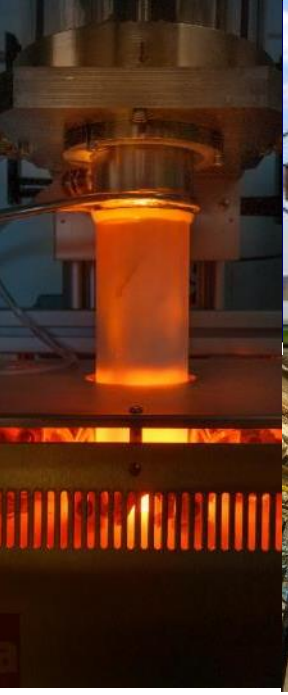





U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Development and Testing of an Integrated Acid Mine Drainage Treatment and Rare Earth/Critical Mineral Plant

- Paul Ziemkiewicz, PhD, WVU
- Jim Constant, PE, WVU
- Aaron Noble, PhD, Virginia Tech
- John Quaranta, PhD, WVU
- Lian Shin Lin, PhD, WVU
- Harry Finklea, PhD, WVU

- West Virginia Dept. of Environmental Protection
- TenCate Corp.
- Rockwell Automation, Inc.
- Shonk Investments LLC

USEA webinar
25 Aug 2020

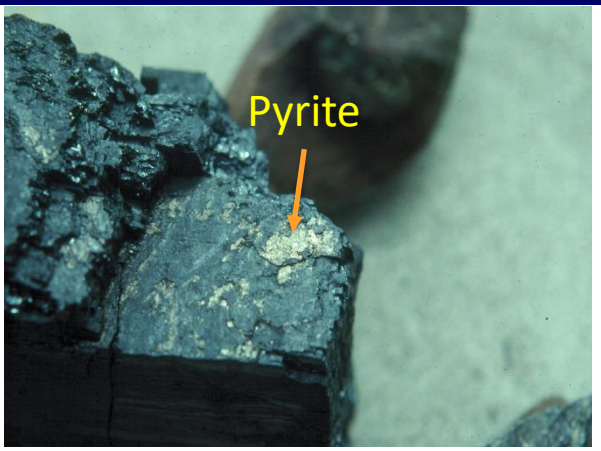
PROJECT OBJECTIVES

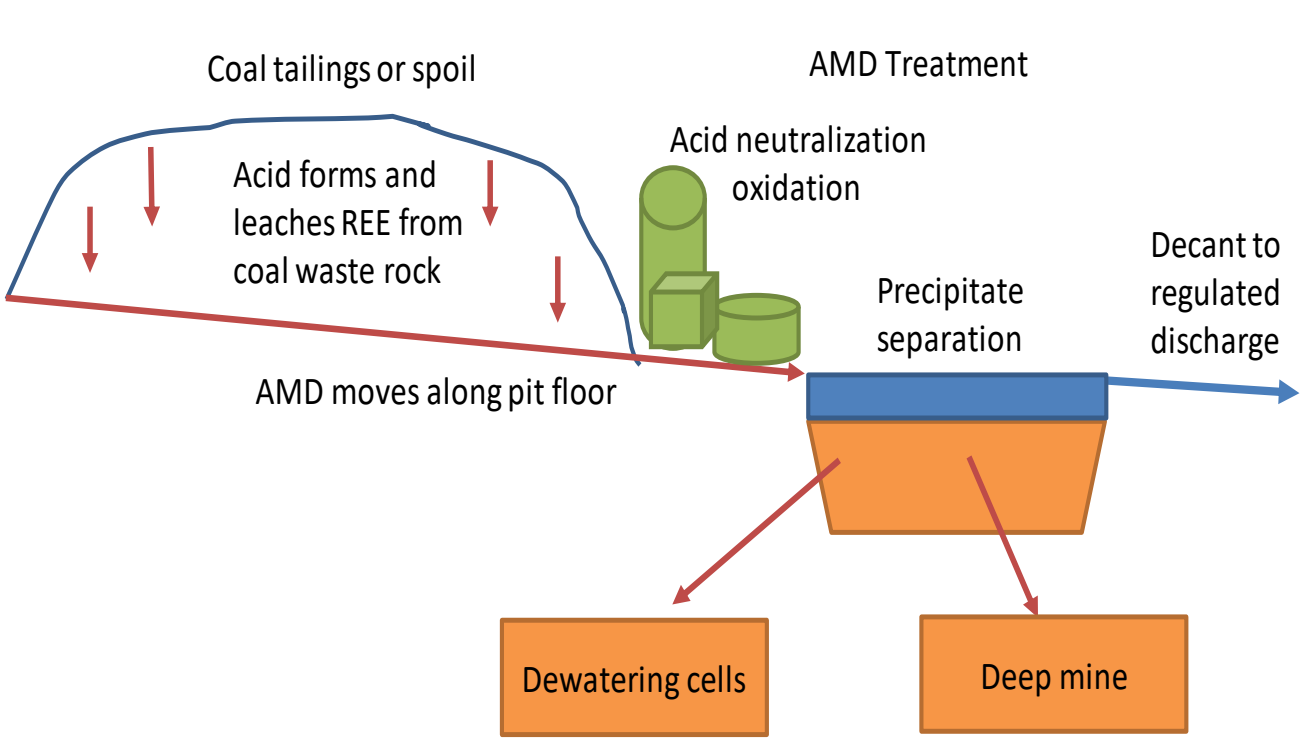
Develop and test a pilot-scale, continuous process for treating Acid Mine Drainage (AMD) while producing an enriched Rare Earth, Critical Mineral product.

