



U.S. DEPARTMENT OF  
**ENERGY**

Fossil Energy and  
Carbon Management

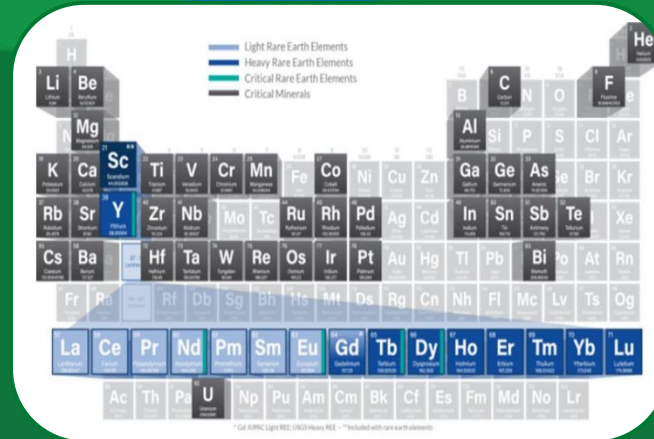
# DOE Minerals Sustainability

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Acting Director, Minerals Sustainability Division

## Tribal Clean Energy Summit

October 5, 2022



# Critical Minerals & Materials Supply Chain Challenge

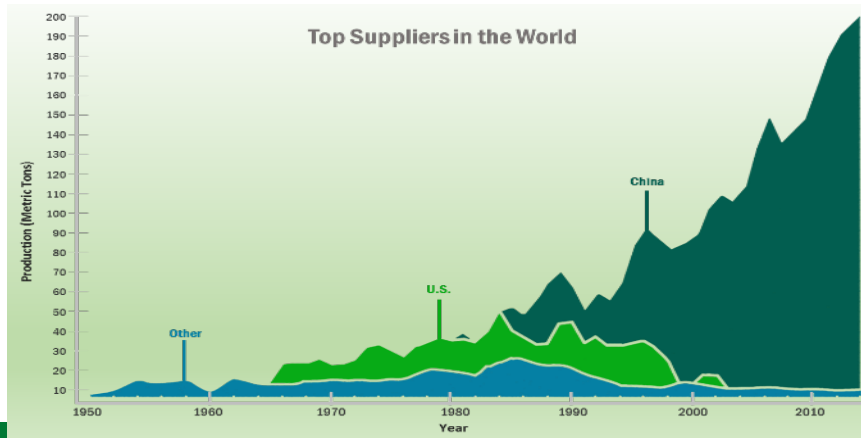


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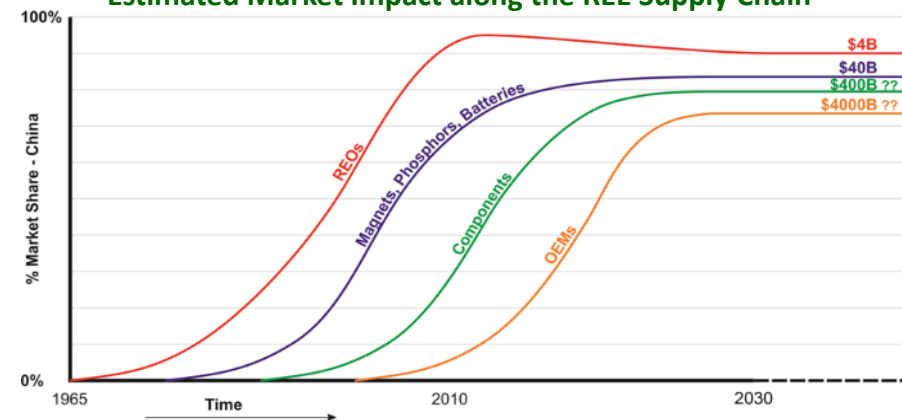
## Key Challenges

- U.S. supply dependence spans from limited imported sources to lack of downstream processing and manufacturing capability to end-of-life and waste management
- Supply chain vulnerability will be amplified by increased demand
- Commodity specific mitigation strategies are needed
- Global and domestic supply chains face many challenges, including sustainability, market issues, and financing

Rare Earth Production by Country



Estimated Market Impact along the REE Supply Chain



This figure is adapted from a presentation made by Professor K.G. van den Boogaart at the SME Critical Minerals Conference in Denver in August 2014.



