

Critical Minerals from Waste Streams in the Powder River Basin of Wyoming and Montana, USA

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Energy Resources

Acknowledgement and disclaimer

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Critical Minerals

- A **critical mineral** is defined as:
 - a non-fuel mineral or mineral material essential to the economic and national security of the United States,
 - the supply chain of which is vulnerable to disruption,
 - that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economy or national security of the United States (Energy Act of 2020).
- In 2022, the US Geological Survey finalized a revised list of 50 critical minerals (Federal Register 2022-04027).

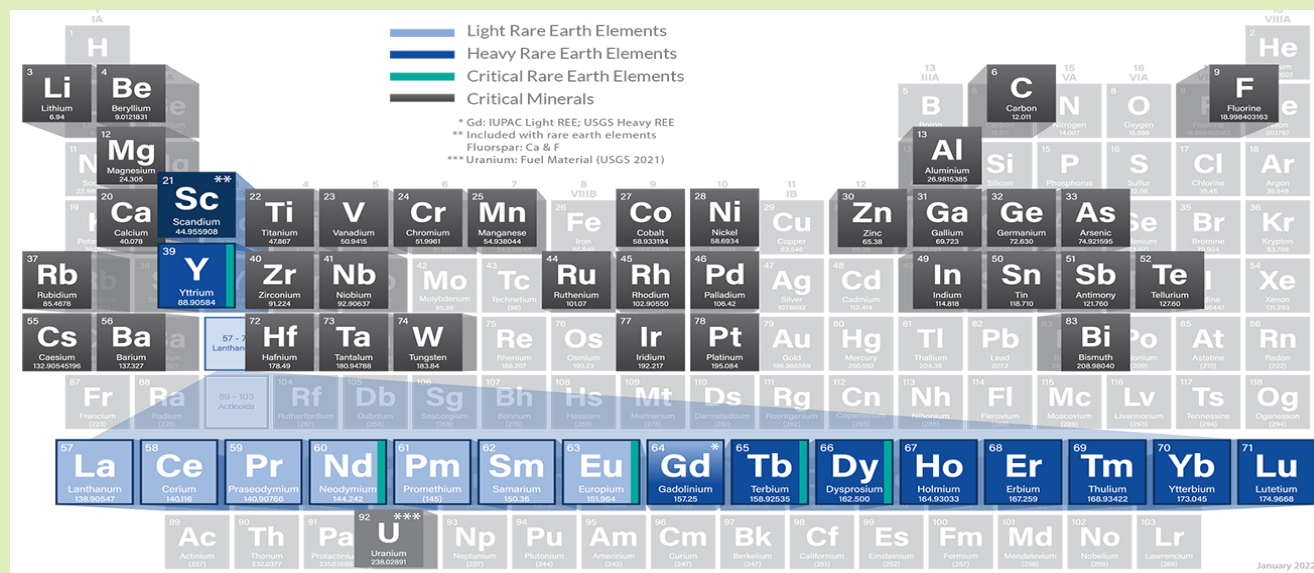
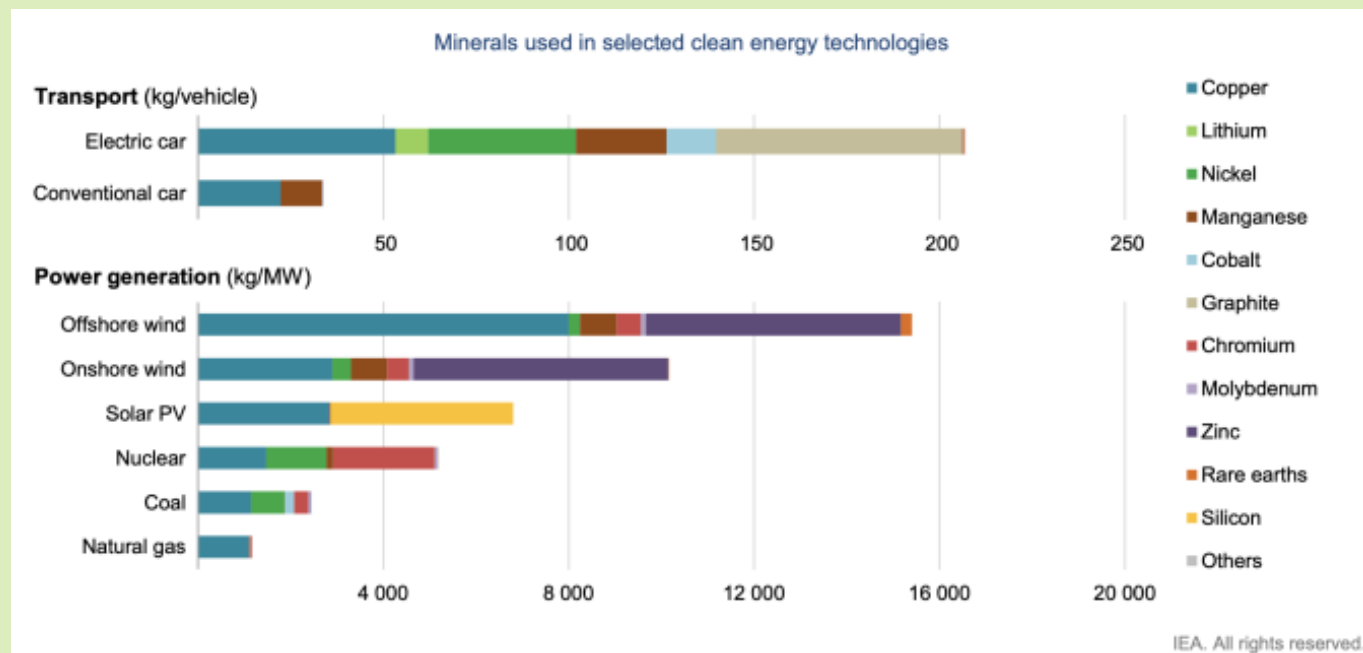