Goals:

- Design, construct and operate a full-scale upstream concentrator and ALSX unit at an active AMD discharge treatment site.
- Pre-Concentrate grade: exceeding 0.5% REE/CM
- Final MREO grade exceeding 90% grade with > 50% HREE+CM/TREE
- Demonstrate production capacity of > 500 kg/yr
- commercially attractive efficiencies and processing costs.
- Not only environmentally benign but a net environmental benefit.

ACID MINE DRAINAGE IS ANALOGOUS TO AN ACID HEAP LEACH



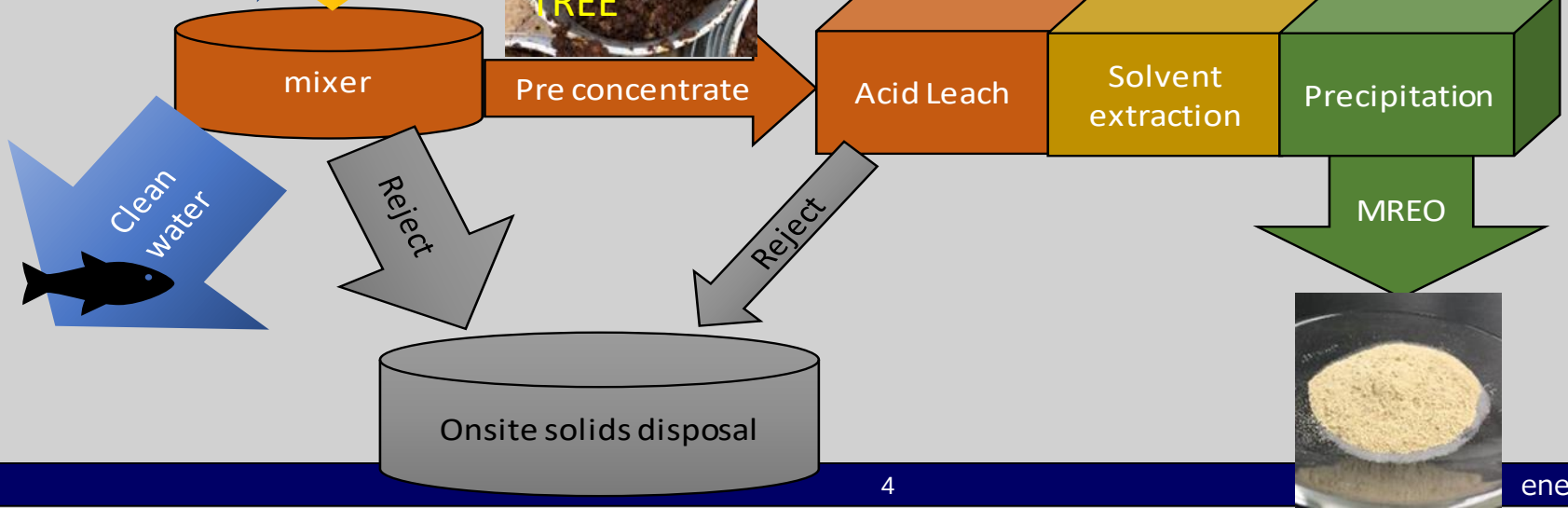


PROJECT ETD67: PILOT PLANT-WVDEP BUFFALO A34 PERMIT

AMD treatment, Upstream Concentrator

REE/CM Refinery

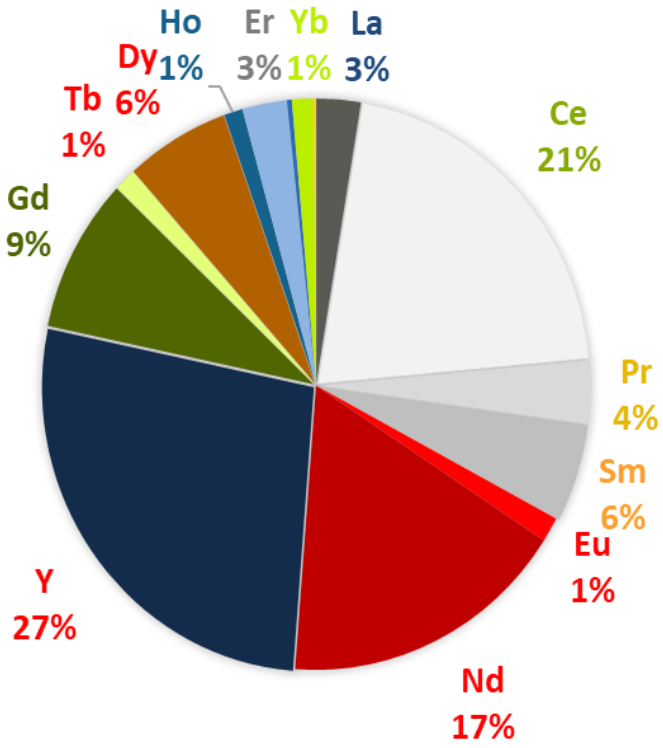
Rockwell's control unit and automated SX plant



PROJECT DISCUSSION: RECENT RESULTS

Recent AL/SX results AMD sludge:
Simple circuit, optimized for HREE

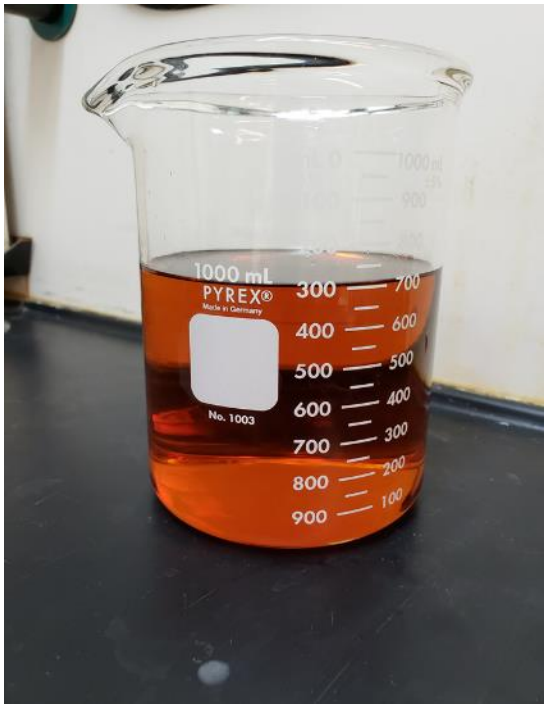
Sample # 2880	Grade
TREE	100.0%
LREE	51.2%
HREE	48.8%
HREE+CM	67.2%



