Extracting Rare Earth and Critical Minerals from Coal Mine Drainage:

Supplying the Nation's Strategic Needs while Improving Our Streams

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Federal Government Goal:

Develop secure, domestic source of rare earth elements and critical minerals to support U.S. industry and defense establishment

Funding: USDOE/National Energy Technology Laboratory

Sources-Coal derived wastes:

- Acid Mine Drainage-AMD
- Coal Ash
- Coal Tailings-Refuse

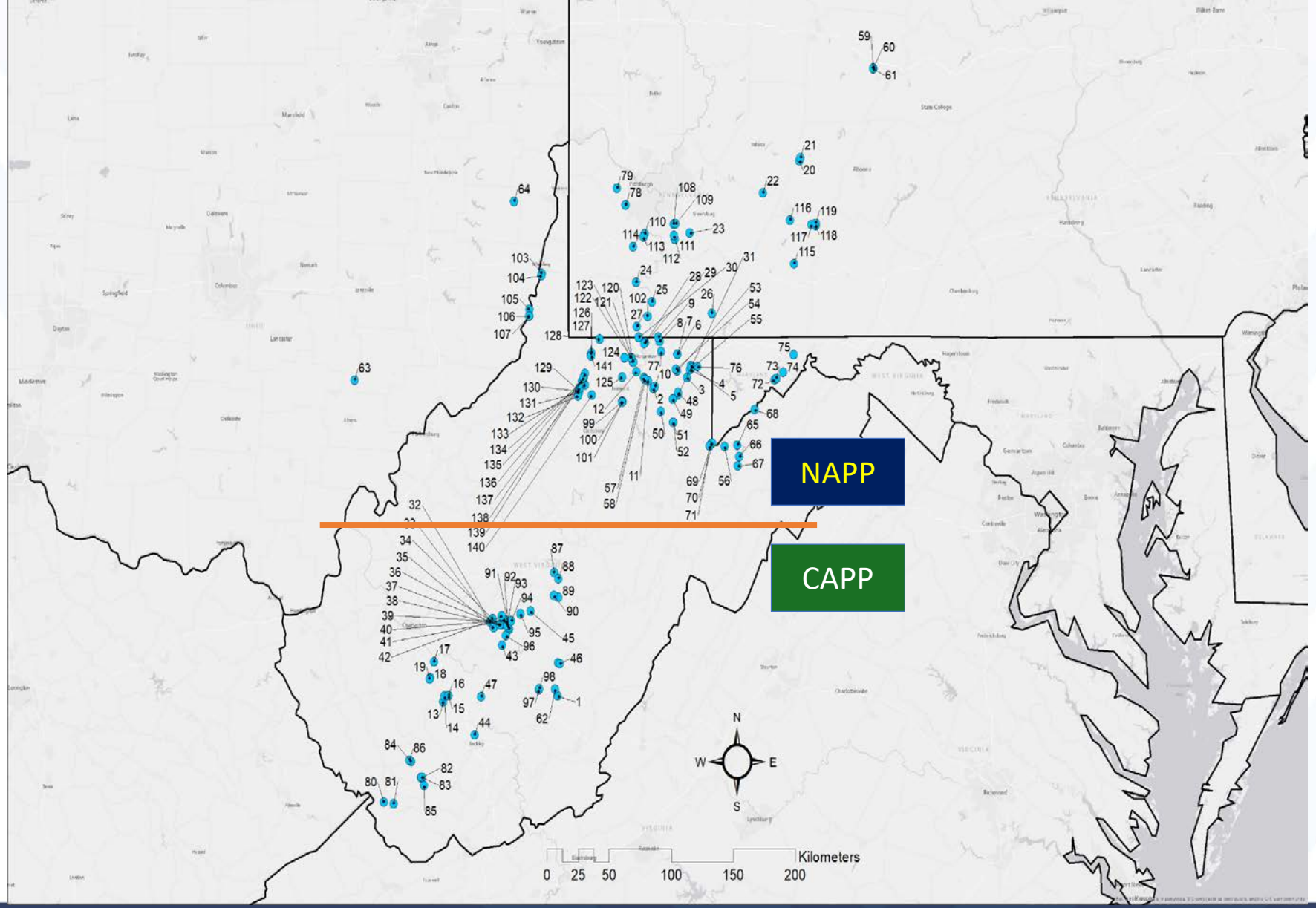
Acid Mine Drainage:
Typical AMD Treatment Facility