Image: U.S. DOE (2022)

Demand for critical minerals

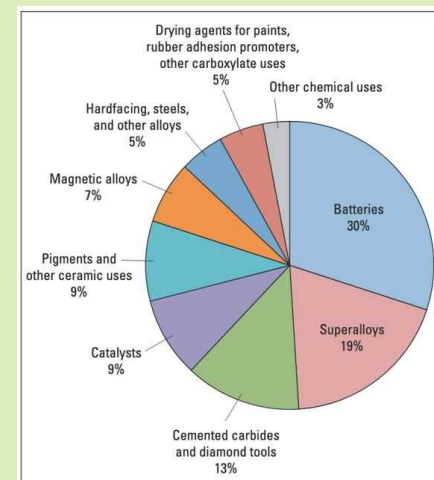
The shift away from fossil-based forms of energy toward low-carbon forms of energy is accompanied by an increase in demand for critical minerals.



World Energy Outlook Special Report, International Energy Agency, 2022



Illustration by Christine Reed



Schulz et al., 2017

The Critical Minerals Supply Chain

REE and CM Supply Chain and Extraction

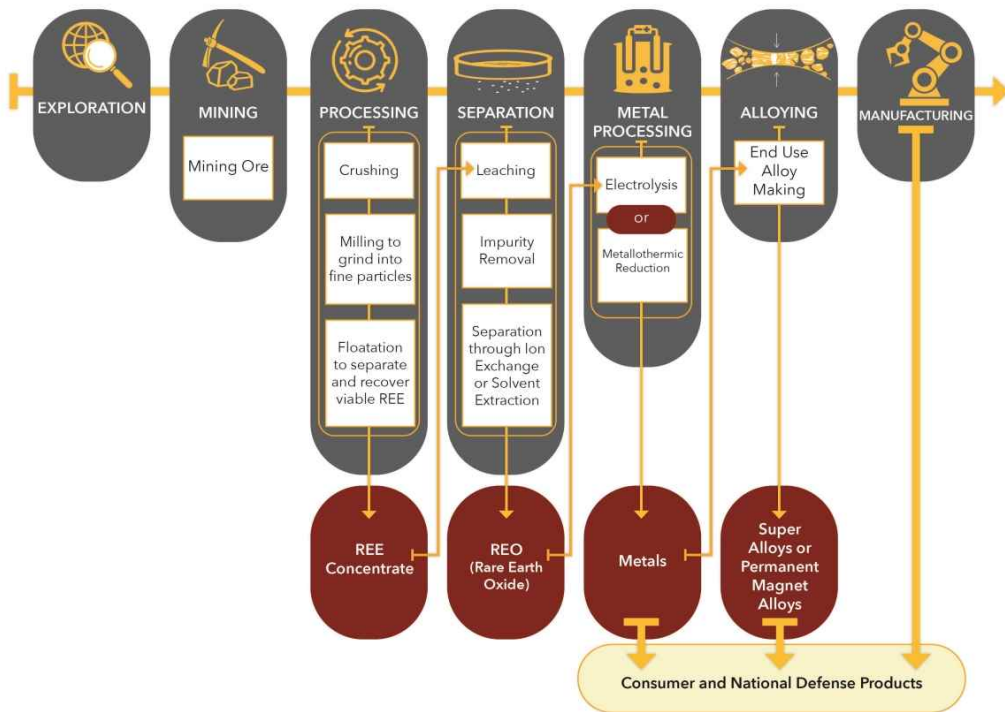
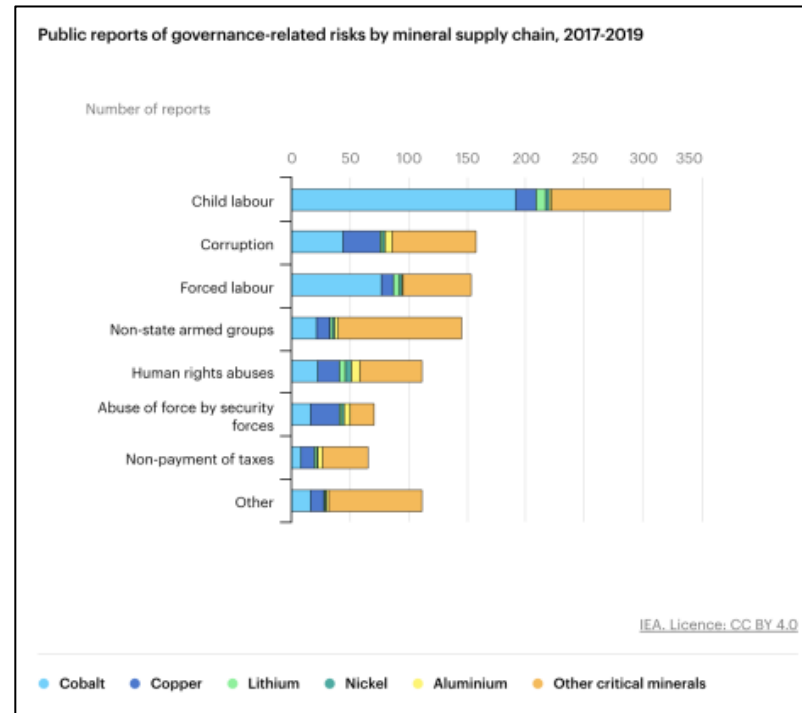


Illustration by Christine Reed



Source: IEA, Why is ESG so important to critical mineral supplies, and what can we do about it? (2022).

