


Mid-APPalachian Carbon Ore, Rare Earth and Critical Minerals (MAPP-CORE) Initiative

DE-FE-0032054

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U.S. Department of Energy
National Energy Technology Laboratory
Resource Sustainability Project Review Meeting
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Project:
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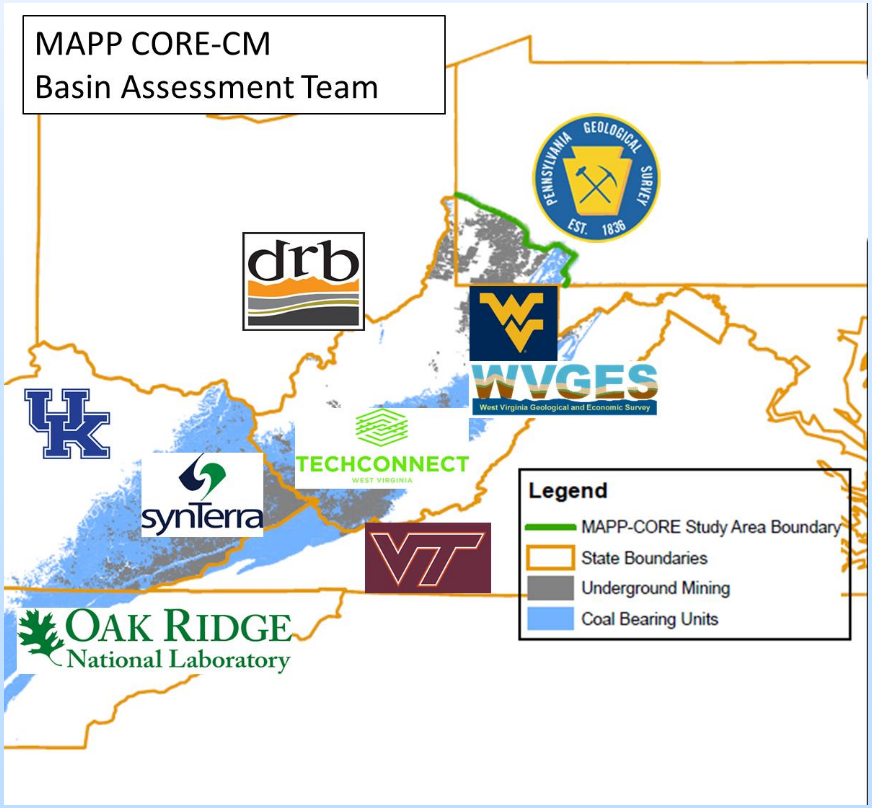
DE-FE032054

Period Of Performance:
10/01/2021 through 08/30/2024

Funding:
Govt. Share: $2,085,000.00
Cost Share: $742,128.00
Total: $2,827,128.00



Project Participants:

- West Virginia University
- University of Kentucky
- Virginia Tech
- West Virginia Geological and Economic Survey
- Pennsylvania Geological Survey
- Kentucky Geological Survey
- DRB Geological Consulting
- Oak Ridge National Laboratory
- SynTerra Corporation
- TechConnect WV

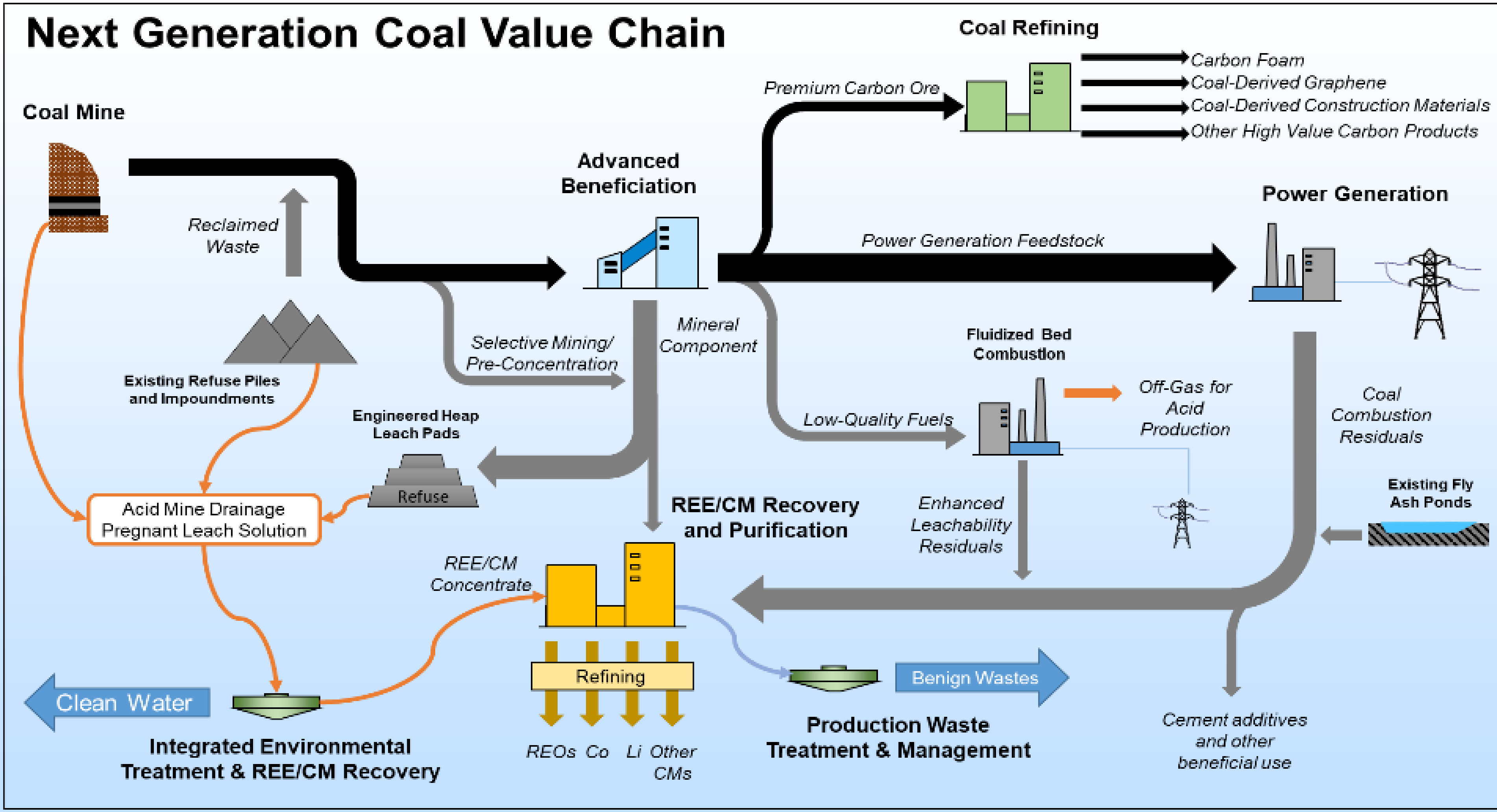
Overall Project Objectives

Near-Term (Tactical)

- Develop resource assessments for CORE-CM feedstocks in basin
- Identify resource production technologies, including novel or low TRL approaches that may have unique application in basin
- Identify key infrastructure resources and infrastructure gaps within the study area
- Engage in-basin industrial/commercial partners to understand materials sourcing requirements and limitations

