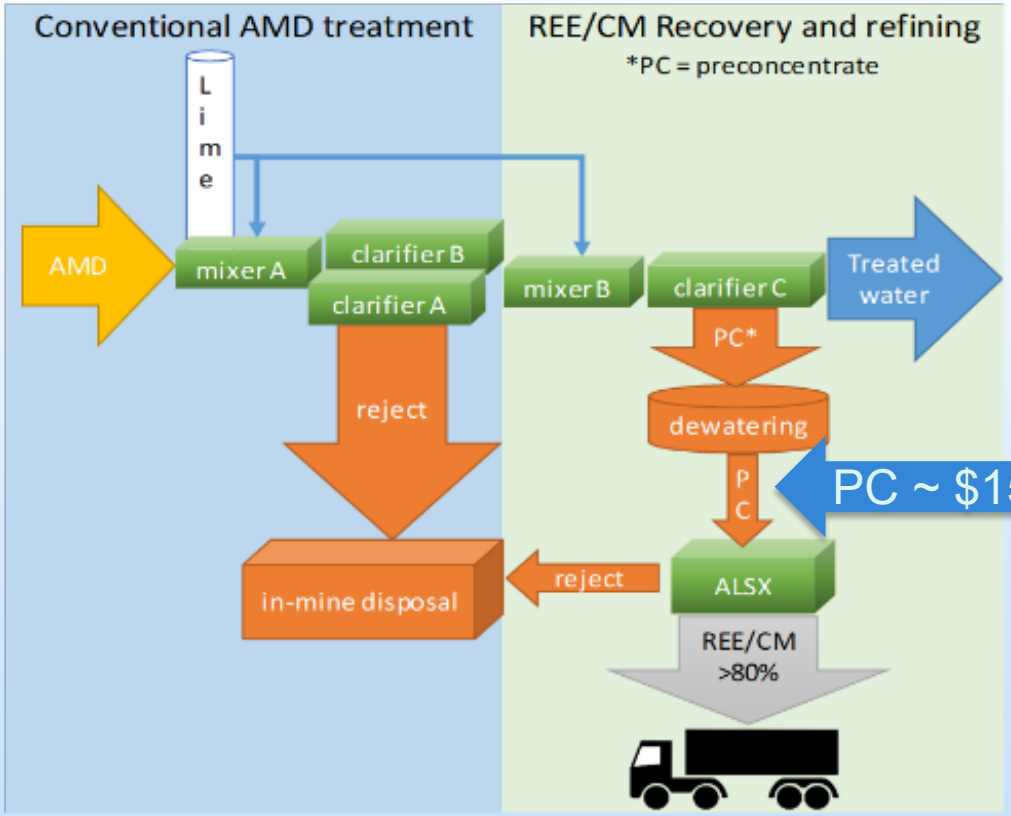
WVU Project #	Funding Support		
	Federal	Non-Federal	Total
ETD30	$ 749,994	$ 200,540	**$ 950,534**
ETD50	$ 2,661,878	$ 727,000	**$ 3,388,878**
ETD39	$ 400,000		**$ 400,000**
ETD53	$ 644,060	$ 205,606	**$ 849,666**
ETD67	$ 4,998,954	$ 1,887,250	**$ 6,886,204**
ETD84	$ 2,132,429		**$ 2,132,429**
ETD85	$ 131,410	$ 360,000	**$ 491,410**
ETD95	$ 199,997	$ 50,000	**$ 249,997**
ETD112	FOA Expected in late 2022		
	$ 11,918,722	$ 3,430,396	**$ 15,349,118**