Critical Mineral Sources



**Hardrock
deposits**



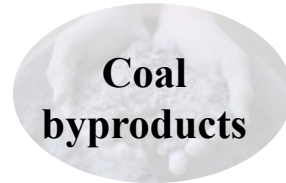
Coal



**Uranium
roll-front
deposits**



**Waste
streams**



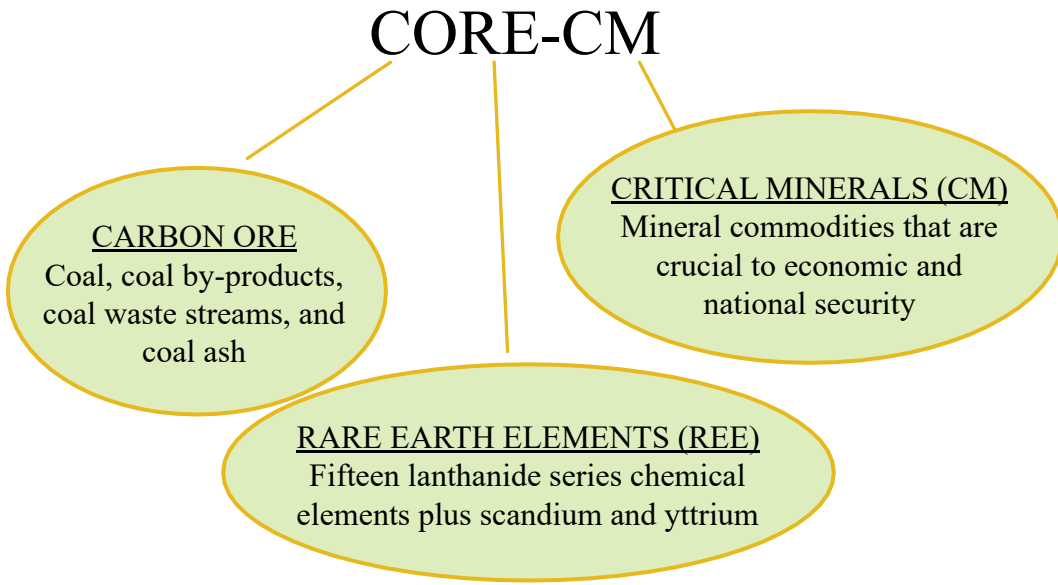
**Coal
byproducts**



**Legacy
mine tailings**

Objective: Identify how unconventional sources of critical minerals, such as existing waste streams, can help to build out an ethical domestic supply chain to address the growing need for critical minerals for low-carbon energy technologies and essential products.