AMD sludge cells, Mine 42 Windber PA

AMD Sludge Samples

Regional AMD sampling program

ETD39



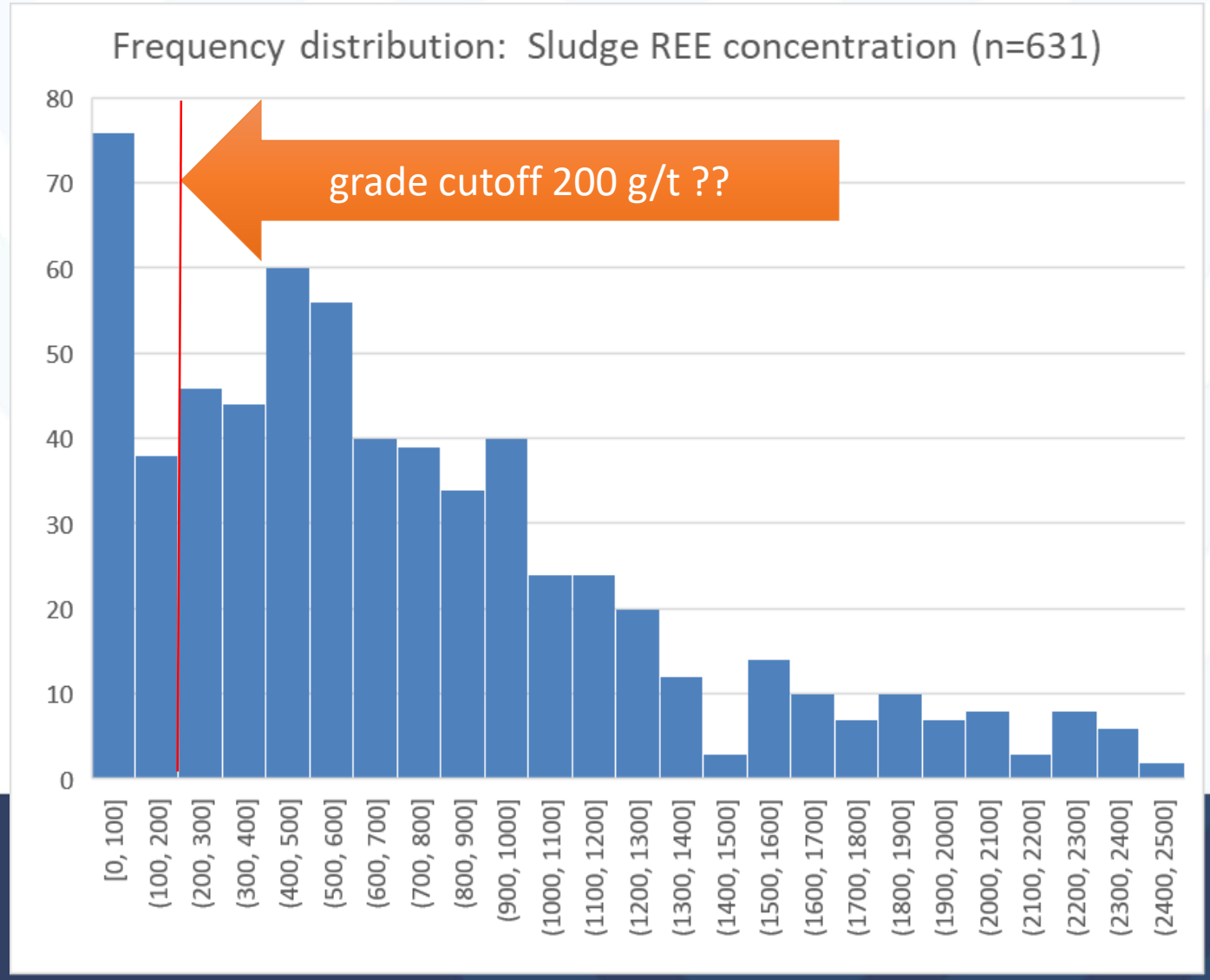
The AMD sludge resource: Central/Northern Appalachian Coal Basins

Key findings:

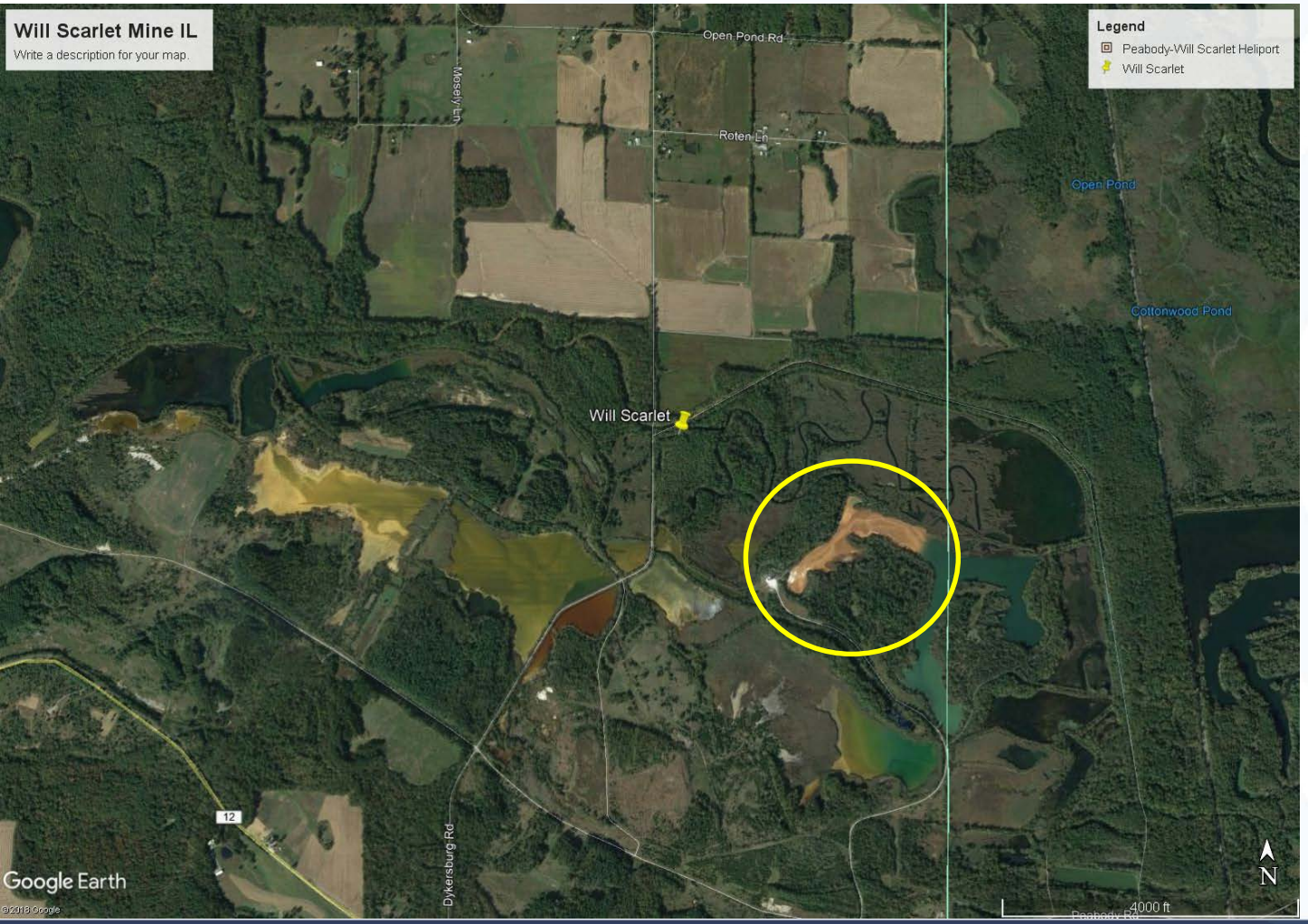
REE content, untreated coal mine AMD		
CAPP	233.5	µg/L
NAPP	304.2	µg/L
all	286.9	µg/L

REE content AMD sludge:		
CAPP	666.4	g/t
NAPP	750.6	g/t
all	708.5	g/t

Available REE stored at mines		
	350	t
$	80	million



Non-Appalachian AMD reserves: Will Scarlet Mine Southern Illinois



ETD 61 Will Scarlet Preliminary Assessment			
Area		18	ac
Depth		39	ft
REE concentration		975	g/t
Contained value	$	166	t SL DW
REE mass		156	tons
REE Contained value	$ 26,486,689		