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# Securing America's Clean Energy Supply Chains

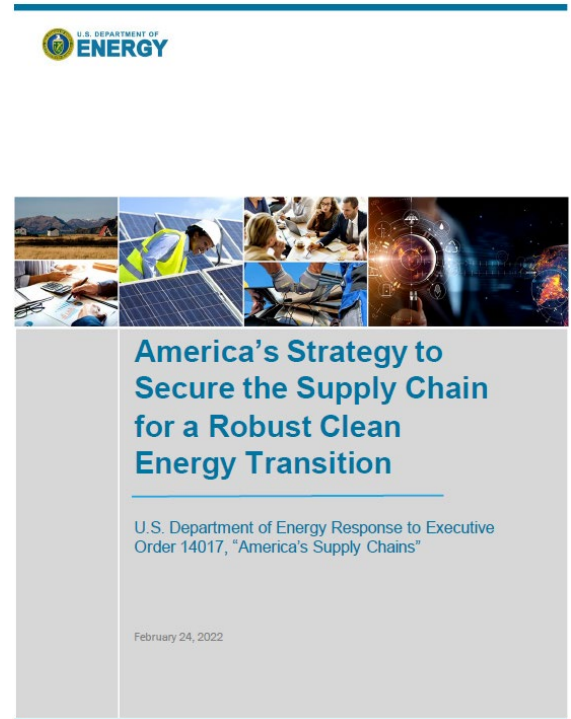
- DOE released **14 reports** on the energy sector supply chains, including 13 issue-specific deep dive assessments and an overarching strategy report
- “America’s Strategy to Secure the Supply Chain for a Robust Clean Energy Transition” is **the first-ever comprehensive U.S. government strategy** to secure our domestic energy supply chains and an Energy Industrial Base
- Lays out **dozens** of critical strategies and actions to build secure, resilient, and diverse domestic energy supply chains
- Part of a larger whole-of-government approach on supply chains

## Deep-Dive Assessment Report Topics

- Carbon capture materials
- Electric grid including transformers and high voltage direct current
- Energy storage
- Fuel cells and electrolyzers
- Hydropower including pumped storage hydropower
- Neodymium magnets
- Nuclear energy
- Platinum group metals and other catalysts
- Semiconductors
- Solar photovoltaics
- Wind
- Commercialization and competitiveness
- Cybersecurity and digital components

# Addressing Risks and Maximizing Opportunities

- Increase raw material availability
- Expand domestic manufacturing capabilities
- Diversify and secure foreign supply chains
- Create clear market signals to support deployment
- Improve end of life management
- Build the workforce to support energy transition
- Enhance data and analytical tools for supply chains
- Technology-specific risks (see individual reports)



## Core RDD&D Activities

Basic Science

Applied R&D

Demonstration

Deployment

### Diversify Supply

- Develop new sources (geosciences, mine tailings, ...)
- Improve extraction, separations, and processing
- Develop new uses for co-products

### Develop Substitutes

- Discover new magnet alloys, phosphors, catalysts
- New manufacturing methods
- Develop new components and systems