140 Sampled locations: MD, OH, PA, WV

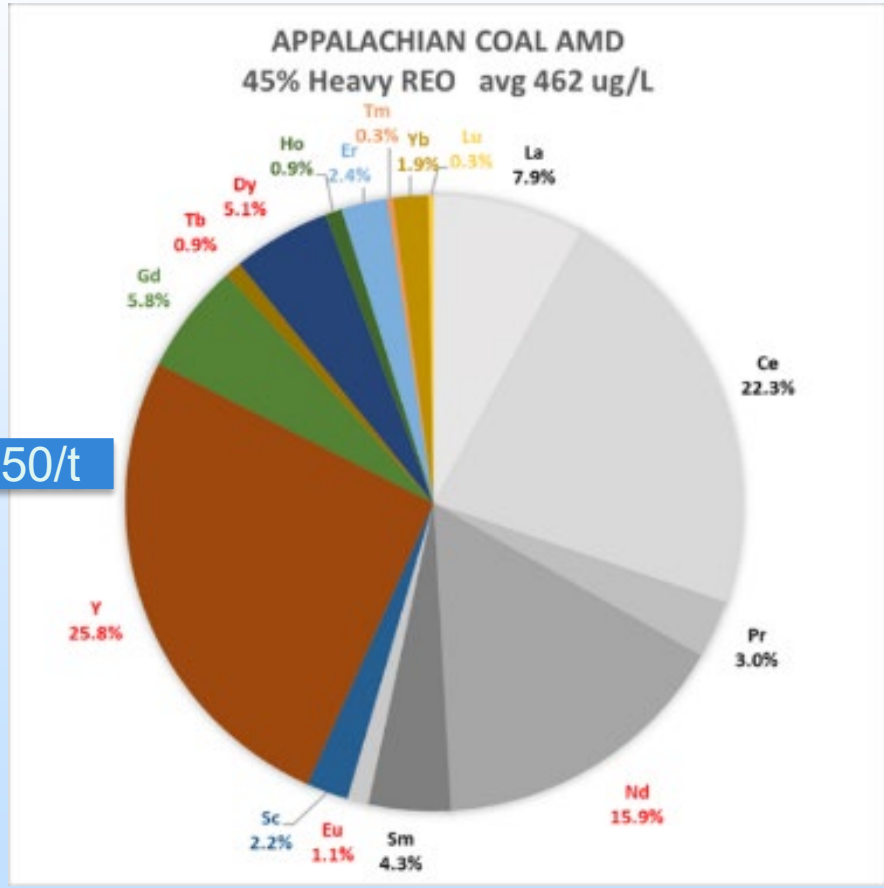


Integrated AMD treatment/REE/CM recovery

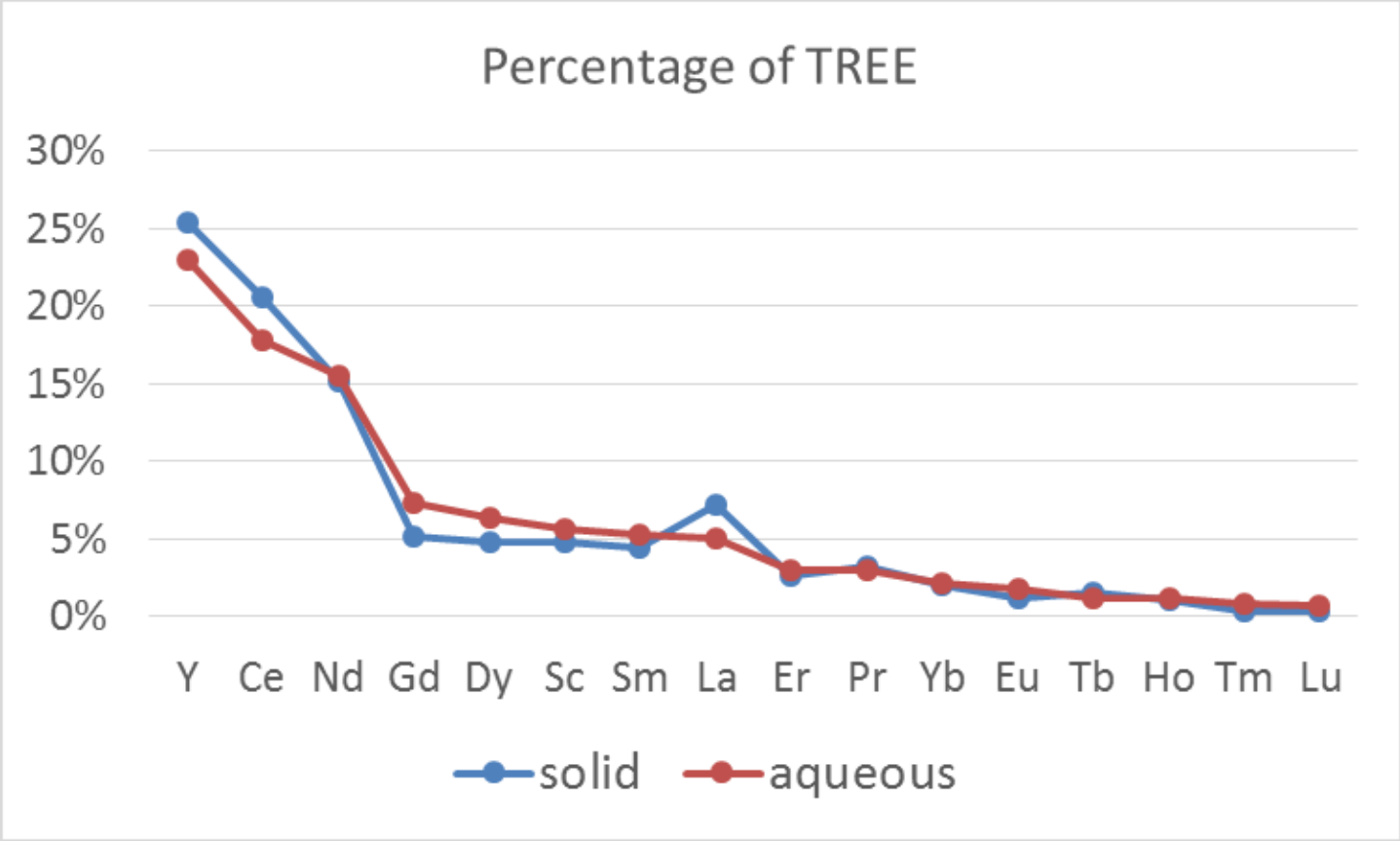
Consistent feedstock:
average of 140 sites
Tb + Dy ~ 7%