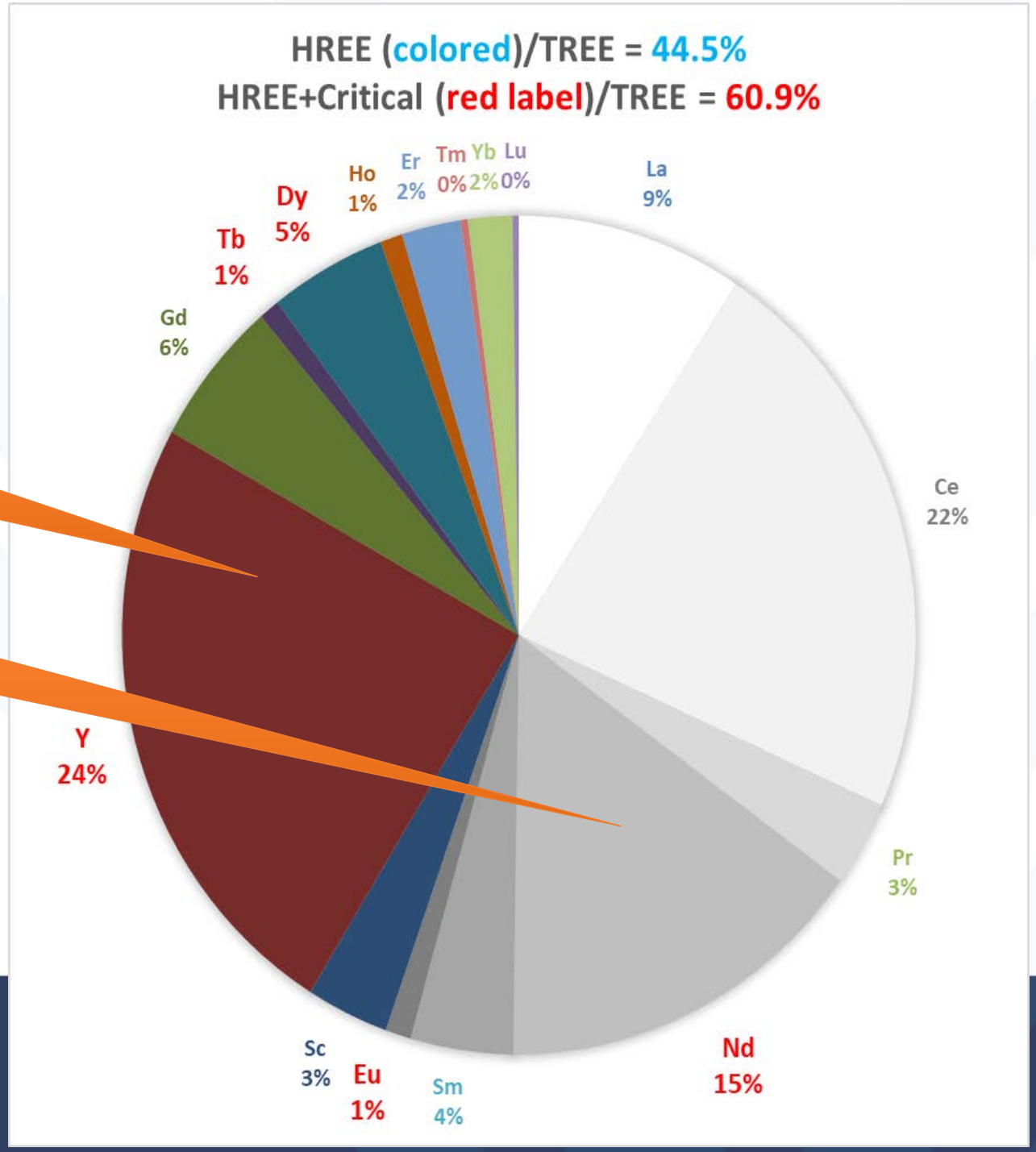
Heavy and Critical REEs in Acid Mine Drainage