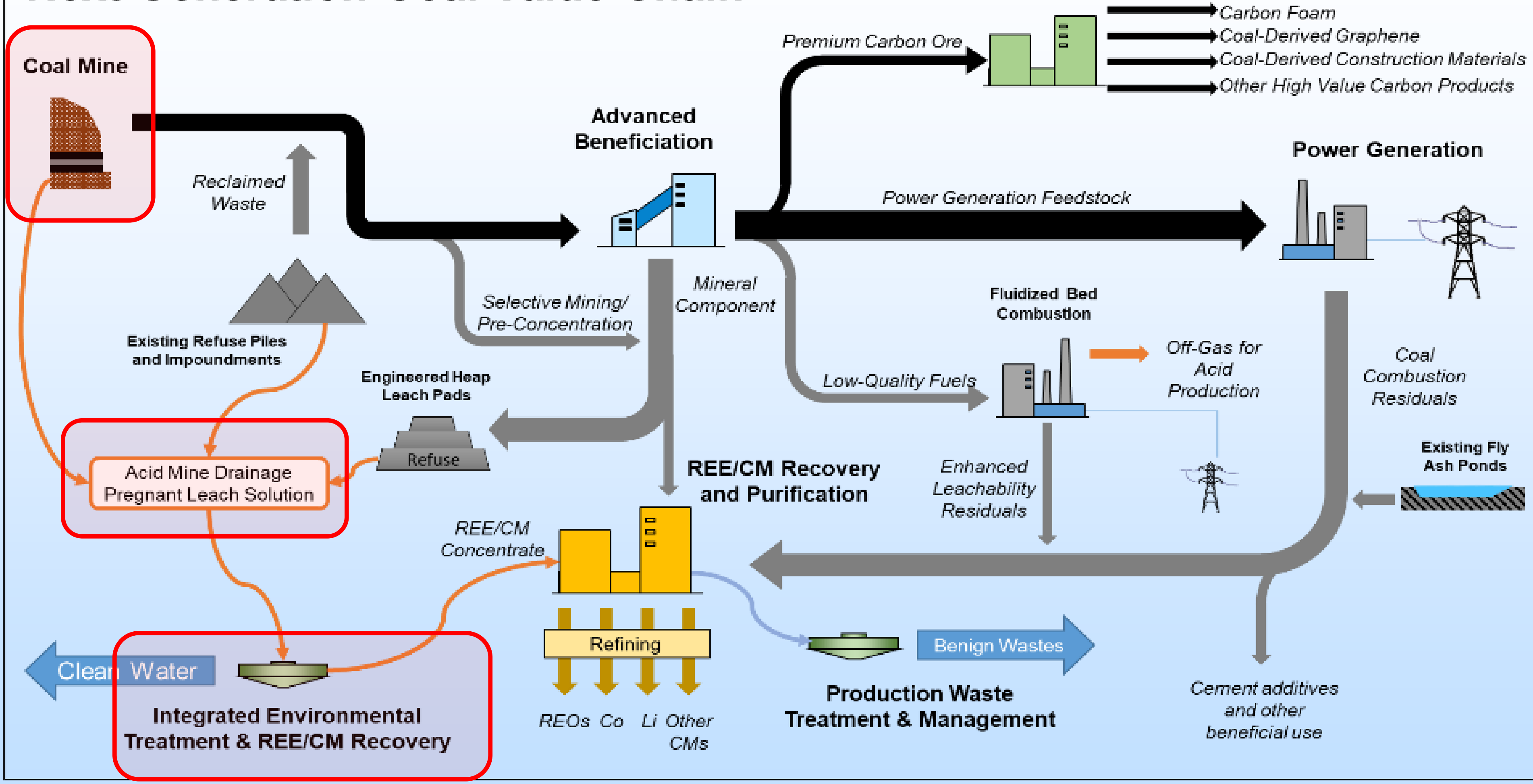
Long-Term (Strategic)

- Enable development of commercial supply chains for regional and national customers.
- Identify “value-added” technologies and technology gaps to enable development and deployment
- Identify domestic supply chain gaps and strategies to fill those gaps for industrial/commercial partners in the region.
- Provide the foundations for technology transfer and commercialization and deployment

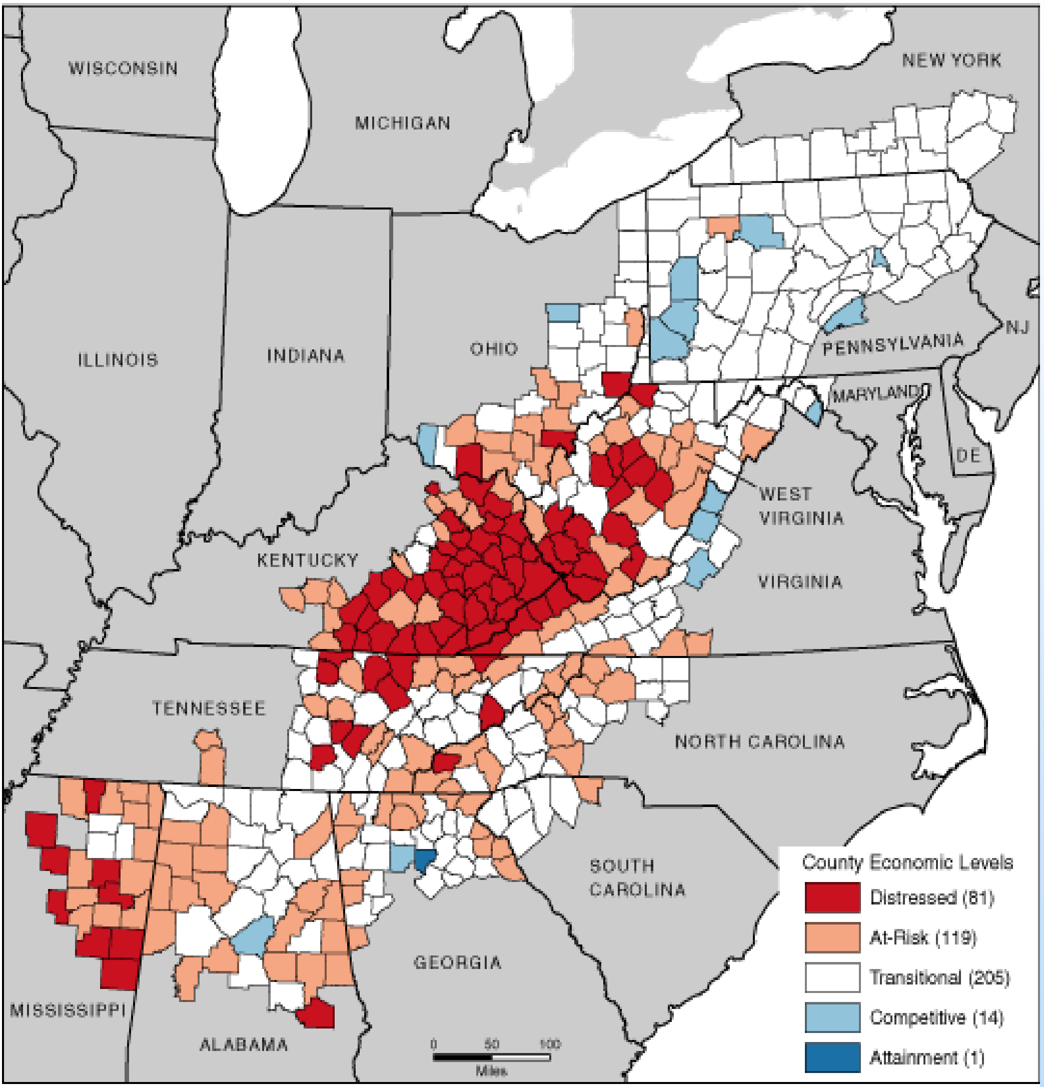


Next Generation Coal Value Chain
Coal Refining
Carbon Foam
Coal-Derived Graphene
Coal-Derived Construction Materials
Other High Value Carbon Products
Premium Carbon Ore
Coal Mine
Advanced Beneficiation
Power Generation
Reclaimed Waste
Power Generation Feedstock
Mineral Component
Selective Mining/ Pre-Concentration
Existing Refuse Piles and Impoundments
Fluidized Bed Combustion
Off-Gas for Acid Production
Coal Combustion Residuals
Engineered Heap Leach Pads
Low-Quality Fuels
Refuse
Acid Mine Drainage Pregnant Leach Solution
REE/CM Recovery and Purification
Enhanced Leachability Residuals
Existing Fly Ash Ponds
REE/CM Concentrate
Refining
Benign Wastes
Clean Water
Integrated Environmental Treatment & REE/CM Recovery
REOs Co Li Other CMs
Production Waste Treatment & Management
Cement additives and other beneficial use

Next Generation Coal Value Chain



MAPP-CORE Vision



Created by the Appalachian Regional Commission, August 2018
Data Sources:
Unemployment data: U.S. Bureau of Labor Statistics, LAUS, 2014–2016
Income data: U.S. Bureau of Economic Analysis, REIS, 2016
Poverty data: U.S. Census Bureau, American Community Survey, 2012–2016

Effective October 1, 2018 through September 30, 2019

- Full-cycle analysis:
  - upstream production
  - midstream refining and processing
  - downstream manufacturing of high value products

- Identified AMD in Central Appalachia as an untapped resource.
  - Technical, workforce and economic considerations.
  - Directly addresses social justice through economic development
  - Directly addresses environmental justice concerns through focus on mine waste cleanup and site reclamation opportunities.