Nd 17%
Pr 4%
Dy 6%
27%

Ce 21%

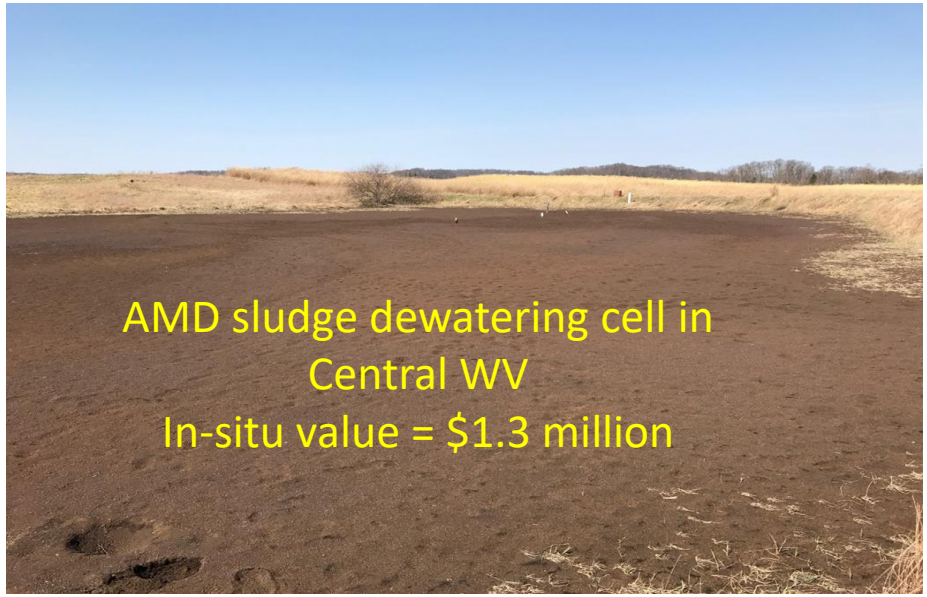
Improved Acid Leach Procedure:
PLS = 200-320 mg TREE/L



PROJECT DISCUSSION: RESOURCE BASE-TWO APPROACHES

AMD Sludge Recovery>300 g/t (ppm)

AMD sludge cells sampled		76	
REE Basket price	$	237	$/kg
Sludge mass DWB		1,062,413	t
Average TREE grade		663	g/t
TREE mass		350	t
Estimated contained value	**$**	**79,633,629**	



Direct AMD Recovery

REE production from AMD: Northern + Central APP			
AMD production		1,503,371	gpm
Average TREE conc.		0.269	mg/L
TREE production		807	t/yr
Estimated contained value	**$**	**191,362,343**	