n=155

Very high Yttrium content…

also Nd, both used in Nd: YAG lasers

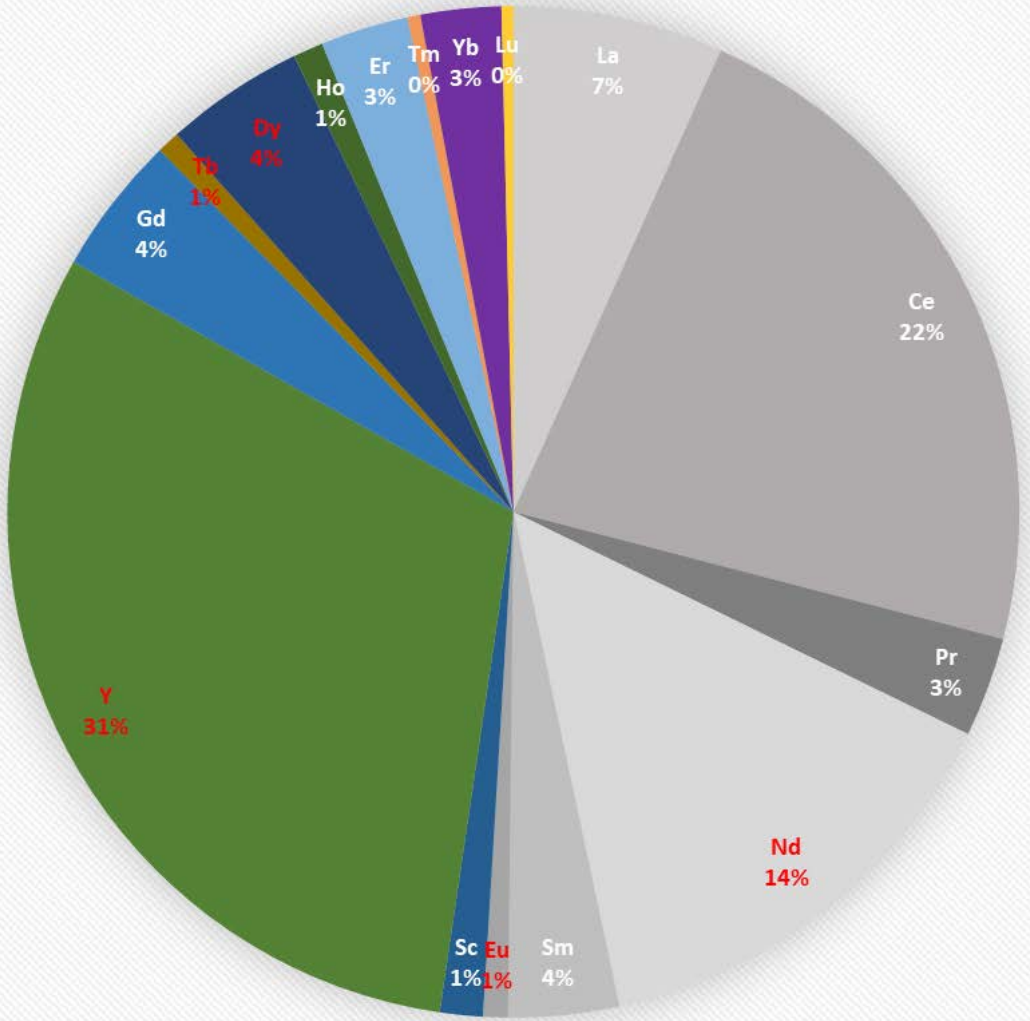
Cobalt is present in all samples.



Similar opportunities exist in the hard rock sector

Berkeley Pit, Copper Mine, Butte MT
AMD precipitates: 140 million m^3
est. REE: 12,000 t dry wt.