### Improve Recycling/Reuse

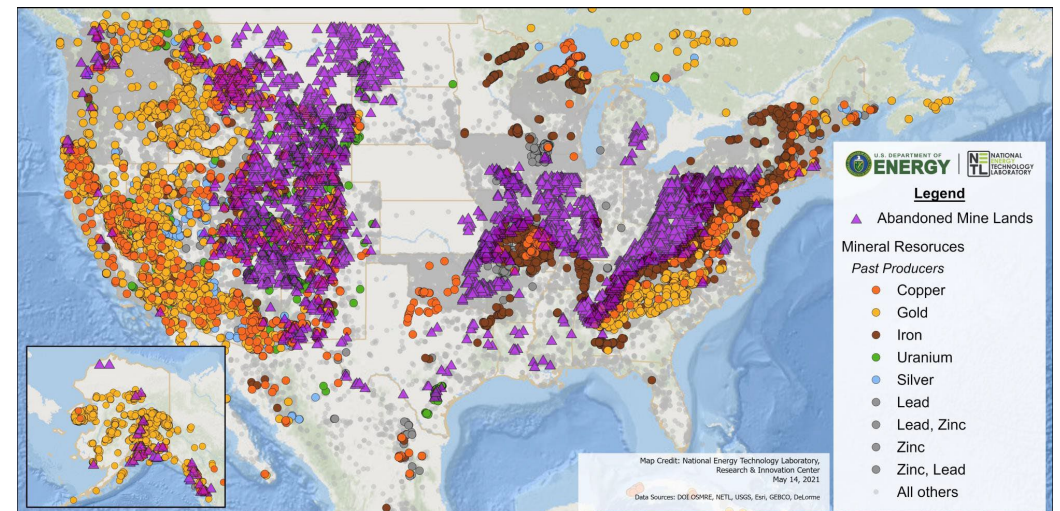
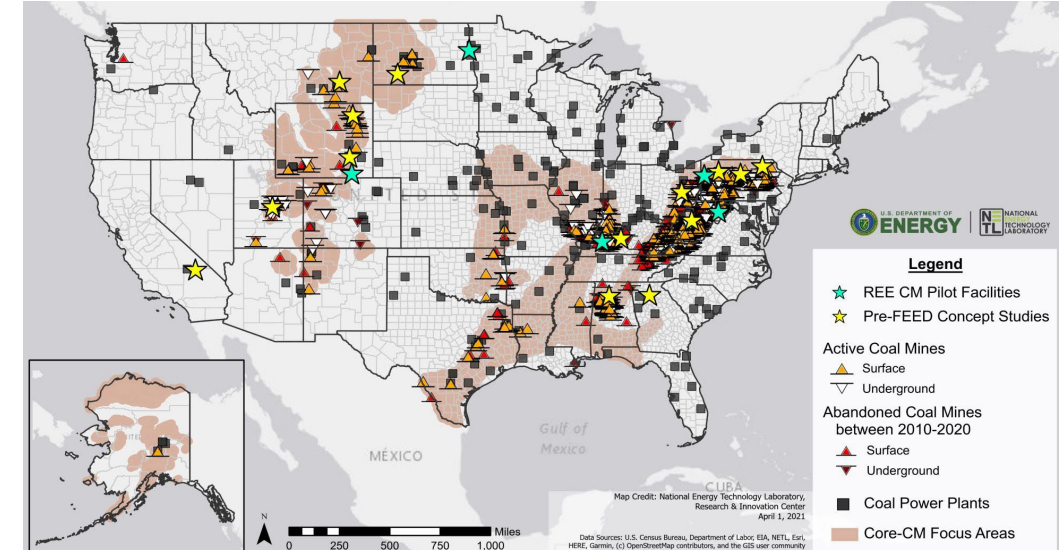
- Recovery from electronics, disk drives
- Chemical/biochemical extraction of critical elements from waste streams
- Additive manufacturing of recycled materials

### Financing

- Loan financing under Title XVII and ATVM (10 CFR 609 and 611; 86 FR 3747)
- Applicable to critical minerals and mining projects

# CM—Unconventional, Secondary Sources

- High-Level Resource Potential Estimates from coal-based resources
  - **11 - 17 million tonnes** REE from known coal reserves,
    - ~30,000t/yr based on current production
  - 68,000 t from Appalachia coal refuse
    - 12,300 t/yr REE (2018\*; 50% recovery), active refuse
  - 331,000 t from PA ash impoundments.
    - Over 10,000 t/yr REE (2018\*; 50% recovery), active ash
  - Between 400-1700 tons/yr REE (50% recovery), Appalachia AMD
- Opportunities to develop CM from metal mine wastes and sequester carbon