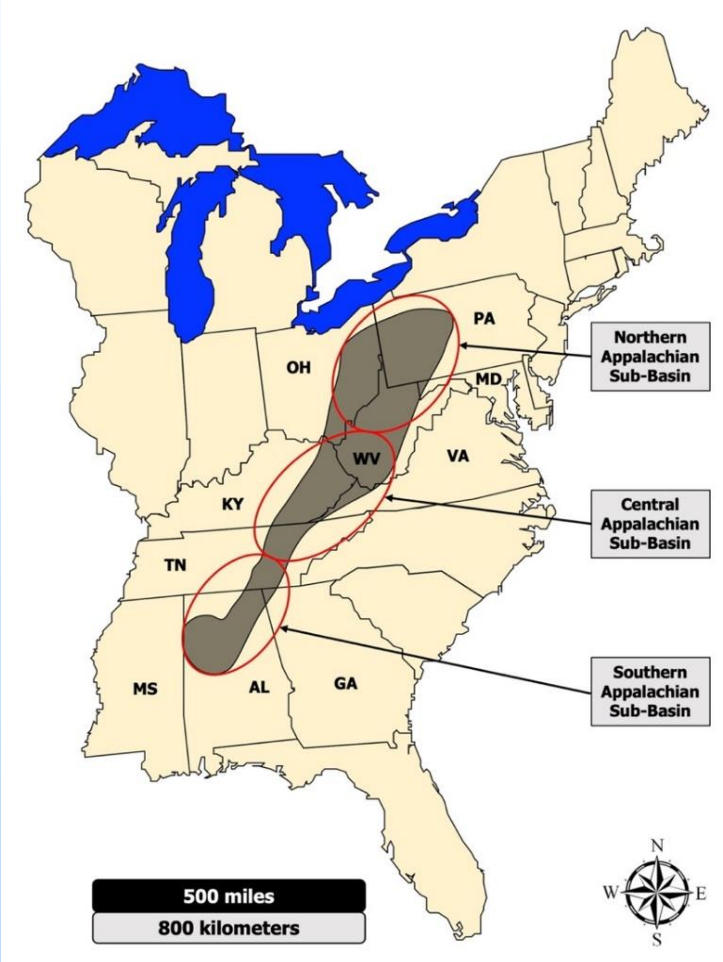
CORE-CM Resource Valuation Rubric

Criteria	Factors Considered	Score				
		1 – Poor	2 – Marginal	3 – Acceptable	4 – Good	5 – Exceptional
Resource Significance	In place tonnage, annual availability, anticipated yield	Insignificant. Potential to supply <5% of total US demand with no major production of critical. Limited upside.	Niche markets. Potential to supply 5% to 10% of total US demand. Potential to be sole supplier to a single application area.	Small US player. Potential to supply 10% to 25% of US demand for a single specific element. Moderate upside with additional exploration.	Moderate US player. Ability to supply 25%+ of several elements. Significant upside/potential in unexplored areas.	Global player. Potential to meet the majority of US demand for several elements. High growth potential to meet additional demand.
Resource Quality	REE/CM Grade, REE Distribution and criticality, Potential for CO/CM Byproducts.	Ore grades show no enrichment versus crustal concentrations (nominally 200 to 250 ppm TREE). Limited or no potential for upgrading. No preferential enrichment of CREE. Potential byproducts are not viable.	Slight enrichment above crustal concentrations (nominally 300 to 1000 ppm) with some potential for further upgrading. Slight preferential enrichment of CREE. Slight potential for marketable byproducts but concerns with viability.	Slight enrichment above crustal concentrations but with potential for significant upgrading to 1000 to 5000 ppm. Moderate enrichment of CREE and moderate potential for marketable products, particularly CO/CM.	Ore grades or potential to enrich >5000 ppm. Moderate enrichment of CREE and moderate potential for marketable CO/CM byproducts.	Ore grades or potential to enrich >10,000 ppm with significant enrichment of CREE. Significant potential for CO/CM byproducts.
Technical Feasibility	Process amenability, anticipated recovery, reliance on conventional processes, scalability	Low recoverability (nominally <5%). Process train requires several non-commercial technologies at each stage. Most processes have not been proven at scale (Average TRL <3). Feedstock entails significant contamination that requires multiple processing stages.	Marginal recoverability (nominally 5% to 25%). Non-commercial solutions are required for most processing steps or the key processing steps. Average TRL across the process train is 3 to 4. Pilot data is very limited. Feedstock entails some contamination that can be properly mitigated.	Acceptable recoverability (nominally 25% to 50%). Process train includes a balanced mix of commercial and non-commercial solutions; however, questions on overall scalability/integration remain. Some pilot data is available but is not conclusive. Contamination is commensurate with conventional ores.	Above average recoverability (nominally 50%+). Process train primarily includes high TRL processes; however, some steps may still rely on non-commercial or developmental solutions (Average TRL = 5 to 6). Pilot data is available to justify the majority of the process variables. Contamination can be managed.	Feedstock allows full control of recoverability to fully optimize the process. All processing steps are derived from commercial solutions or have been validated and integrated. Significant pilot data supports process assumptions.
Economic Feasibility	REE/CM Basket price, anticipated production	Anticipated production costs significantly exceed basket price	Production costs exceed basket price, but are within a	Basket price slightly exceeds production costs, but the project is	Basket price exceeds production costs and project is moderately	. Basket price substantially exceeds production cost.

Basinal assessment of CORE-CM resources

Focused on Economically Significant Coal Beds in Central and Northern Appalachian sub-basins (eastern KY, western PA, WV)

- Current resource volumes for major coal seams
- REE distributions in coal beds

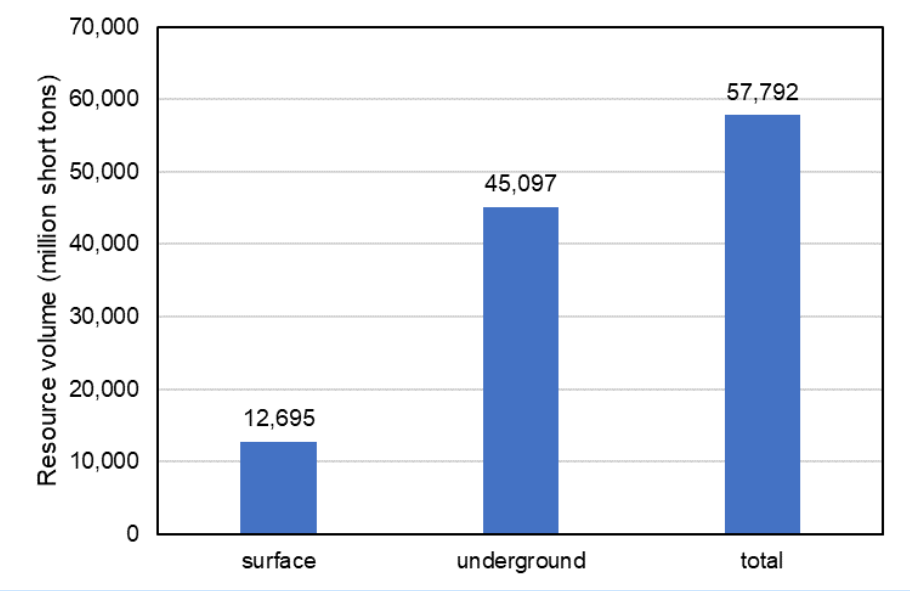


System	Series	Group / Formation WV	Group / Formation KY	Group / Formation PA	Eastern Kentucky Coal Beds	West Virginia Coal Beds	Western Pennsylvania Coal Beds
Pennsylvanian	Upper	Monongahela	Monongahela	Monongahela	*Conemaugh + Monongahela strata present in NE Kentucky with no mineable coal*	Waynesburg	Waynesburg
						Sewickley	Sewickley
						Redstone	Redstone
						***Pittsburgh**	***Pittsburgh**
		Conemaugh	Conemaugh	Conemaugh		Little Pittsburgh	Little Pittsburgh
						Little Clarksburg	Little Clarksburg
					Harlem	Harlem	Harlem
					Bakerstown	Bakerstown	Bakerstown
					Brush Creek	Brush Creek	Brush Creek
	Middle	Allegheny	Breathitt	Allegheny	Princess No.9	Mahoning	Mahoning
					Princess No. 8	***Lower / Upper Freeport**	***Lower / Upper Freeport**
					Princess No. 7	Middle Kittanning	Middle Kittanning
					Princess No. 6	***Lower Kittanning / No. 6 Block**	***Lower Kittanning**
					Princess No. 5 a,b	Clarion / No. 5 Block	Clarion
					Princess No. 5	Little No. 5 Block	Brookville
					Hazard No. 9	***Stockton**	Upper Mercer
		Kanawha		Pottsville	Hazard No.8	***Coalburg**	Lower Mercer
					***Hazard No. 7**	Winifrede	
					Taylor	Chilton	Tionesta
					***Fire Clay**	Fire Clay	
					U. Whitesburg	Cedar Grove	
					L. Whitesburg	Alma	
					***Upper Elkhorn No. 3**	***No. 2 Gas**	Quakertown
					Upper Elkhorn No. 1,2	Powellton	
					***Lower Elkhorn**	***Eagle**	Sharon
	Lower				Manchester	Matewan	*base of Pennsylvanian section in western Pennsylvania*
		New River			Tunnel	Iaeger	
					Cumberland Gap	***Sewell**	
					base of Pennsylvanian section in Kentucky	Fire Creek	
		Pocahontas				Pocahontas No. 8	
						Pocahontas No. 7	
						Pocahontas No. 6	
						Pocahontas No. 5	
						Pocahontas No. 4	
						Pocahontas No. 3	
						Pocahontas No. 2	