Berkley Pit AMD sludge:
TREE: 291 g/t
HREE/TREE=49%, (HREE+Critical)/TREE=64%



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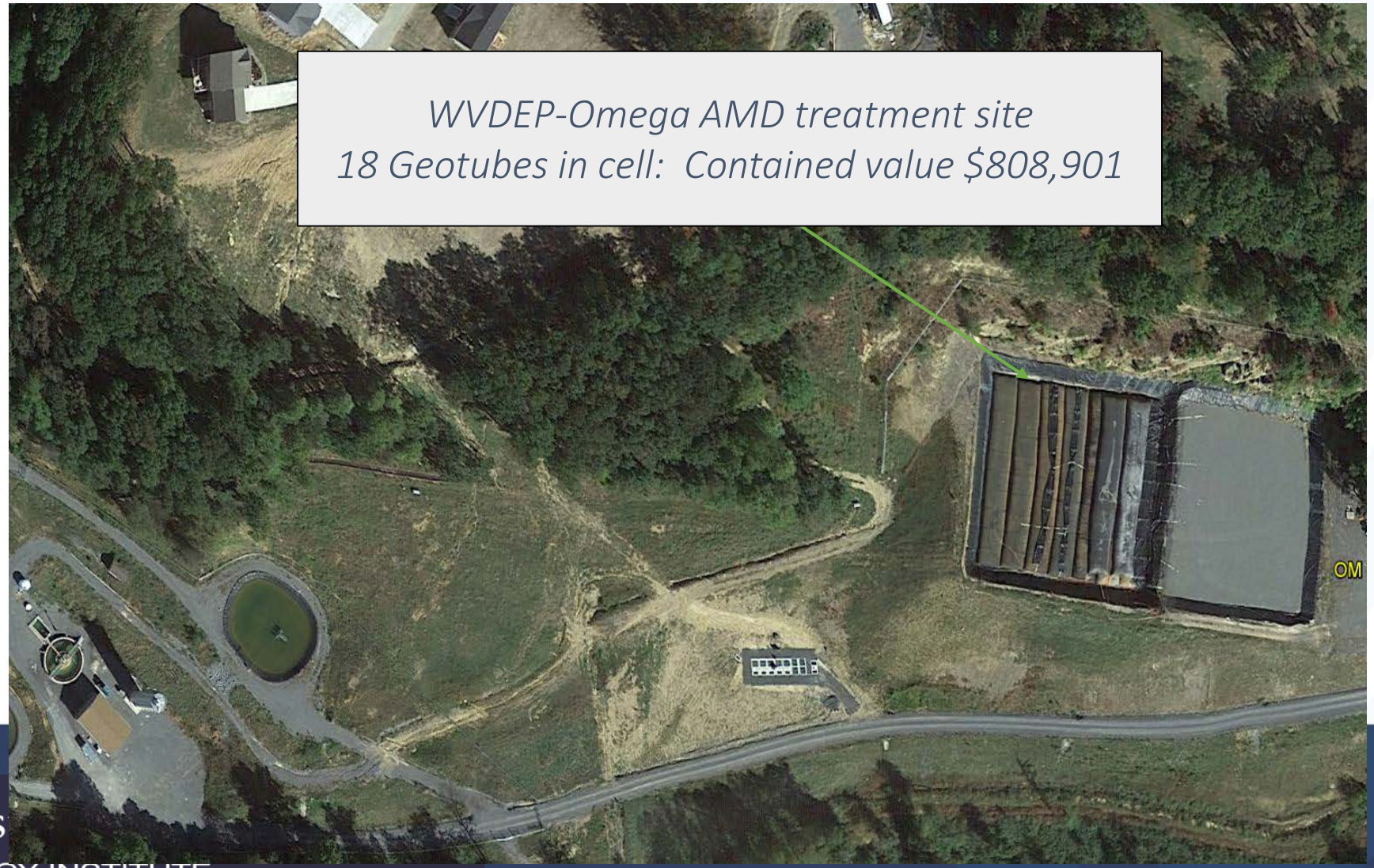
Contained sludge value=market value of REEs excluding transport and processing

Accessibility/Extractability/Dewatering



Estimated REE production CAPP/NAPP

Sludge cells sampled, this project			**76**
Sludge volume (Dry)		482,915	m^3
Sludge mass (Dry)		1,062,413	tons DW
average TREE grade		663	g/t
TREE mass		**350**	**tons**
REE Basket Price (MREO)	$	237.23	/kg TREE
estimated CV	**$**	**79,633,629**	

Estimated annual REE production: Appalachian Basin

		low		**High**	
AMD production		1,503,371		6,626,156	gpm
avg. TREE concentration		0.269		0.269	mg/L
Annual TREE production		807		3,555	tons/year
REE Basket Price (MREO)	$	237.23	$	237.23	/kg
Contained TREE value	**$**	**191,362,343**	**$**	**843,435,793**	**/yr**

Mountain Pass Reserve Statement January 2012[1]

		TREO (tons)	
	TREO	Contained	Recoverable
Proven	8.5%	11,935	6,570
Probable	8.0%	1,321,723	734,593
Total		1,333,658	741,163