ECONOMIC AND ENVIRONMENTAL IMPACTS

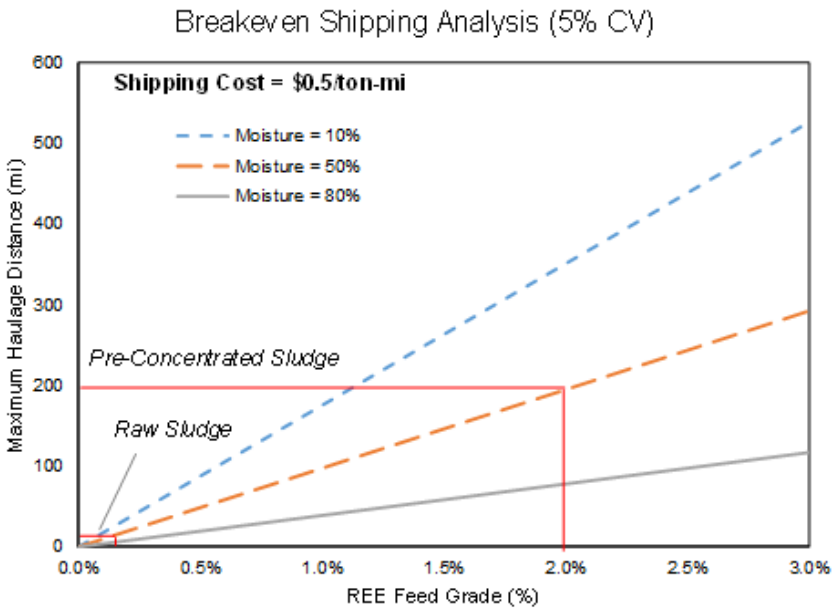
Anticipated 'profit' from A34 plant

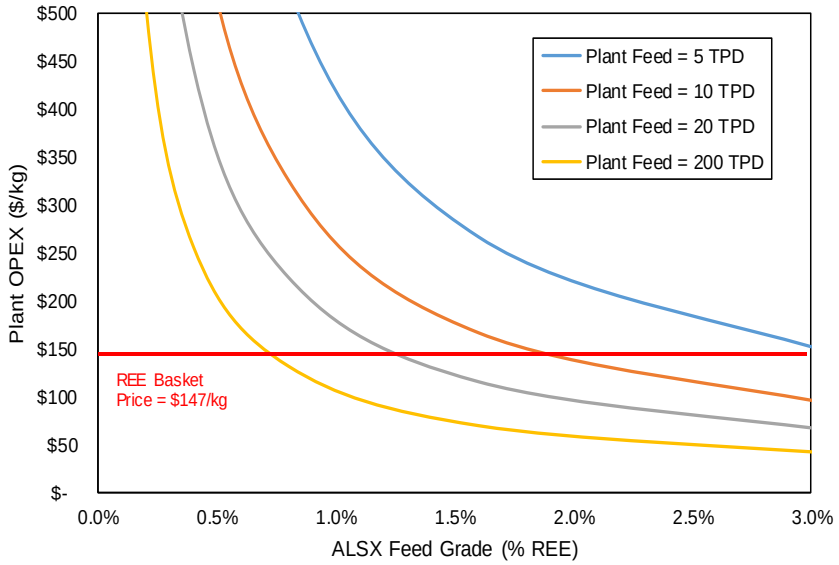
Basket price	$	237	/kg MREO
Total processing cost	$	54	/kg MREO
Estimated profit	$	183	/kg MREO

AMD feed	500	gpm
AMD quality	0.8	mg TREE/L
Production	880	kg MREO/yr
	669	kg Cobalt/yr
Production	1,549	kg/yr
Estimated annual profit*	$184,448	

Does not include:
- capital cost recovery
- taxes
- elemental losses
- oxide separation costs