***Economically significant coal beds**

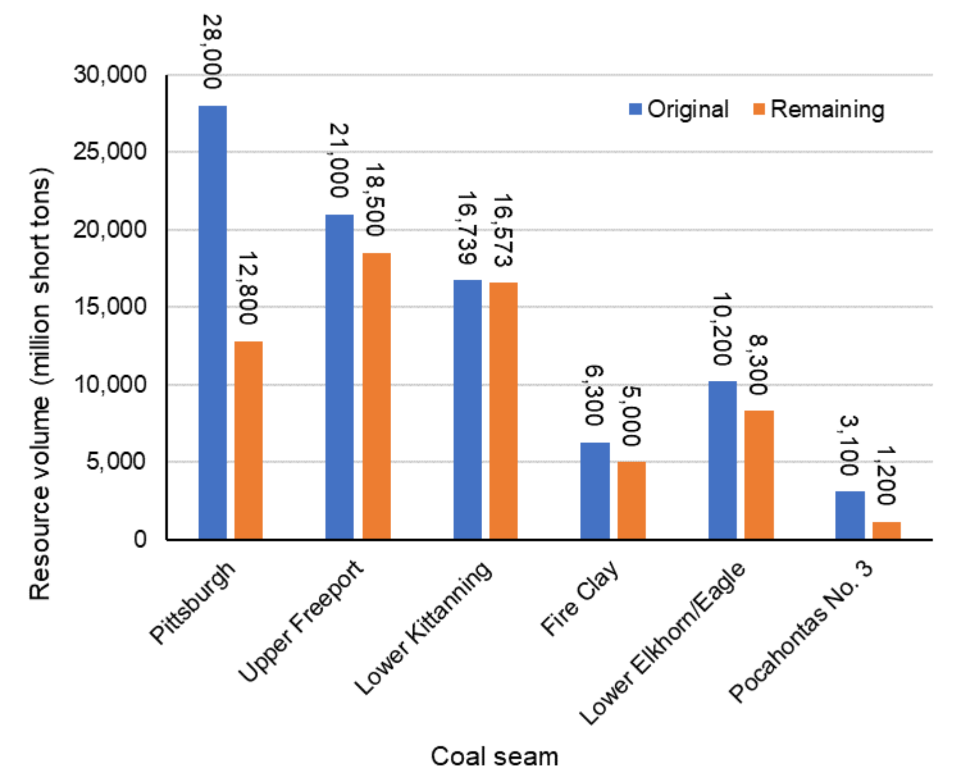
Appalachian coal resources

Demonstrated coal reserve base by mine type



(Source: EIA, 2023)

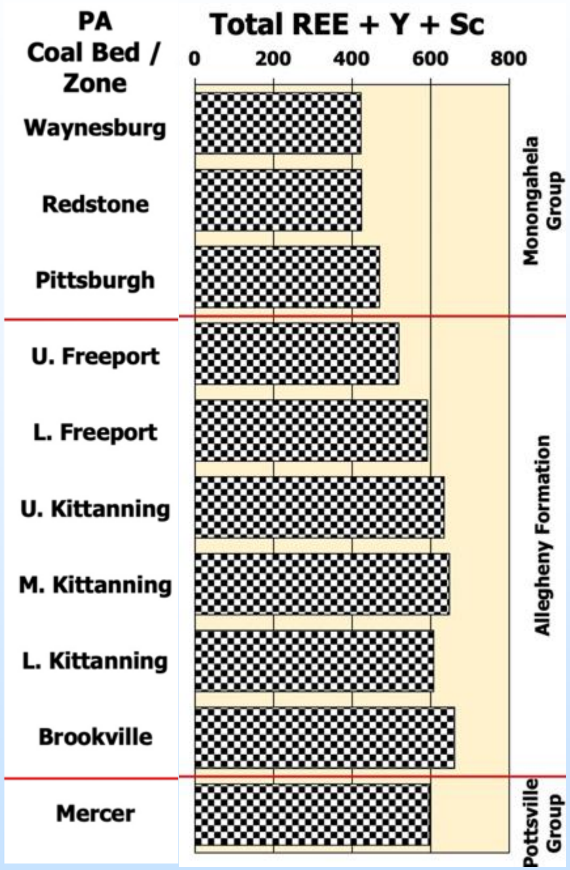
Resources by coal seam



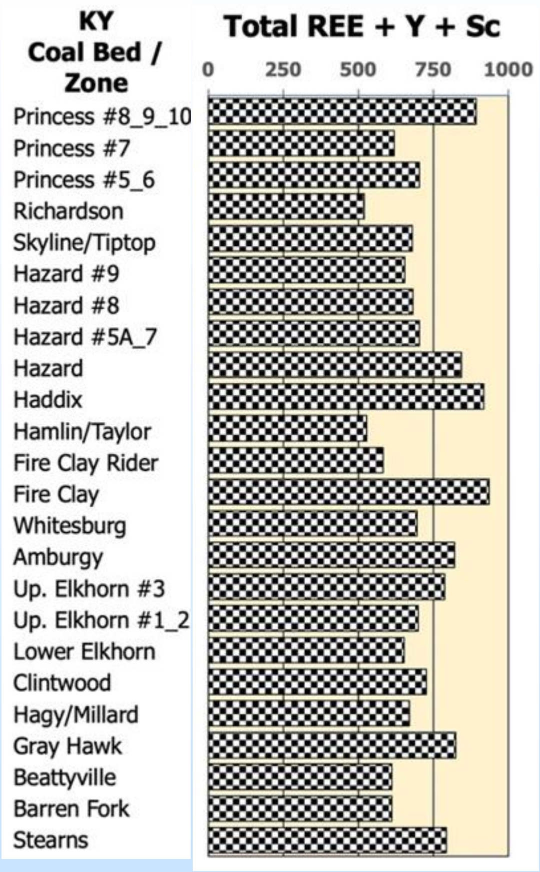
(Source: USGS, 2001)

Distribution of REEs in Appalachian coal beds

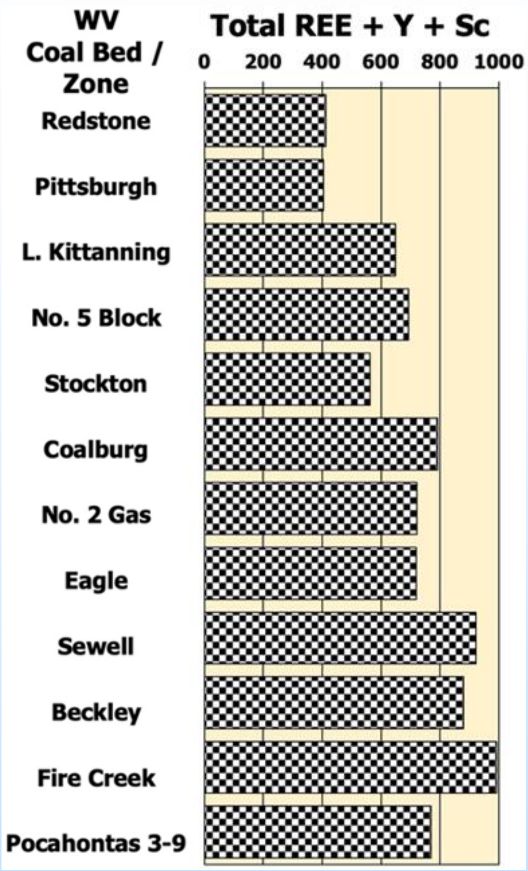
(ppm, mg/kg)



(ppm, mg/kg)



(ppm, mg/kg)

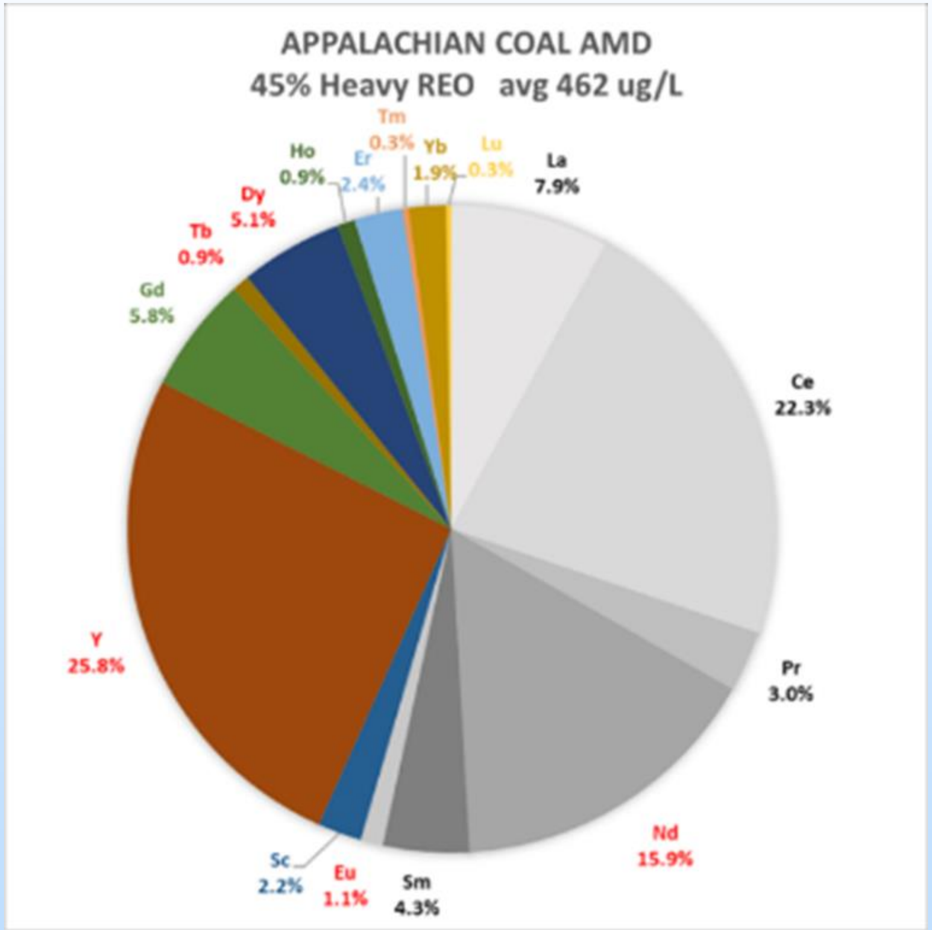


(Source: Palmer et. Al., 2015)