[1] *SRK Consulting, 2012*

Nearly all light REEs, shipped to China for refining

Bench-Scale, Continuous Flow Plant

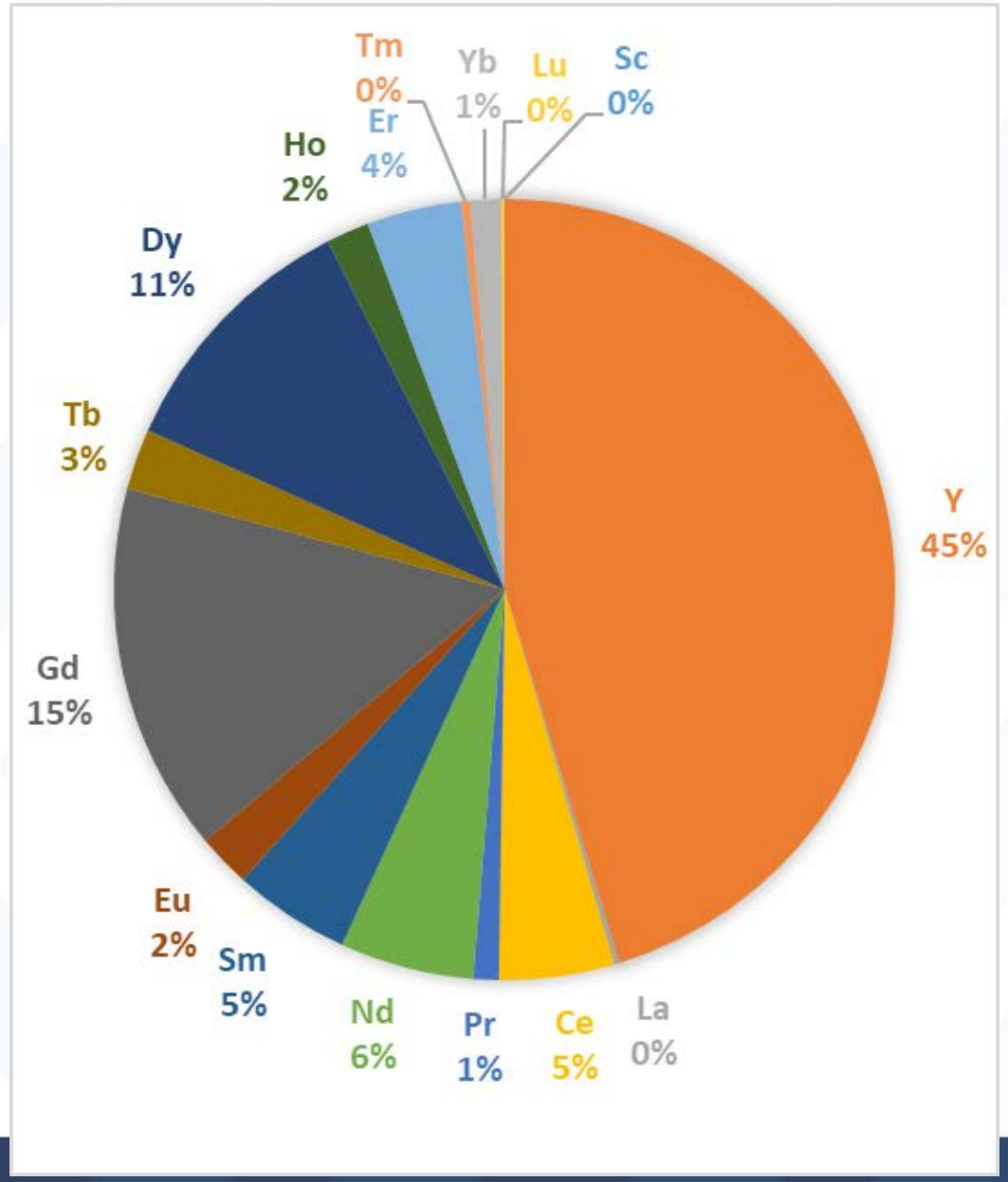
Rockwell Automation is providing controls, sensors and expertise

AL/SX pilot

Rockwell's Support

Recent ALSX results AMD sludge: Simple circuit, optimized for HREEs, thus low Nd

ALSX Mass Proportionation	mg/kg	19'2071
total oxides	914,450.3	91.4%
unaccounted	85,549.7	8.6%
LREE	163,266.3	18.6%
HREE	713,079.1	81.4%
TREO	876,345	87.6%
TMM	38,105	3.8%
TAc	0.00	0.00%
Total oxides	914,450	91.4%



Regulatory Issues:

- Active Permits: Potential Loopholes:
  - Liability dumps: CERCLA (reach back) vs. SMCRA
  - Keep CWA and SMCRA permits in play
  - Remember “Coal Refuse Reprocessing?”
- Abandoned Mines: CWA incentives:
  - NPDES? Tech Based discharge limits?
  - Remining discharge limits?
  - In-stream NPDES for watershed scale remediation?
- SMCRA-termination of jurisdiction:
  - Does the SMCRA permit remain open during REE recovery?
- NRC/UMTRCA:
  - Would Bevill Amendment apply if wastes are radioactive?