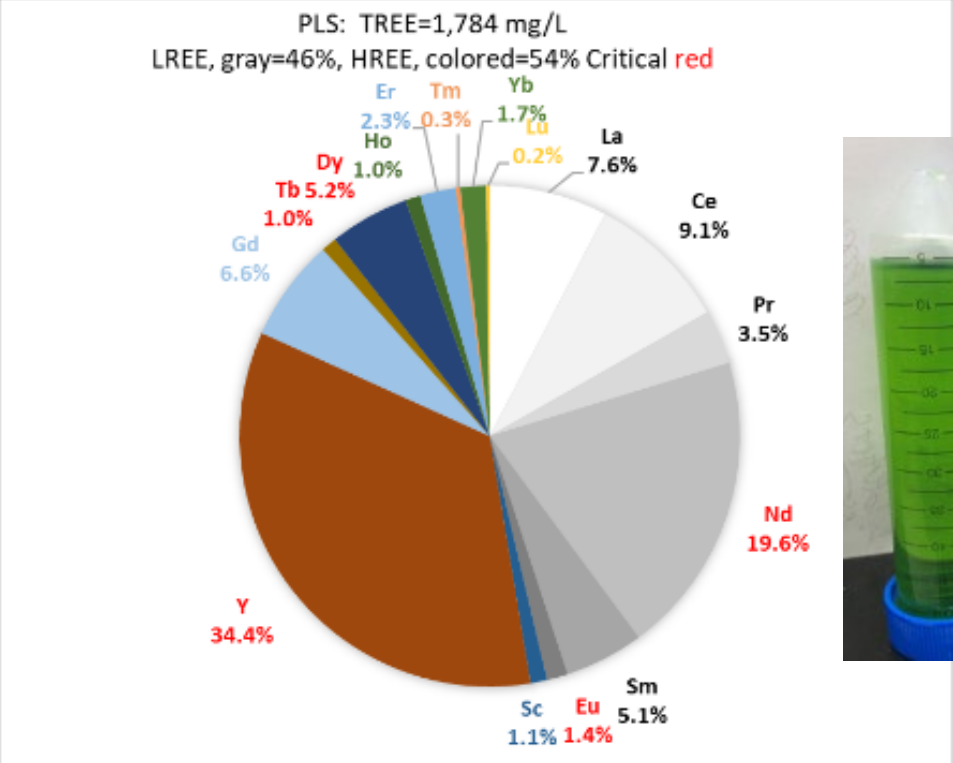
PC ~ $150/t

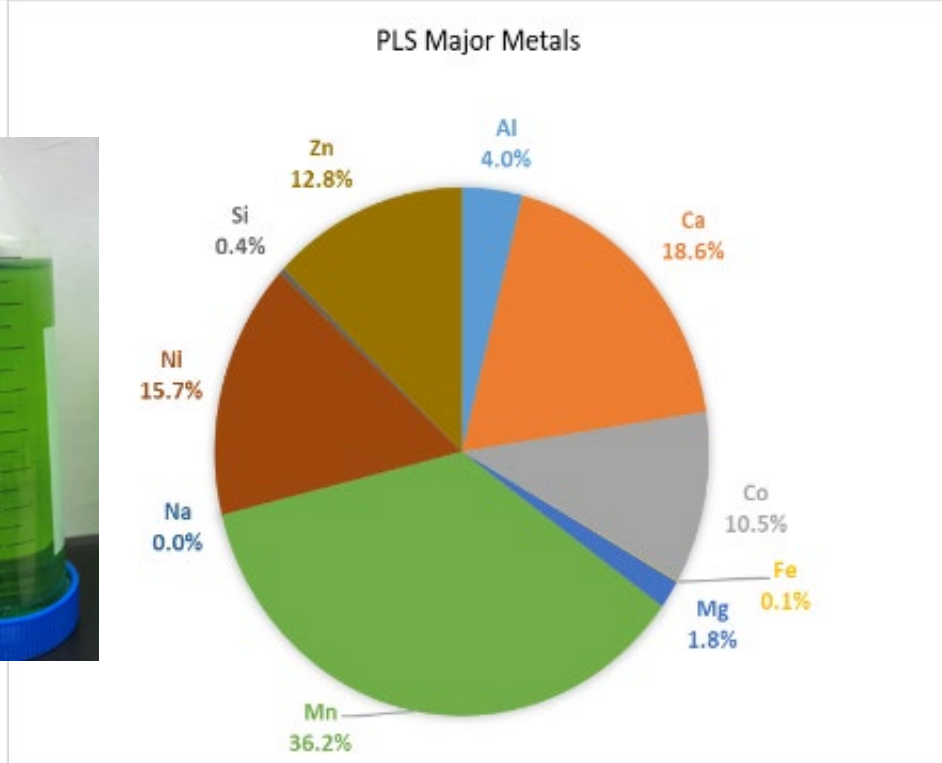


All REEs precipitate to AMD sludge nearly equally

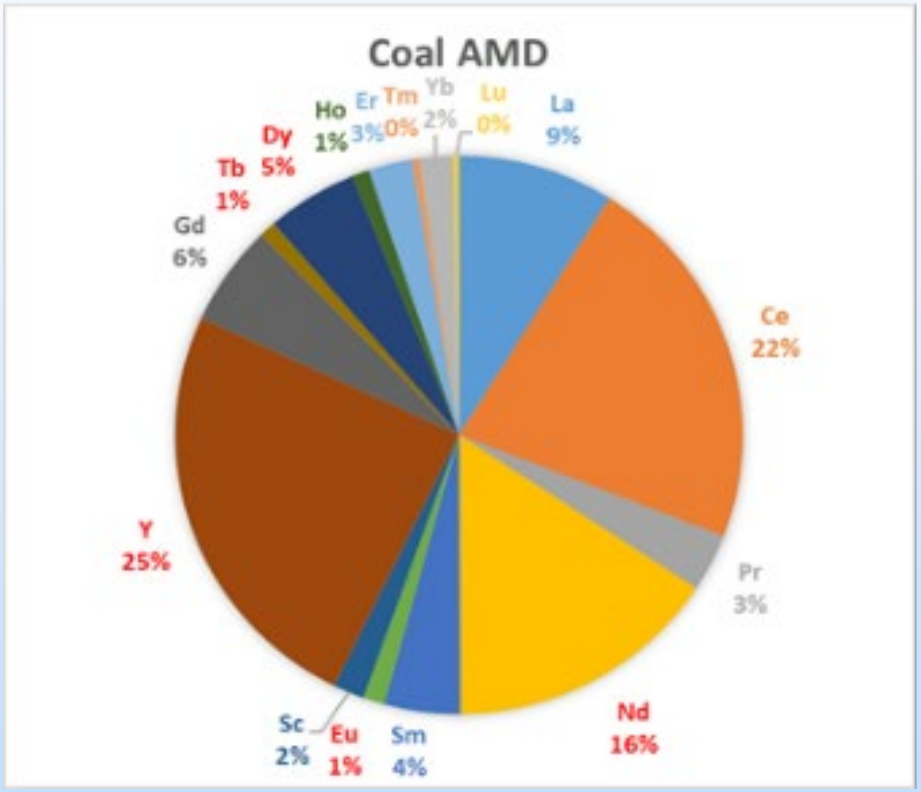


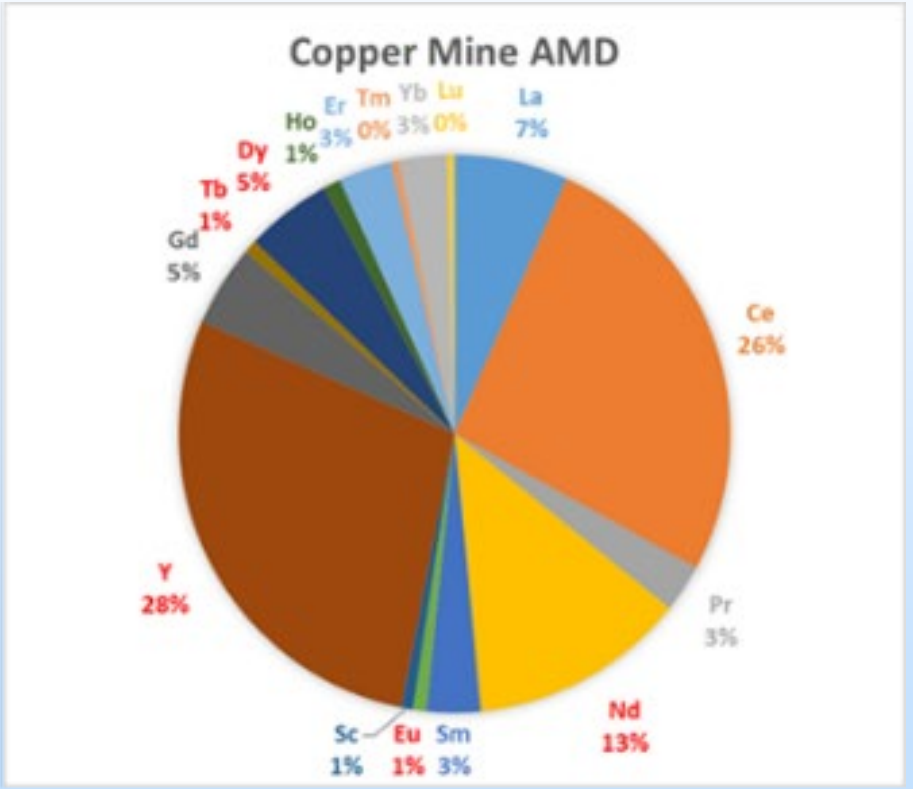
Recent PLS production: 1,784 mg TREE/L, 54% HREE
almost no Al, Si





Coal and Copper mine AMD samples have nearly identical REE distributions





Disadvantages of sourcing REE/CM from AMD

- Low concentrations
- Requires collection from many sites
- Need to manage upstream supply chain
- Quality control: moisture, grade

Advantages of sourcing REE/CM from AMD

- Already permitted sites, no delays due to permitting
- Easy to quantify yield, minimal exploration cost
- Environmentally beneficial, byproduct is clean water
- Solid wastes are RCRA subtitle D, non hazardous
- Distributes jobs and benefits across broad areas
- Incentivizes treatment of legacy AMD discharges
- Uniform feedstock, across mines and sectors
- Attractive economics
- No rads

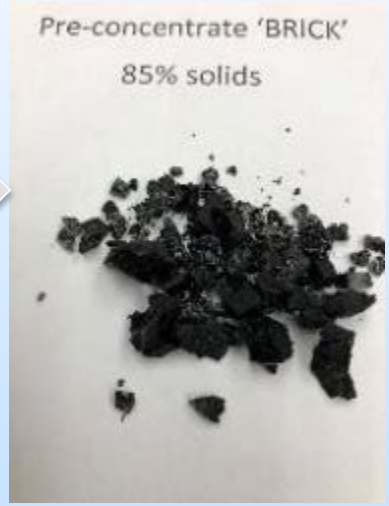
Process:

1. Generate pre-concentrate (brown floc)
2. GeoTubes passively dewater to 40-85% solids
3. Transport to a central processing facility
4. Convert it to high-grade PLS (green), then MREO
5. Elemental oxide, reduction to metal