The CORE-CM Initiative



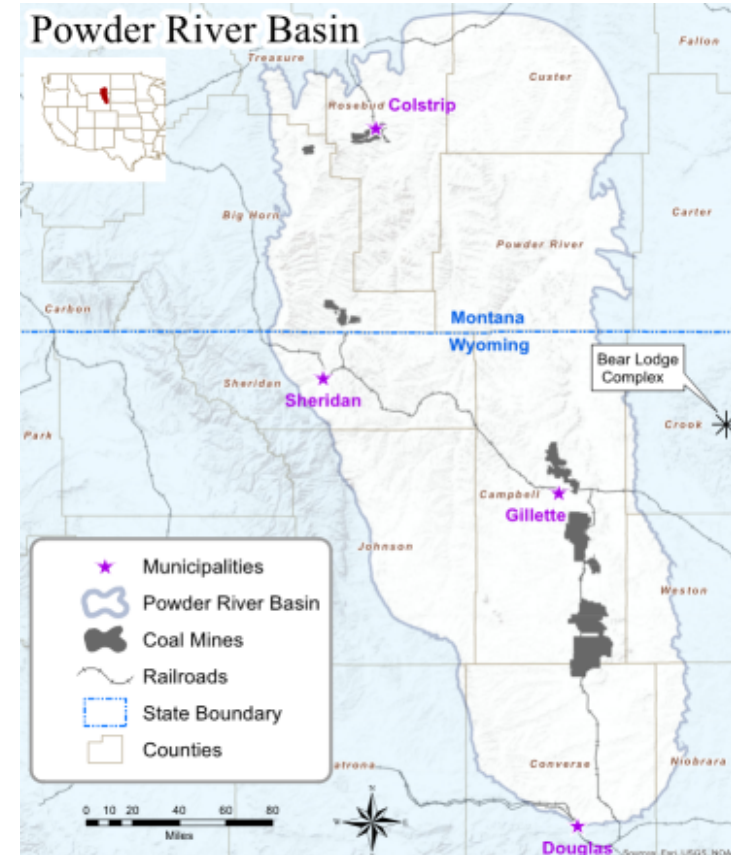
CORE-CM INITIATIVE



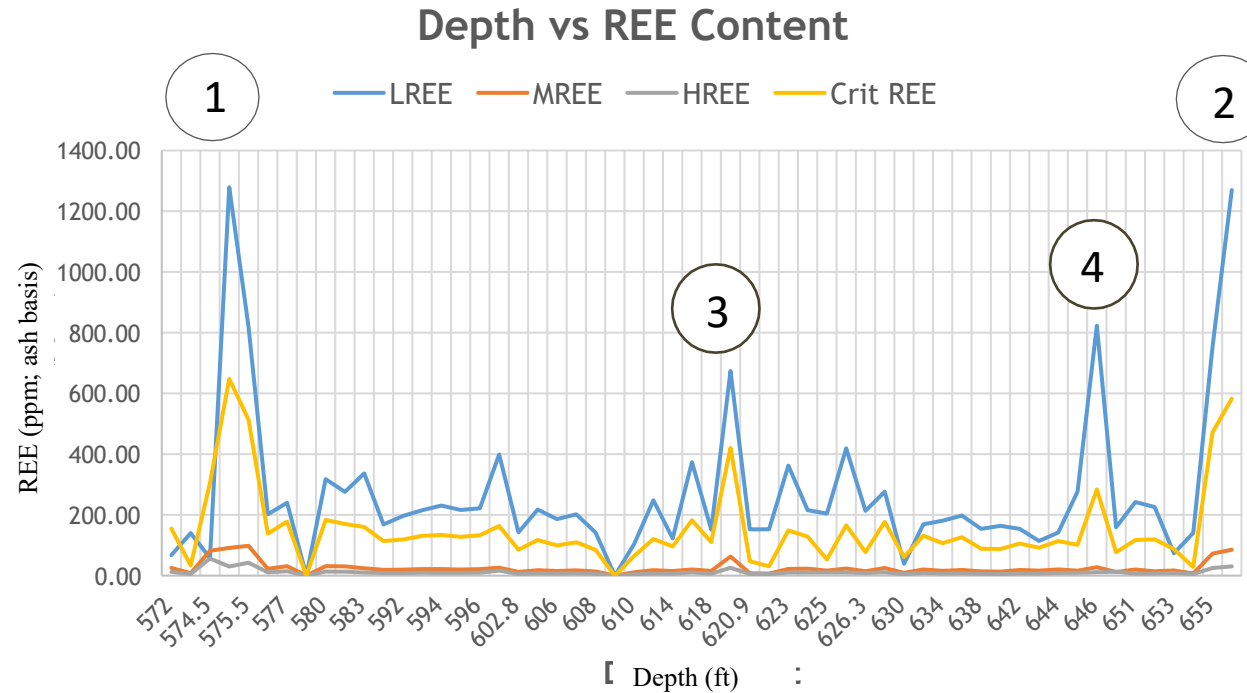
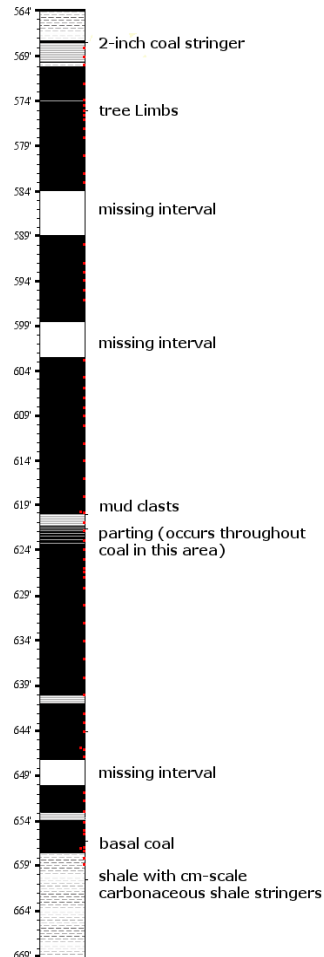
Powder River Basin CORE-CM: Advancing Strategies for Carbon Ore, Rare Earth Element, and Critical Mineral Resource Development in the Nation's Largest Coal Producing Basin

Focused on catalyzing basin-wide economic growth and job creation around all parts of the carbon ore, rare earth element, and critical mineral value chains.

- Resource assessment, geospatial database development, and preliminary geologic modeling
- Waste stream inventory
- Infrastructure, industry, and business inventory
- Technology assessment
- Stakeholder outreach, education, and workforce development