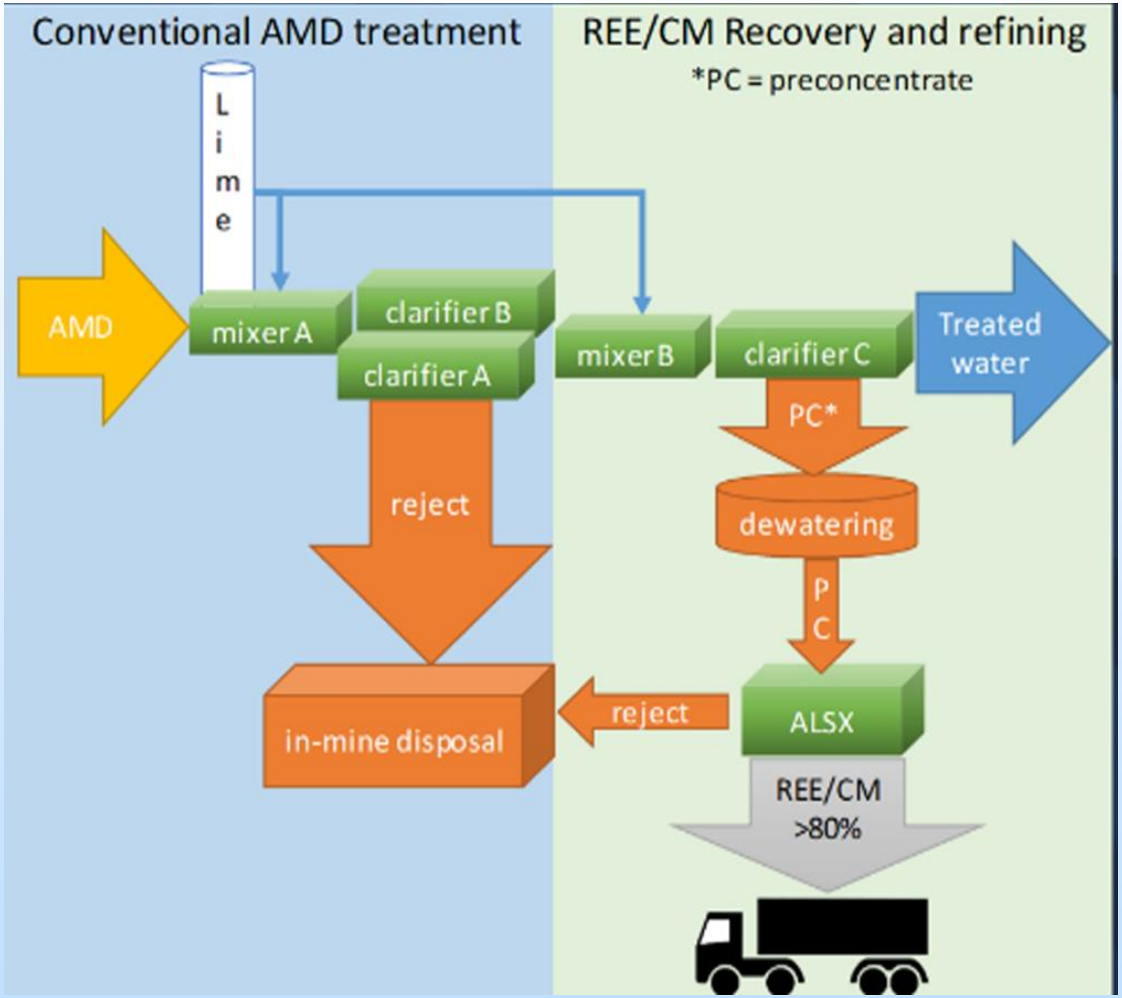
- REE/CM ratios are similar across the basin
- REE concentrations 400-1000 ppm (mg/kg)

Rare earth elements (REEs) and critical materials (CMs) in acid mine drainage (AMD)

- <u>AMDREE Program</u>: WVWRI finds REEs consistently exist in Raw Coal AMD across 140 separate sites
- <u>Current efforts</u>: 146 AMD sources sampled to-date for CORE-CM to identify watershed candidates for REE/CM recovery
- WVWRI also finds that CMs such as Cobalt and Nickel exist in equal concentration to REEs



REE/CM recovery from AMD



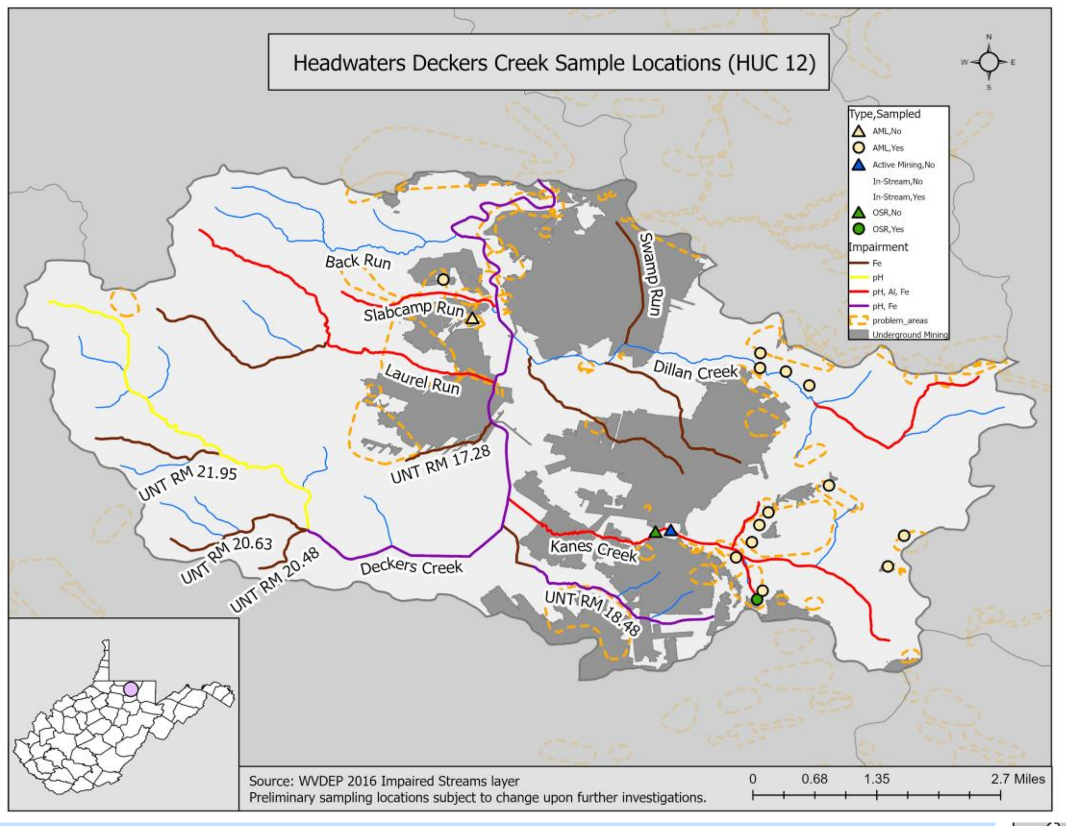
Advantages:

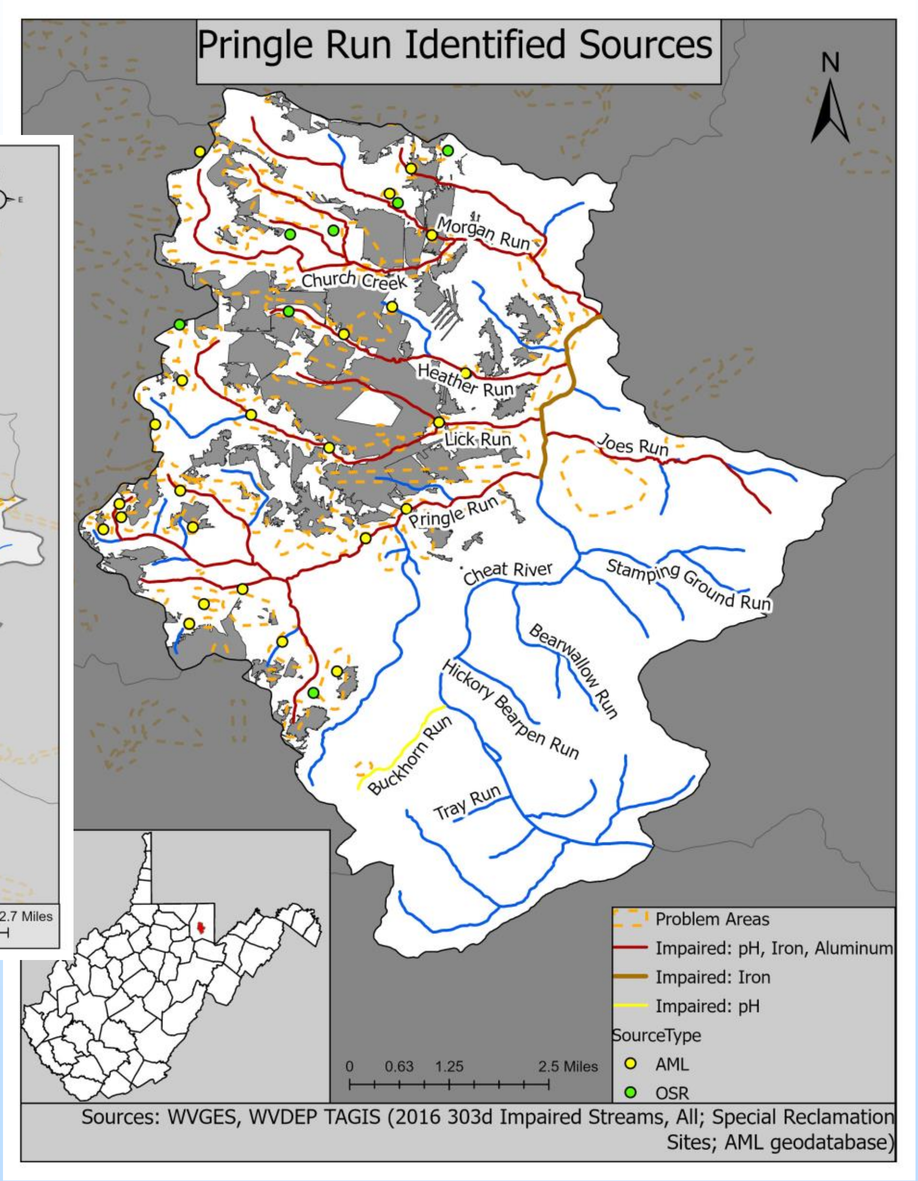
- Concentrates are 45% HREE
- Incentivizes AMD treatment
- Discharges CWA compliant water
- Already permitted sites
- Can go into production almost immediately
- Modest additional CapX
- No rads, solid rejects are non-hazardous

Disadvantages:

- Small, dispersed, upstream production sites

CORE CM Project: Characterize REE/CM recovery potential in multiple impaired watersheds

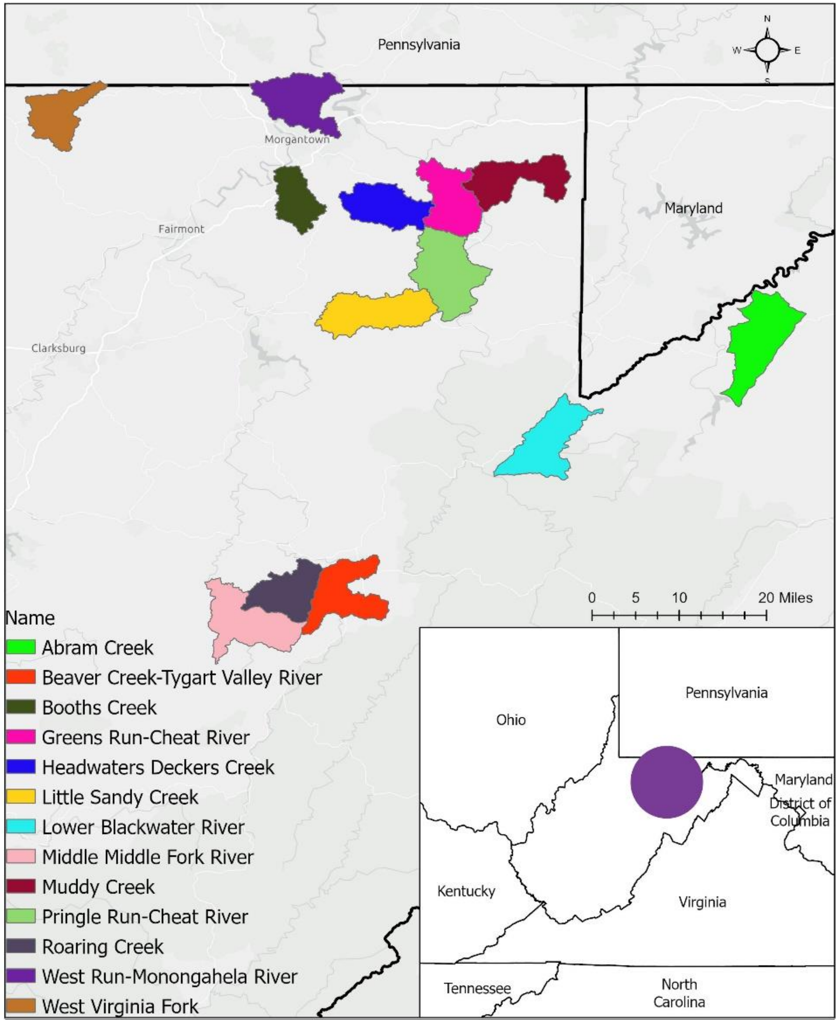




REE/CM loads in AMD-impacted Appalachian watersheds

Watershed	REE load (ton/yr)	CM load (ton/yr)
Muddy Creek (Cheat River)	0.55	8.80
Middle Cheat (Cheat River)	4.93	78.88
Greens Run (Cheat River)	0.61	9.76
Lower Deckers (Mon River)	0.53	8.48
Upper Deckers (Mon River)	0.14	2.24
Long Run (Blackwater)	0.60	9.60
Three Fork (Tygart)	0.50	8.00
Total	**7.86**	**125.76**

- Sampling at sources in AMD-impacted watersheds
- 146 sites sampled to date
- Common for REE load to exceed target of 0.5 ton/yr
- Non-REE CMs: Co, Ni, Mn
- Integrated into AMD treatment
- REE/CM recovery to offset OpX costs
- Network of sites for domestic REE/CM supply chain



Sources: USGS National Map Viewer (NHDPlus Hydrologic HUC4 0502 Dataset)

Integrating REE/CM recovery into watershed-scale restoration

- Treat AMD and restore streams at watershed-scale
- Evaluate restoration based on designated use and TMDL instead of NPDES
- Recover REE/CM from multiple sources as part of treatment to offset costs and contribute to supply chain

1. Characterize Watersheds →

- Sources
- Acid load (TMDL)
- **REE/CM potential**
- Design constraints

2. Conceptual Designs →

- Load reduction goal
- Treatment strategies
- CapX + OpX costs
- **REE/CM revenue**

3. Evaluate Watersheds →

- Stream recovery
- Acid load reduction
- Cost
- Feasibility
- Prioritize watersheds