Moving Science into the Economy

- Scale up from bench to pilot plant
- Use existing technology and skills
- Minimize technical and economic risk

WV DEP's Muddy Creek AMD treatment plant, Albright WV

Interior of plant showing controls

clarifiers, mixers, control room and lime silo

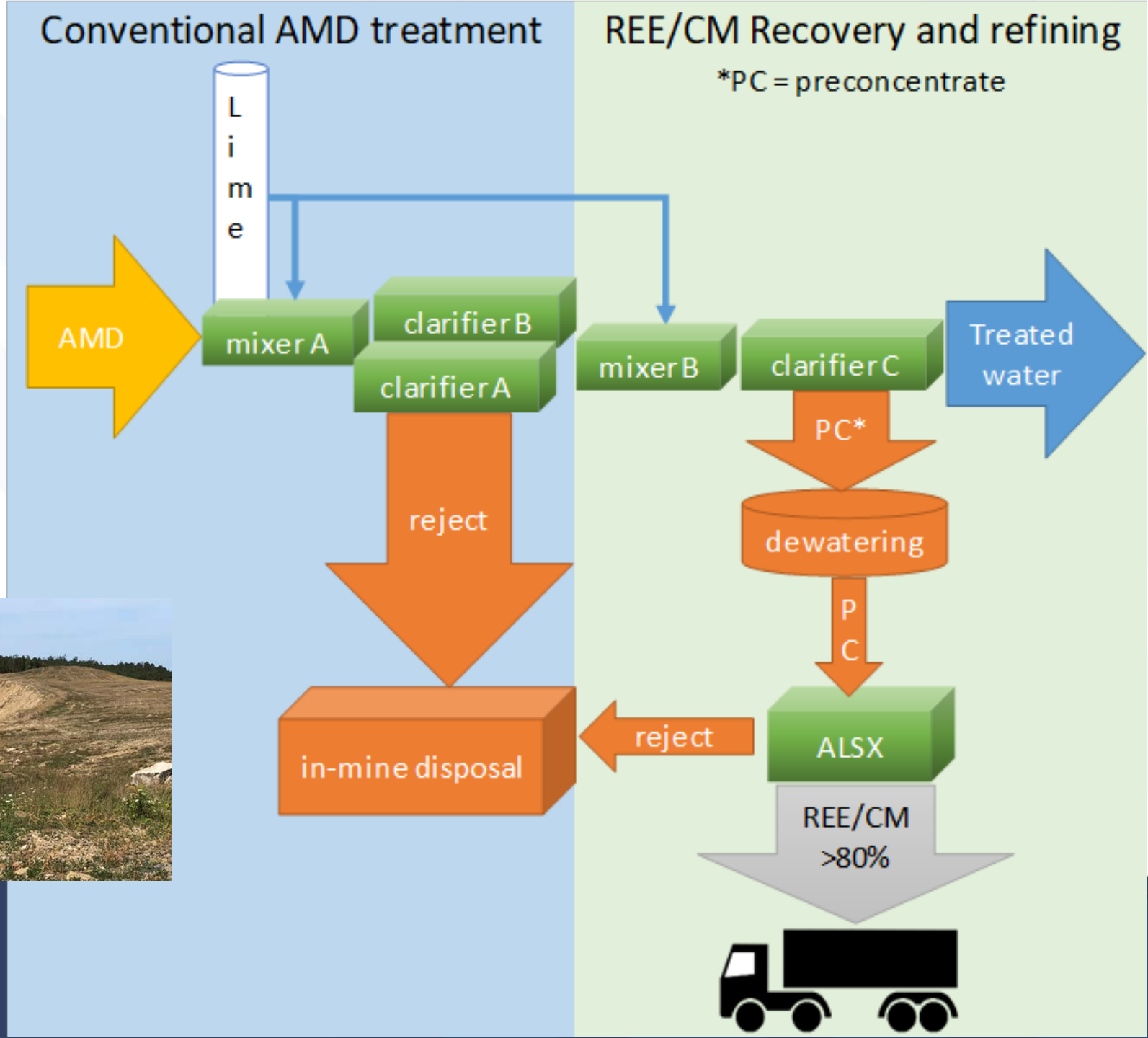
WVU's Rare Earth Recovery Team awarded $5 million to continue groundbreaking work

The Water Research Institute at WVU was given the go ahead by the U.S Department of Energy to scale up its groundbreaking Rare Earth Recovery Project.

- Contributions:
  - USDOE/NETL $5,000,000
  - WVDEP/OSR $1,250,000
  - TenCate Corp $ 537,000
  - Rockwell Automation $ 100,000
  - Total $6,887,000

General design of the A34 plant

- Near Bismarck WV
- Designed to:
  - Treat AMD to meet CWA compliance levels
  - Recover high grade Rare Earth Oxide
- Waste is AMD sludge without the Rare Earths
  - Non-hazardous
  - Onsite disposal



Questions?

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