Pre-conc. TREE: 0.5%

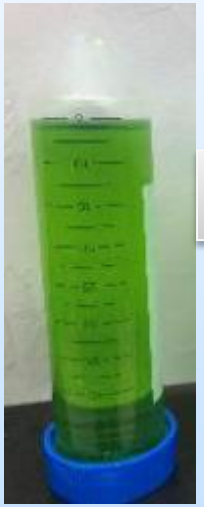
0.1% solids

Brick TREE: 0.5-5.0%

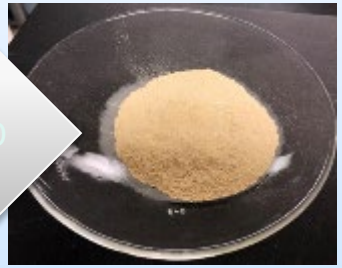


Hi grade PLS

PLS TREE: 100-1,800 mg/L



MREO



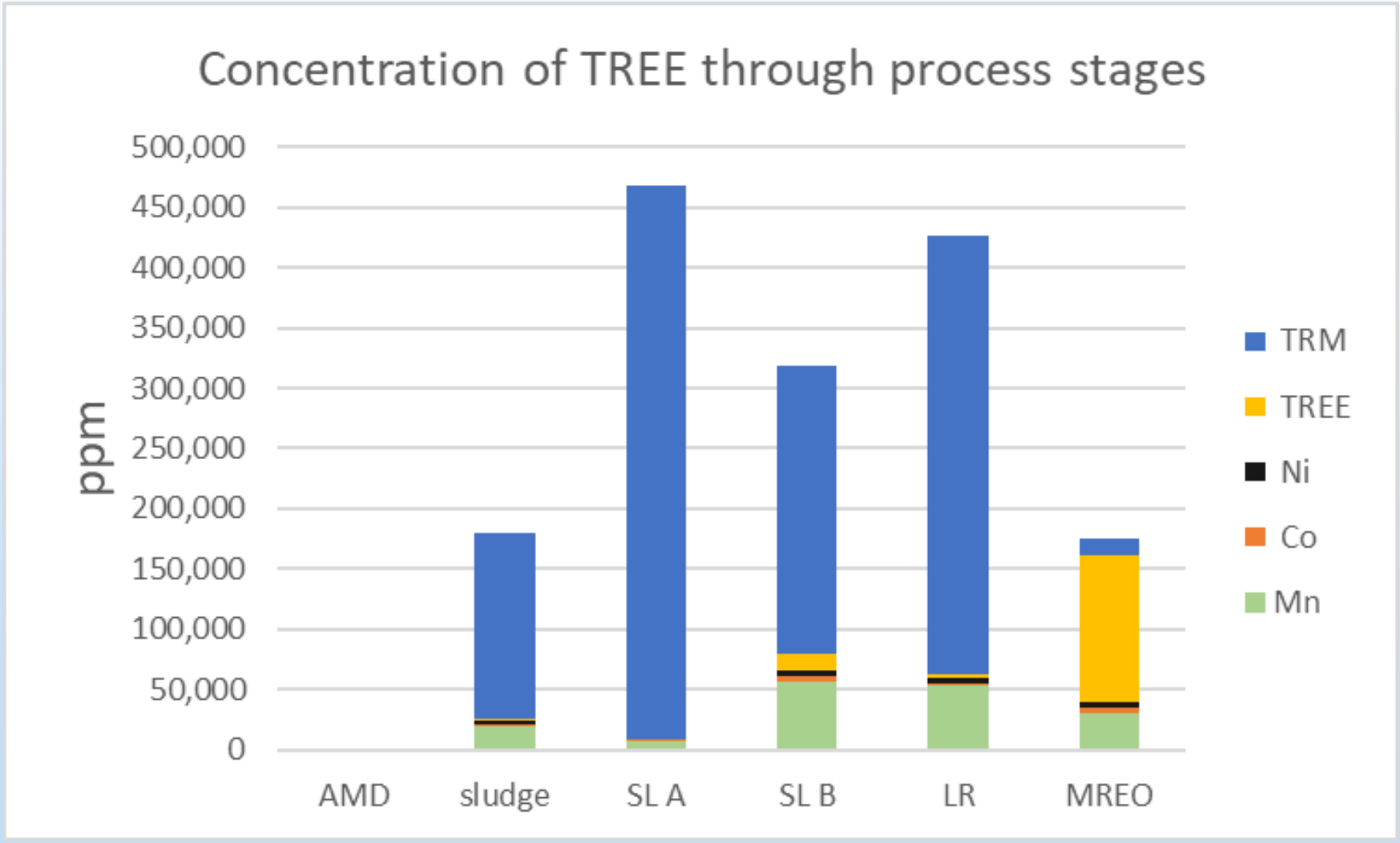
MREO TREE: 90-99%

Our process increases the REE/CM grade from AMD to Product

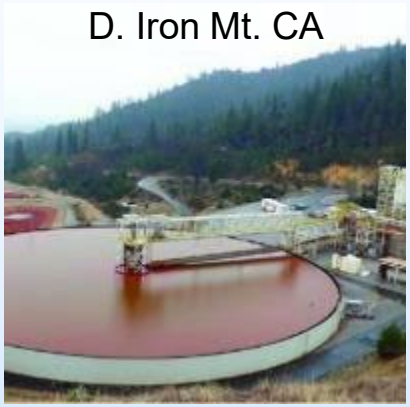
TRM=total reject metals

	AMD	SL pond	SL A	SL B	LR	MREO
Concentration (ppm)						
Mn	24	19,236	7,879	56,834	53,327	30,314
Co	1	1,957	92	4,825	2,406	4,227
Ni	1	2,196	200	4,782	3,306	5,635
TREE	1	2,727	352	12,941	3,964	120,678
TRM	184	154,022	458,818	239,684	363,281	13,782
Enrichment factors (% increase)						
Mn	1	787	322	2,325	2,182	1,240
Co	1	2,419	114	5,964	2,975	5,225
Ni	1	2,381	217	5,185	3,584	6,110
TREE	1	2,343	302	11,116	3,405	103,665
TRM	1	837	2,494	1,303	1,975	75

Rejection of gangue
Ni, Co report to other circuits for recovery



Conceptual supply chain: Concentrates move to central processing facilities



Potential source districts

A: Northern/Central APP
B: Southern APP/Illinois basin
C: Southern Rockies metal belt
D: Sierra metal belt
E: Northern Rockies metal belt
F: Minnesota iron range