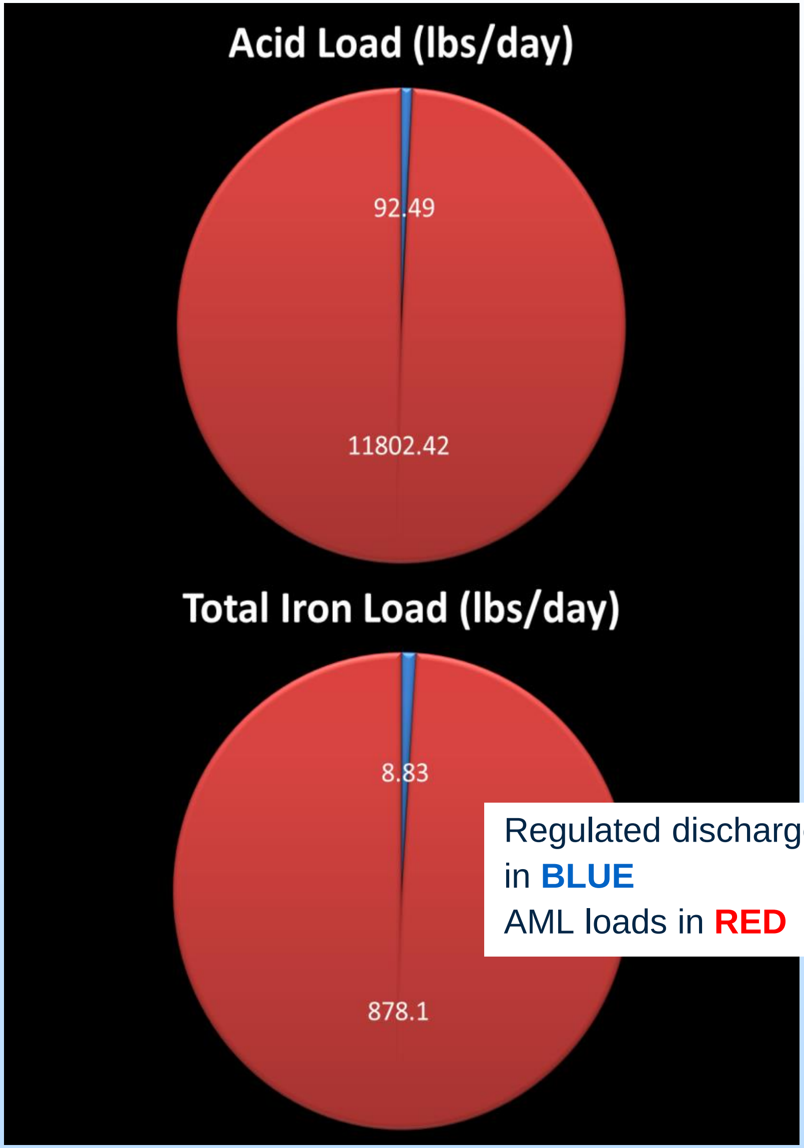
4. Implement Plan

- Allocate funding
- Establish long-term financing
- Design-Build
- Manage w/ State's Bond Pool

<u>Case study</u>: Muddy Creek Watershed / T&T AMD Treatment Plant

Before "watershed-scale restoration"

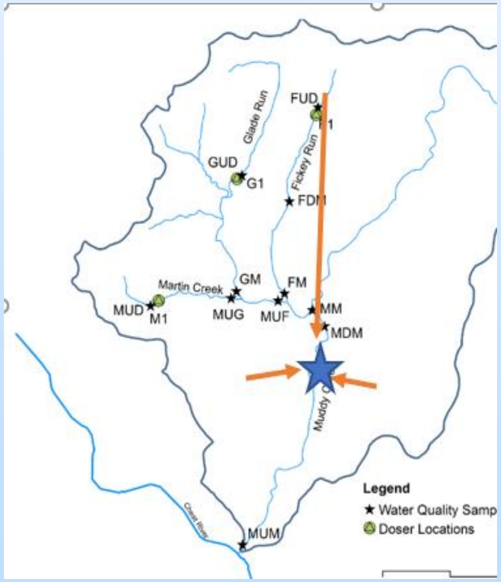
- Impairments
  - Muddy Ck responsible for ~50% of acid load to Cheat River
  - Three tributaries severely polluted: Fickey Run, Martin Ck, Glade Run
  - Cheat River dead downstream of Muddy Creek
- Regulatory Structure
  - Point discharges (OSR, NPDES) (Title 5) vs,
  - AML discharges (Title 4)
- Initial restoration plan
  - Multiple AMD treatment units on Bond Forfeiture sites
  - Expensive w/ no stream recovery

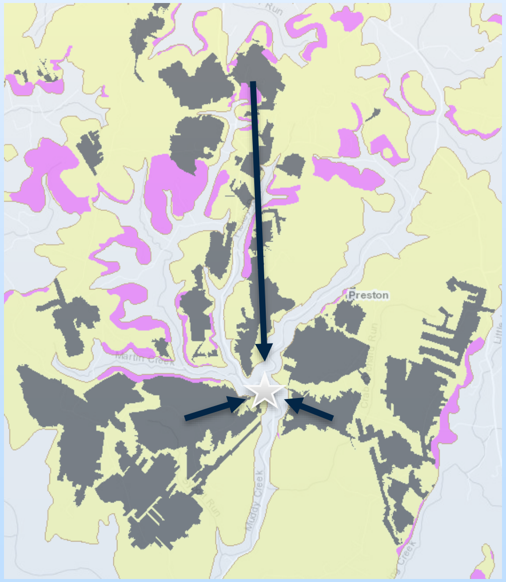


Regulated discharges in **BLUE**
AML loads in **RED**

Watershed treatment approach

- Treat ALL sources to recover watershed
- Many point sources and bond forfeiture AMD treatment units replaced by centralized treatment plant
- Consolidated deep mine AMD
- EPA granted in-stream NPDES permit variance





Financial Outcomes

Comparing Watershed to Point Source

- Higher CapX: water transfer, central facility
- Lower OpX: road maintenance, compliance monitoring, QC, supplies
- Contribution from Southwestern Energy (SWE)
- Documented costs/benefits attractive to external sponsors

Long-Term Costs (10-yr basis)

- Point source: $22.5 M
- Watershed: $21.2 M
- Watershed (w/ SWE contribution): $15.2 M