Rare Earth Elements in Powder River Basin Coal



Modified from Bagdonas et al., 2019

USGS Core E929

1 = Bounding enrichment at roof

2 = Bounding enrichment at floor

3 and 4 = Internal tonstein enrichments

Waste Stream Approach

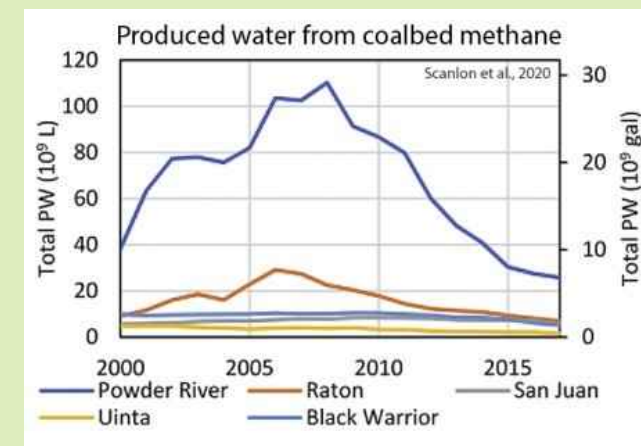
Activity/industry	Number of occurrences	Waste-Stream material(s)
Operating coal mines	16	Overburden and underburden; clinker
Coal power stations	9	Fly ash (9.8 mt of unused coal ash in the PRB*)
Uranium mining	6	Vanadium/lixiviant
Natural gas power stations	5	
Clay mining (bentonite)	4	
Oil, gas, coal bed methane operations	>160 operators	Produced water (373,962,369 Bbls in 2022#)
Petroleum refining	2	Process wastewater, ballast & cooling water
Natural gas separation/processing	1	
Legacy hard-rock mining	Unknown	Tailings piles



Extracting critical minerals from existing waste streams (e.g., coal ash, tailings piles)

Re-purposing waste from critical minerals processing (e.g., spent acids or solvents)

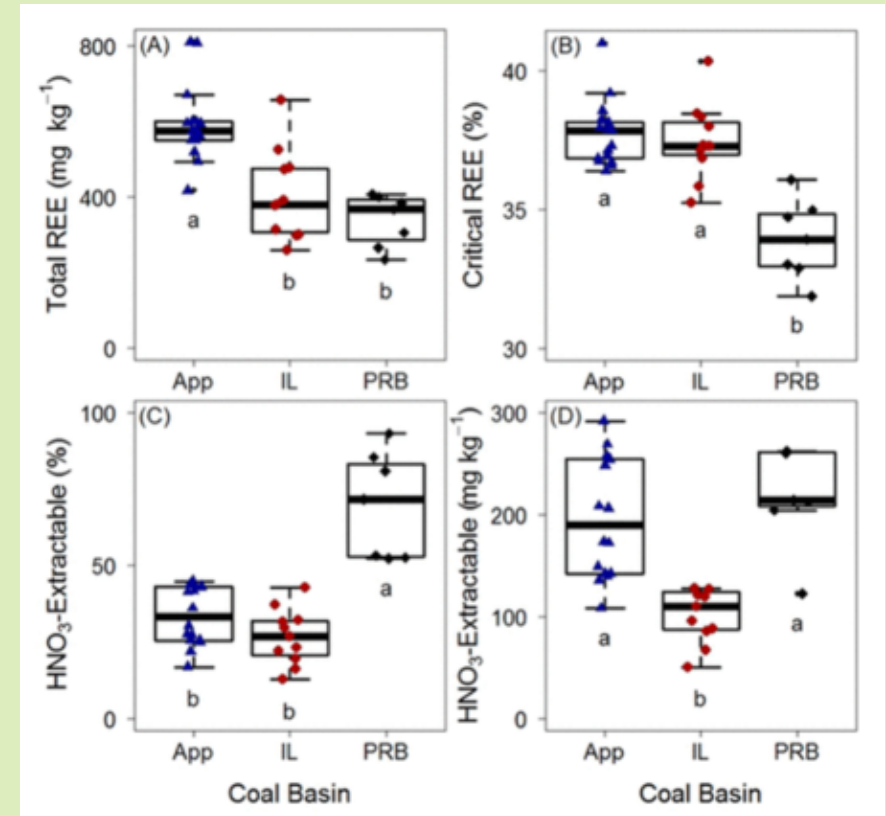
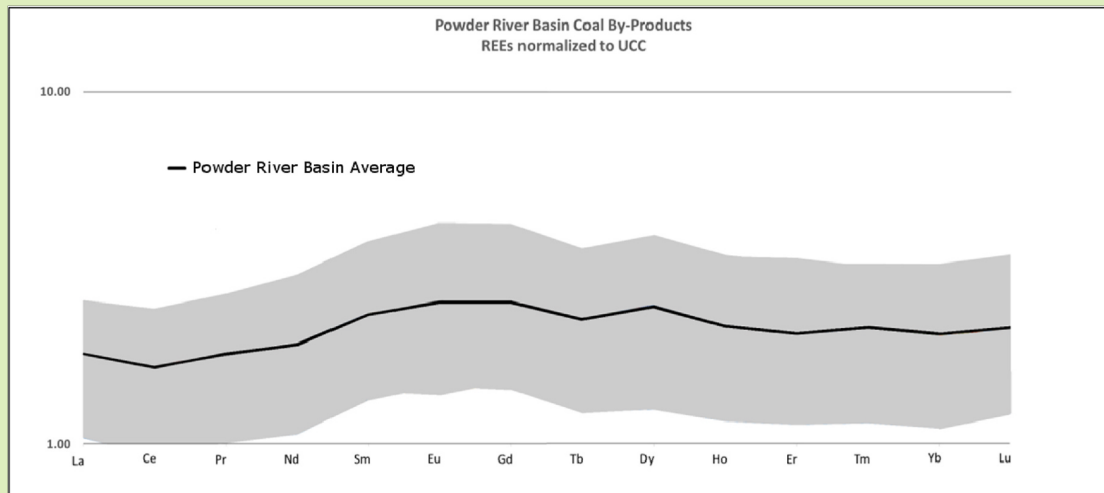
Utilizing existing waste streams in the critical mineral supply chain (e.g., oil and gas produced water)