Project ETD67: Mt. Storm Pilot Plant

AMD treatment: Up to 1,000 gpm,

Production rate ~ 1 tpy each: REE, Cobalt, Nickel

Much more: Manganese, Lithium, Zinc

A34 components

Inside the Lime Silo

Three clarifiers

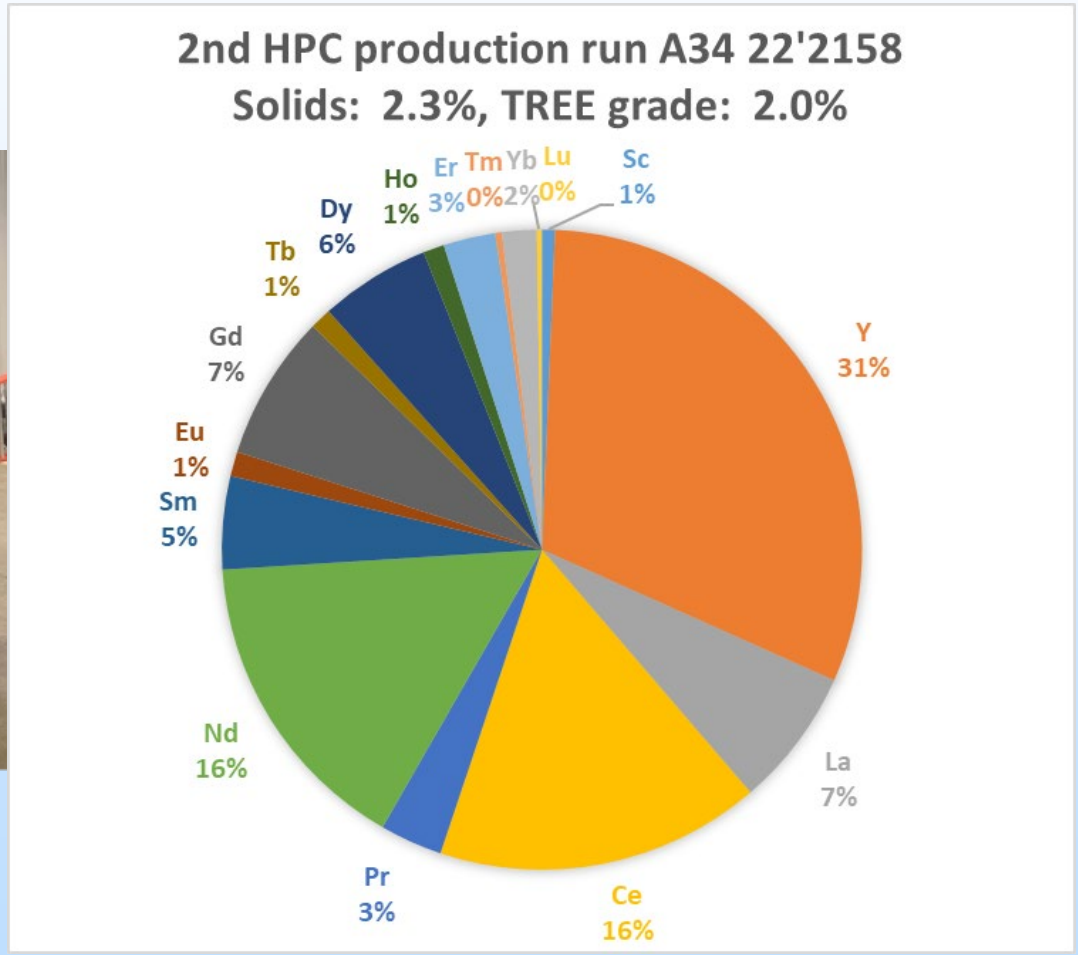
Downstream Processing

Solvent Extraction

Raffinate Storage

Second Batch of Preconcentrate leaving A34

6 Oct 2022: 70 kg Tb+Dy/yr
190 kg Nd+Pr/yr



Supply Chain

Middle Cheat Project: Four tribs generate about 60 t REE/CM per year

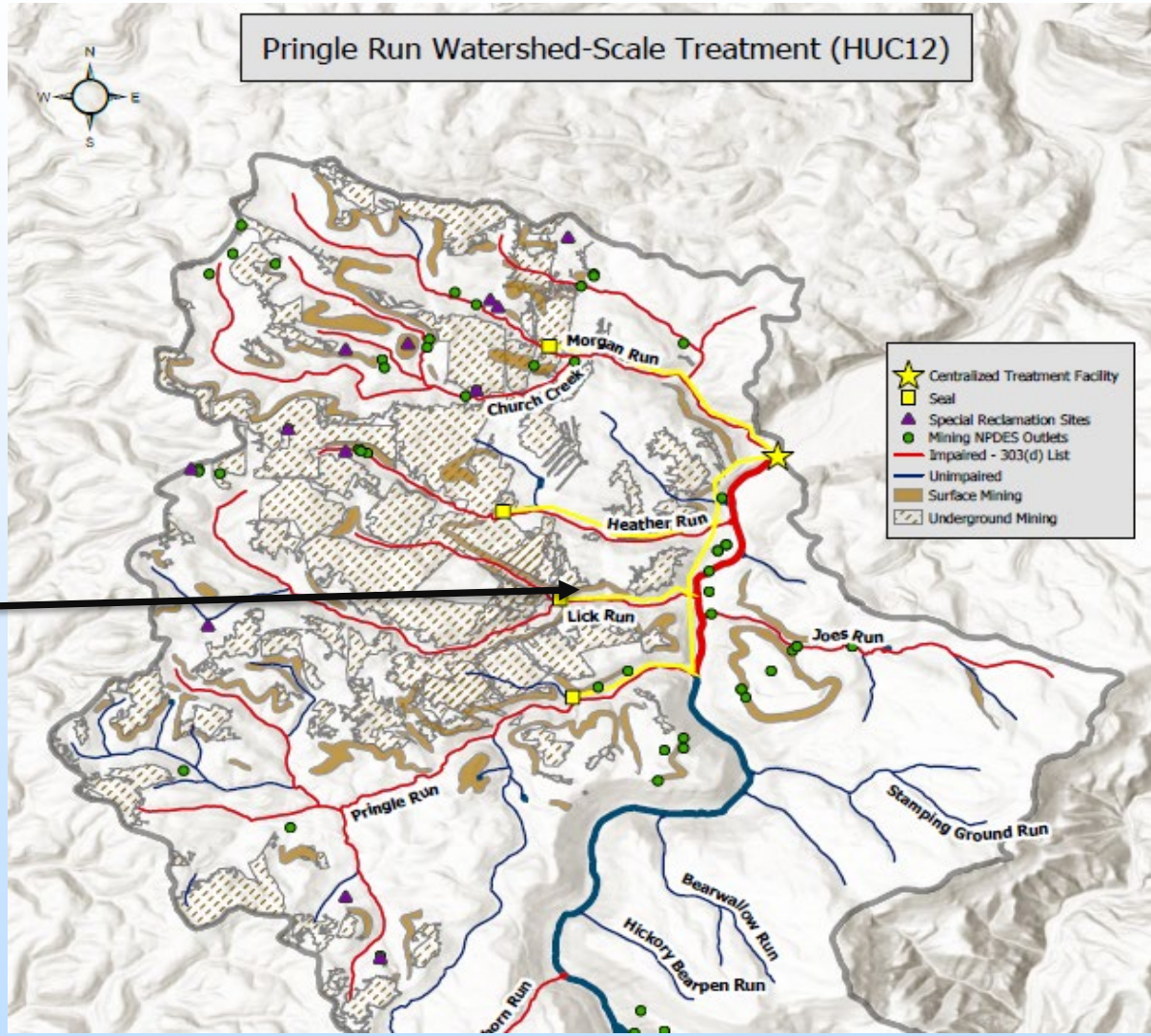
Morgan Run

Lick Run

Middle Cheat River

Estimate:

UG area	5,000 ac
Q	2,500 gpm
REE/Co	13.5 t/yr (Lick Run only)



Outreach and Workforce Development Efforts or Achievements (If Applicable)

- Outreach
  - Over 60 public presentations/briefings since 2016:
    - Senate/Congressional delegations, staff
    - Citizen watershed groups
    - State, Federal agencies
    - Professional organizations
    - Industry meetings

- Workforce Development
  - Graduate research experience
  - Undergraduate work experience

Summary Slide

- Achievement of target TREE grade and moisture content at fully operational, 500 gpm AMD/REE facility
- ALSX unit should be operational within the month
- Ready for buildout to new AMD treatment facilities