Future Plans

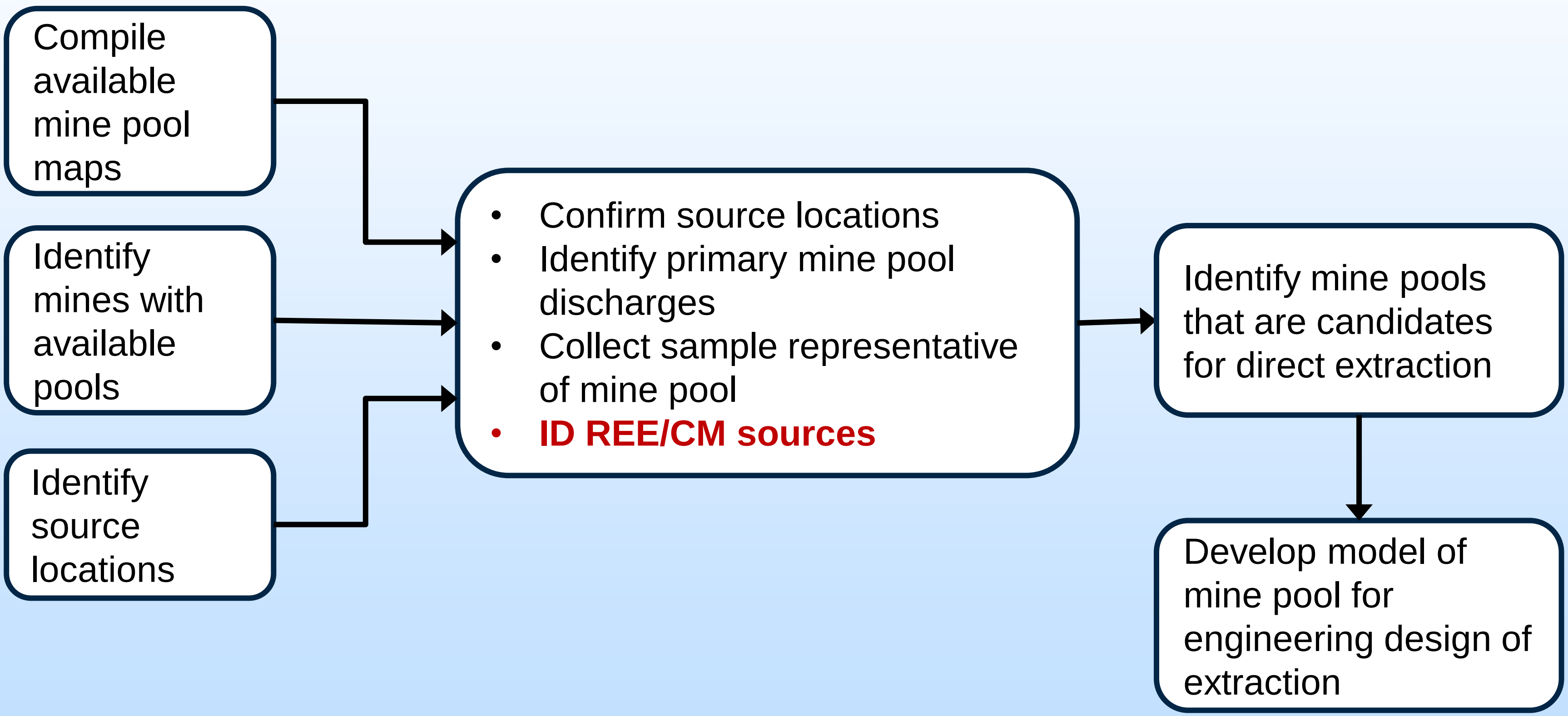
- REE/CM recovery
- Offset to OpX costs

Restoration Outcomes

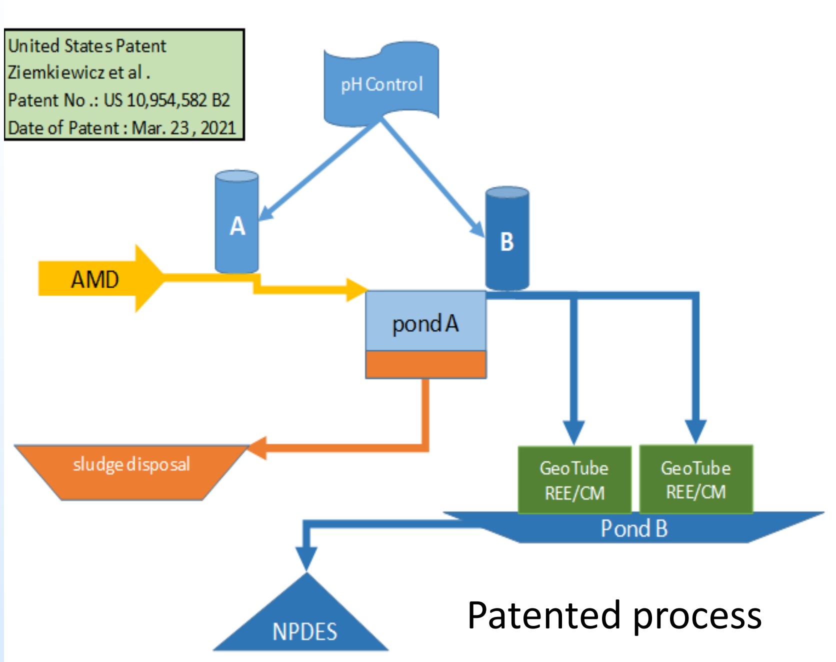
Confluence of Muddy Ck and Cheat River before and after completion of T&T plant

- Reductions in major metals
- pH increase
- Improvement in biological indictors (fish and macros)

Mine Mapping (coordination w/ WVGES)



REE/CM Production Technologies



Patented process

Active treatment

Passive treatment

Feedstock storage

Future CORE-CM Development

1. Continued partnerships with government agencies to find sources of REE/CM in other waste feeds

2. Continue to build partnerships with industry partners to find both sources of REE/CM and find environmentally benign solutions to treating waste streams

3. Scale up of AMD treatment to restore watersheds while **recovering REE/CM**

Summary

- Basinal assessment of CORE-CM resources.
- WVU Water Research Institute has begun the $500K extension to sample REE/CM in AMD-impacted watersheds of West Virginia.
- Using BIL funds via WVDEP, install multiple watershed restoration projects incorporating REE/CM recovery.

Questions?

Nate DePriest, WVWRI
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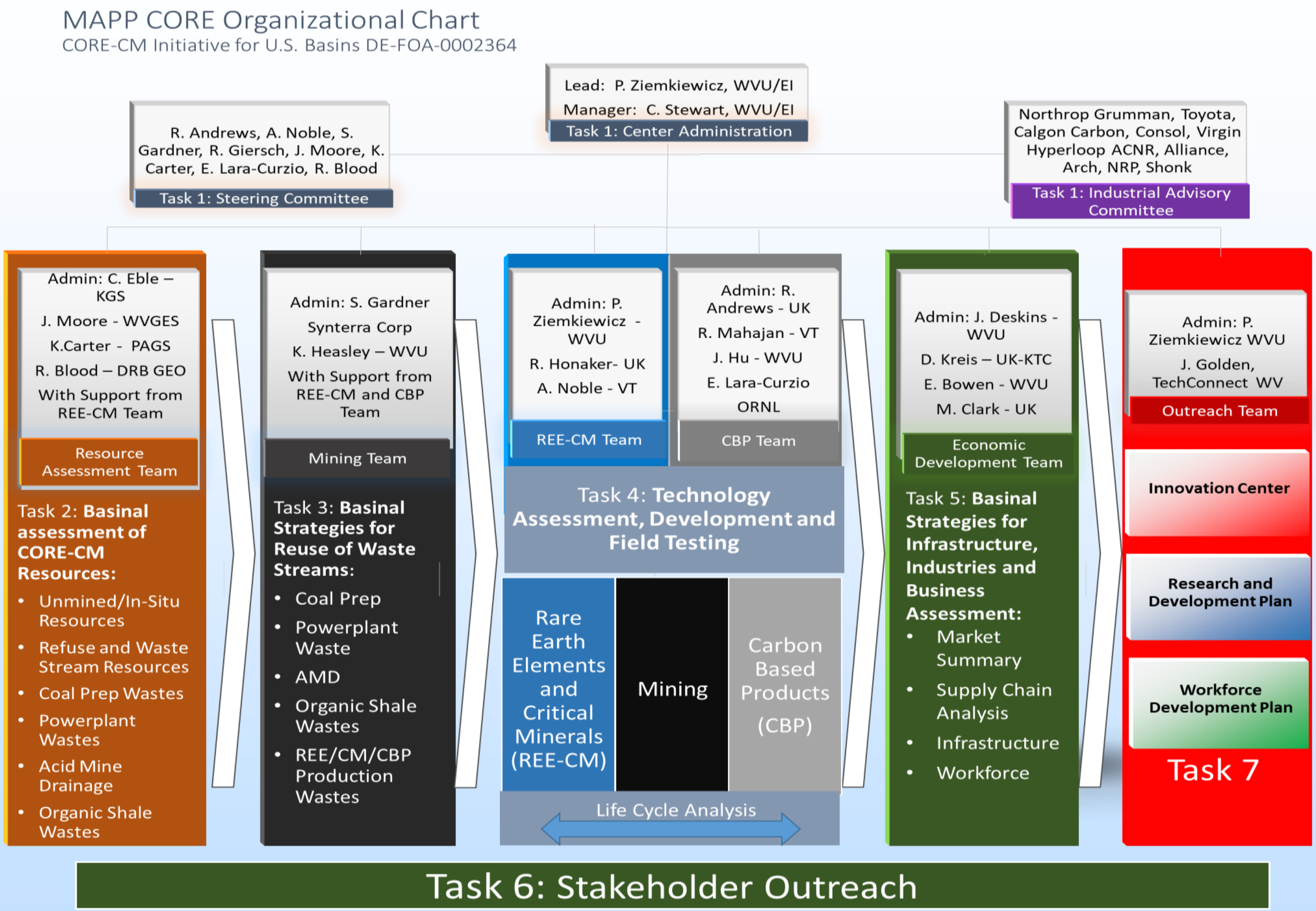
Appendix

Project Structure and Team



MAPP CORE Gantt Chart

TASK	ASSIGNED TO	PROGRESS	START	END
Task 1 - Project Management		100%	10/1/21	8/30/24
Task 2 - Basinal Assessment of CORE-CM resources				
2.1 - Unmined/In-Situ Resources (I.e. unmined seams)		100%	10/1/21	8/30/24
2.2 - Refuse and Waste Stream Resources		100%	10/1/21	8/30/24
2.2.1 - Coal Prep Wastes		100%	10/1/21	8/30/24
2.2.2 – Powerplant Wastes		100%	10/1/21	8/30/24
2.2.3 – Acid Mine Drainage		100%	10/1/21	8/30/24
2.2.4 – Organic Shale Wastes		100%	10/1/21	8/30/24
2.3 - Basinal Resource Assessment and Characterization and Data Acquisition F			10/1/21	8/30/24
Task 3 - Basinal Strategies for Reuse of Waste Streams				
3.1 Pre-Combustion Coal Refuse		100%	10/1/21	8/30/24
3.2 Low Flow Acid Mine Drainage		100%	10/1/21	8/30/24
3.3 Selective Mining and Sorting		100%	10/1/21	8/30/24
3.4 Fluidized Bed Combustion of Waste Coals		100%	10/1/21	8/30/24
3.5 - REE/CM/CBP Production Wastes		100%	10/1/21	8/30/24
3.6 - Waste Stream Reuse Plan		100%	10/1/21	8/30/24
3.X - CROSSCUT Task - TEA (Tasks 3.1, 3.2, 3.3, 3.4, 3.5)		100%	10/1/21	8/30/24
Task 4: Basinal Economic Assessment:				
4.1 - CORE-CM Market Summary - Industries and Products		100%	10/1/21	8/30/24
4.2 - Supply Chain Analysis		100%	10/1/21	8/30/24
4.3 – Infrastructure		100%	10/1/21	8/30/24
4.4 - Economic Impacts of CORE-CM Products		100%	10/1/21	8/30/24
4.5 - Data Check and Report Preparation – Basinal Strategies for I		100%	10/1/21	8/30/24
4.6 Summary of Environmental Justice Considerations		50%	10/1/21	8/30/24
Task 5: Technology Assessment, Development and Field Testing:				
5.1 Upstream Technology Development		100%	10/1/21	8/30/24
5.2 Downstream Technology Development		100%	10/1/21	8/30/24
5.3 - Data Check and Report Preparation - Technology Assessme		50%	10/1/21	8/30/24
5.4 - Sampling Extension		20%	10/1/21	8/30/24
Task 6 - Stakeholder Outreach				
6.1 Identify regional stakeholders		100%	10/1/21	8/30/24
6.2 Develop Plan for Outreach and Education		50%	10/1/21	8/30/24
Task 7 - Technology Innovation Center				
7.1 - Technology Innovation Center Plan		50%	10/1/21	8/30/24