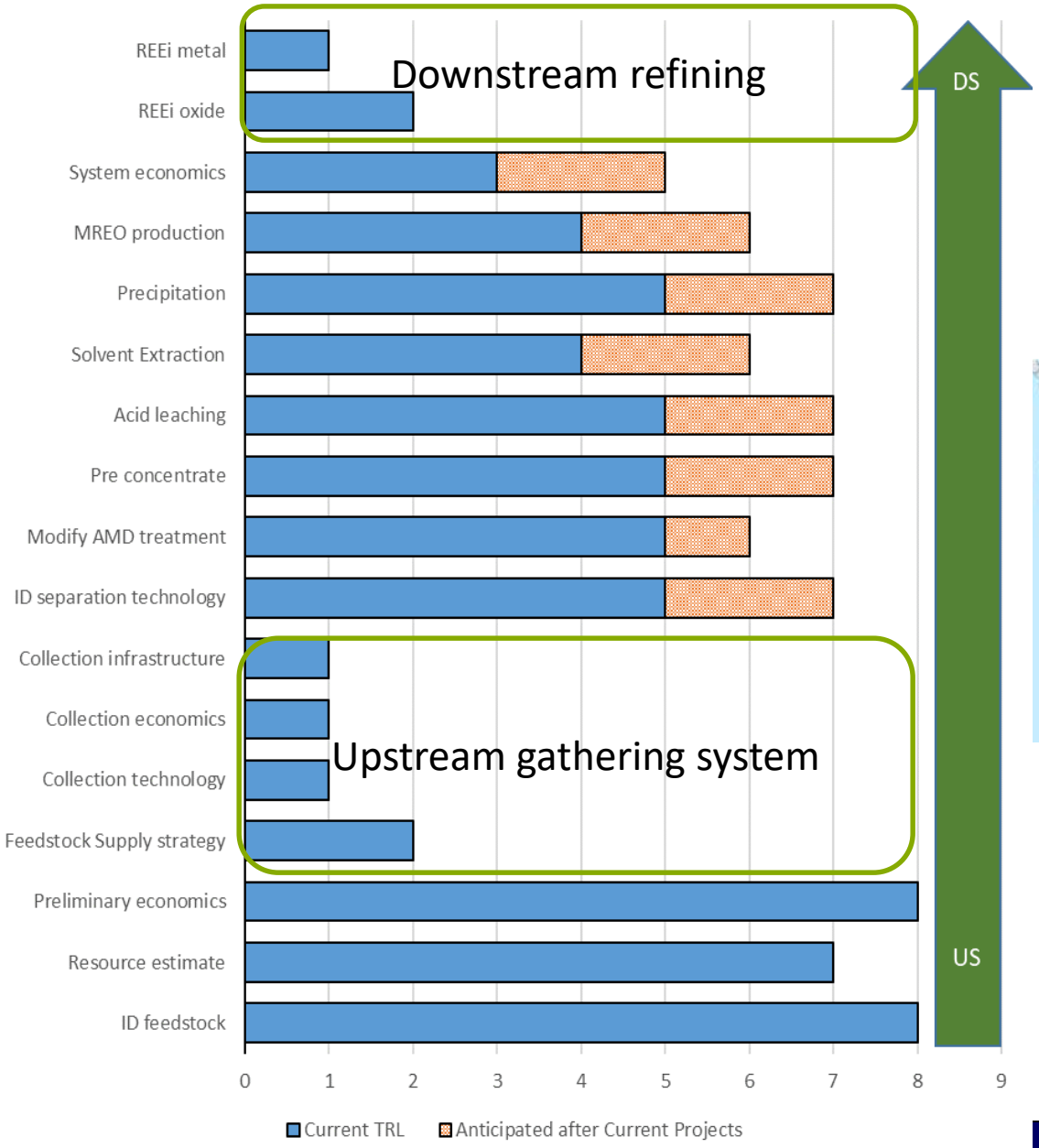
ECONOMIC FEASIBILITY ANALYSIS





Economic Parameter	Value
Plant Feed Rate/Grade	175 TPD @ 2% REE
Product Rate/Grade	2 TPD @ 90% MREO
Operating Period	20 years; 10% discount rate
REE Basket Price	$147 /kg
REE Recovery	59%
Plant CAPEX	$20 Million
Plant OPEX	$54 / kg
NPV	$80 Million
IRR	61%
Payback period	1.5 operating years

SCALING UP TECHNOLOGIES



Hypothetical Hub and Spoke Arrangement for collecting AMD concentrates for regional processing facilities

KEY POINTS

1. Leveraging: Our feedstock is a byproduct of AMD treatment-most capital costs are included in the AMD treatment plant
2. Environmentally Benign:
    1. Supports stream and river remediation efforts
    2. No Radioactivity in the tailings
3. High value product: 67% Heavy + Critical to Total REE
4. No to minor permitting issues
5. Short time to reach production: months
    - Minimum exploration costs
    - No mining cost
    - Pre development cost