*Taggart et al., 2016; #Wyoming Oil and Gas Commission

Rare Earth Elements in Powder River Basin Coal Ash

- Average rare earth element concentration of 317 ppm total REE+Y
- Critical REE (Nd, Eu, Tb, Dy, Er, Y) concentrations fall into “promising” category
- Calcium enriched PRB coals conducive to high recovery REE extraction



Taggart et al., 2016

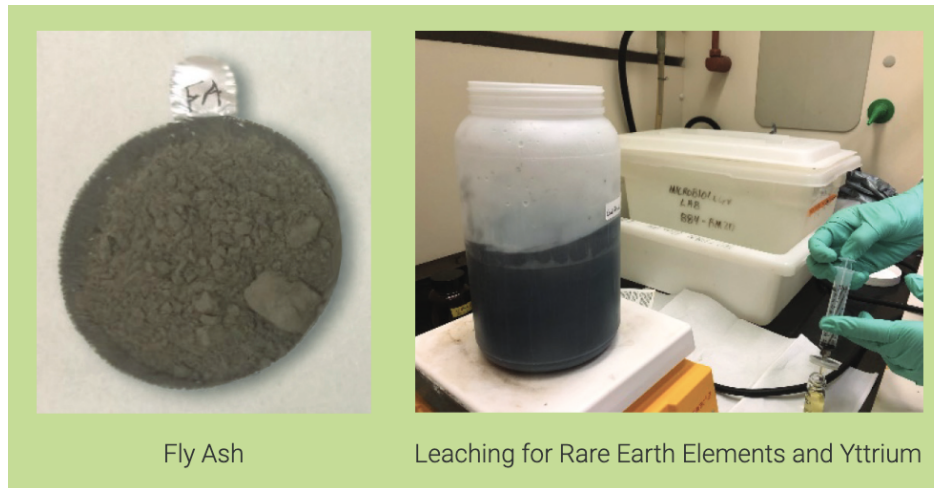
Rare Earth Element Extraction from Coal Ash

Department of Energy Technology Commercialization Fund (TCF-20-21358) - Pilot-scale rare earth element extraction from Powder River Basin coal ash

- Project led by the National Energy Technology Laboratory (NETL)
- Scale up of patent-pending rare earth element extraction technology from Ca-rich PRB coal, developed by NETL



The Wyoming Innovation Center, Energy Capital Economic Development in Gillette, Wyoming



Fly Ash

Leaching for Rare Earth Elements and Yttrium

Stuckman, M.Y., Lopano, C.L., and Tarka, T. (2021) U.S. Patent Pending, Serial No.: 63/053,925
<https://netl.doe.gov/node/10318>

Critical Minerals in a Circular Economy



Considerations

- An emerging industry – opportunity to build out an ethical domestic supply chain
- Necessity to address water-wise approaches, especially in the western U.S.
- Community engagement, especially in underserved communities
- Education and training, with a focus on quality jobs
- Exploring meaningful approaches to environmental and social justice

Thank you

Questions?

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