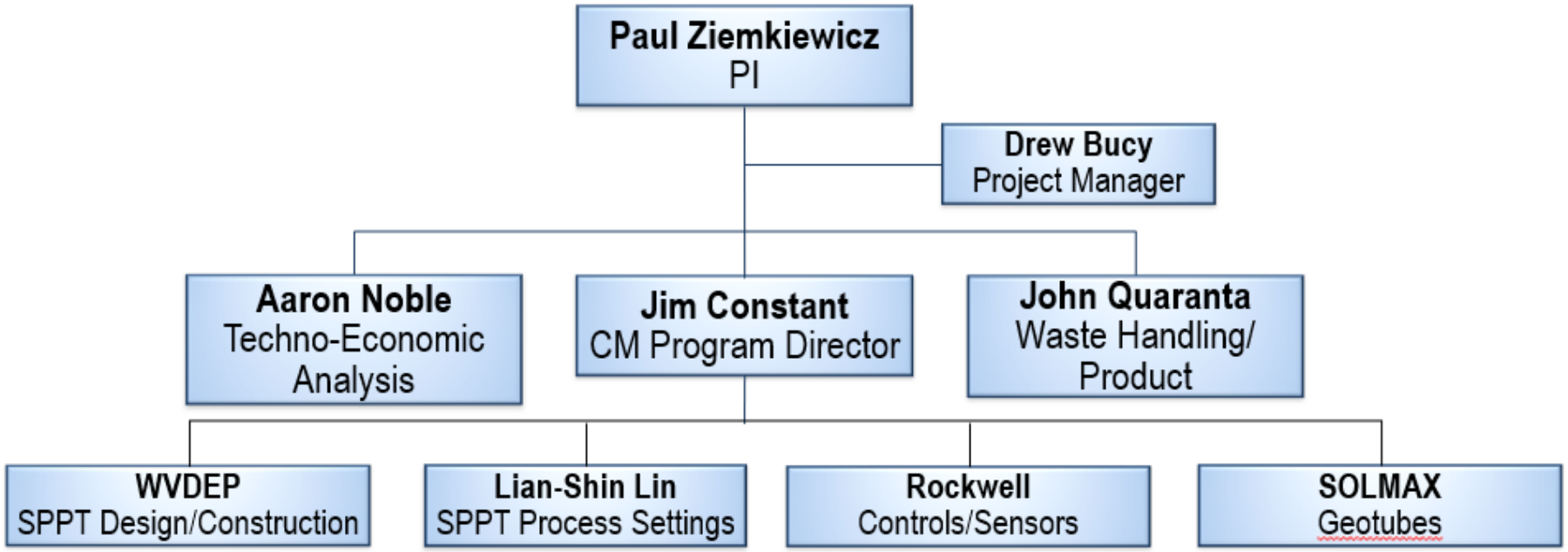
WVU Water Research Institute

REE/CM Recovery from Acid Mind Drainage:
Summary of progress 2016-2022

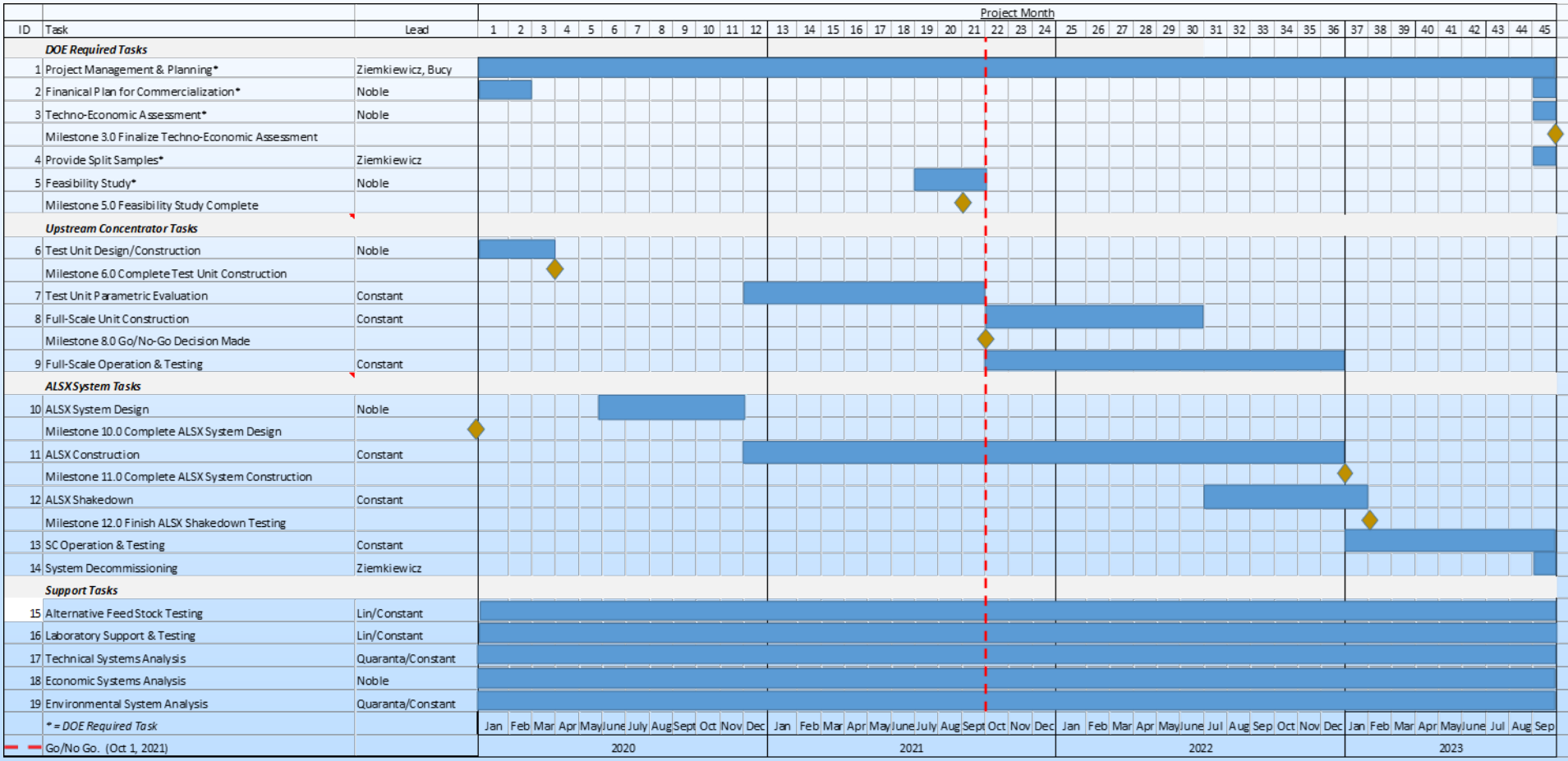
Paul Ziemkiewicz, Director
WVU Water Research Institute
pziemkie@wvu.edu

Appendix

Organization Chart



Project ETD67 Gantt Chart



ID	Task	Lead
	DOE Required Tasks	
1	Project Management & Planning*	Ziemkiewicz, Bucy
2	Finanical Plan for Commercialization*	Noble
3	Techno-Economic Assessment*	Noble
	Milestone 3.0 Finalize Techno-Economic Assessment	
4	Provide Split Samples*	Ziemkiewicz
5	Feasibility Study*	Noble
	Milestone 5.0 Feasibility Study Complete	
	Upstream Concentrator Tasks	
6	Test Unit Design/Construction	Noble
	Milestone 6.0 Complete Test Unit Construction	
7	Test Unit Parametric Evaluation	Constant
8	Full-Scale Unit Construction	Constant
	Milestone 8.0 Go/No-Go Decision Made	
9	Full-Scale Operation & Testing	Constant
	ALSX System Tasks	
10	ALSX System Design	Noble
	Milestone 10.0 Complete ALSX System Design	
11	ALSX Construction	Constant
	Milestone 11.0 Complete ALSX System Construction	
12	ALSX Shakedown	Constant
	Milestone 12.0 Finish ALSX Shakedown Testing	
13	SC Operation & Testing	Constant
14	System Decommissioning	Ziemkiewicz
	Support Tasks	
15	Alternative Feed Stock Testing	Lin/Constant
16	Laboratory Support & Testing	Lin/Constant
17	Technical Systems Analysis	Quaranta/Constant
18	Economic Systems Analysis	Noble
19	Environmental System Analysis	Quaranta/Constant
	** = DOE Required Task*	
	Go/No Go. (Oct 1, 2021)	