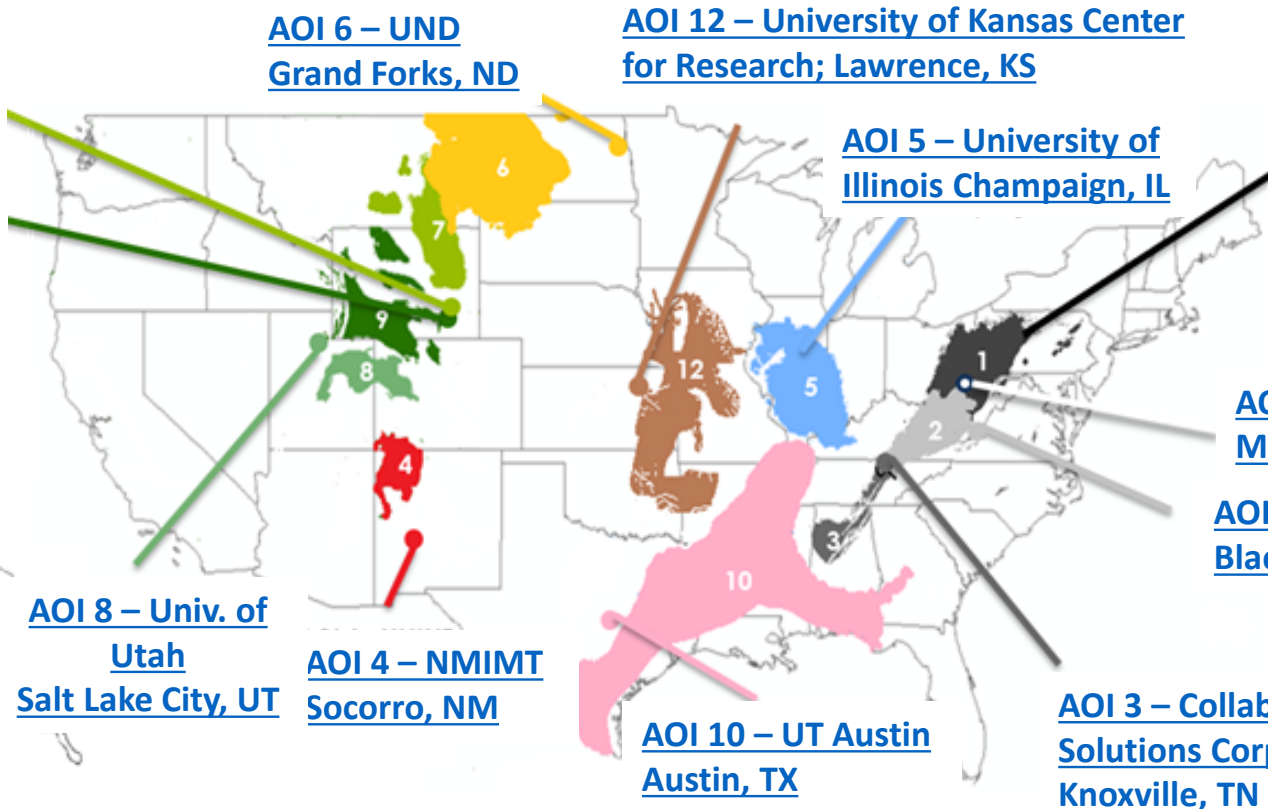


# CORE-CM Assessing Regional Opportunities

[AOI 7 – University of Wyoming; Laramie, WY](#)

[AOI 9 – University of Wyoming; Laramie, WY](#)

[AOI 11 – University of Alaska Fairbanks](#)



[AOI 6 – UND Grand Forks, ND](#)

[AOI 12 – University of Kansas Center for Research; Lawrence, KS](#)

[AOI 5 – University of Illinois Champaign, IL](#)

[AOI-1 PSU University Park, PA](#)

[AOI 8 – Univ. of Utah Salt Lake City, UT](#)

[AOI 4 – NMIMT Socorro, NM](#)

[AOI 10 – UT Austin Austin, TX](#)

[AOI 13 – WVU RC Morgantown](#)

[AOI 2 – Virginia Tech Blacksburg, VA](#)

[AOI 3 – Collaborative Composite Solutions Corporation Knoxville, TN](#)

- Build broad-based regional coalition teams, including Tribal Nations, local communities
- Investigate regional resources (materials, facilities, infrastructure, workforce), opportunities, and challenges
- Catalyze regional economic growth and job creation, while addressing legacy waste and environmental justice
- Enable production of REE, CM and high-value, nonfuel, carbon-based products

# DOE Investing in Technology Advancements

- **First-of-a-Kind small-scale projects demonstrated technical feasibility to produce high purity REE from dilute sources (e.g., coal, refuse, ash, AMD)**
- **Feasibility studies for large-scale pilot projects (1-3 metric tons/day CM-REE)**
  - integrate conventional with advanced separation technologies and novel techniques
  - economically recoverable and environmentally sustainable production of CM-REE
- **Advance novel extraction and separations technologies to improve cost and environmental performance**
- **See link for more information: [Critical Minerals Sustainability | netl.doe.gov](https://netl.doe.gov/CriticalMineralsSustainability)**





# Small scale REE/CM pilot facilities

*Pilot-Scale Facilities Producing High Purity MREO, CM (Co, Mn, Ni, Ga, Gd) from Domestic Coal-Based Sources*



- Separating MREO concentrate from **lignite**
- October 2021 pilot facility start-up

2018	2019	2020	2021
5 – 10 g	500 g	Under Construction	
5 – 15% purity	30 – 85% purity		



- Pilot plant produced > 1 kg mixed rare earth salts from **post combustion coal ash** in 2020

2018	2019	2020	2021
0.004 kg ≤ 10% purity	.057 kg ≤ 14% purity	0.41 kg ≤ 67% purity	0.67 kg ≤ 91% purity



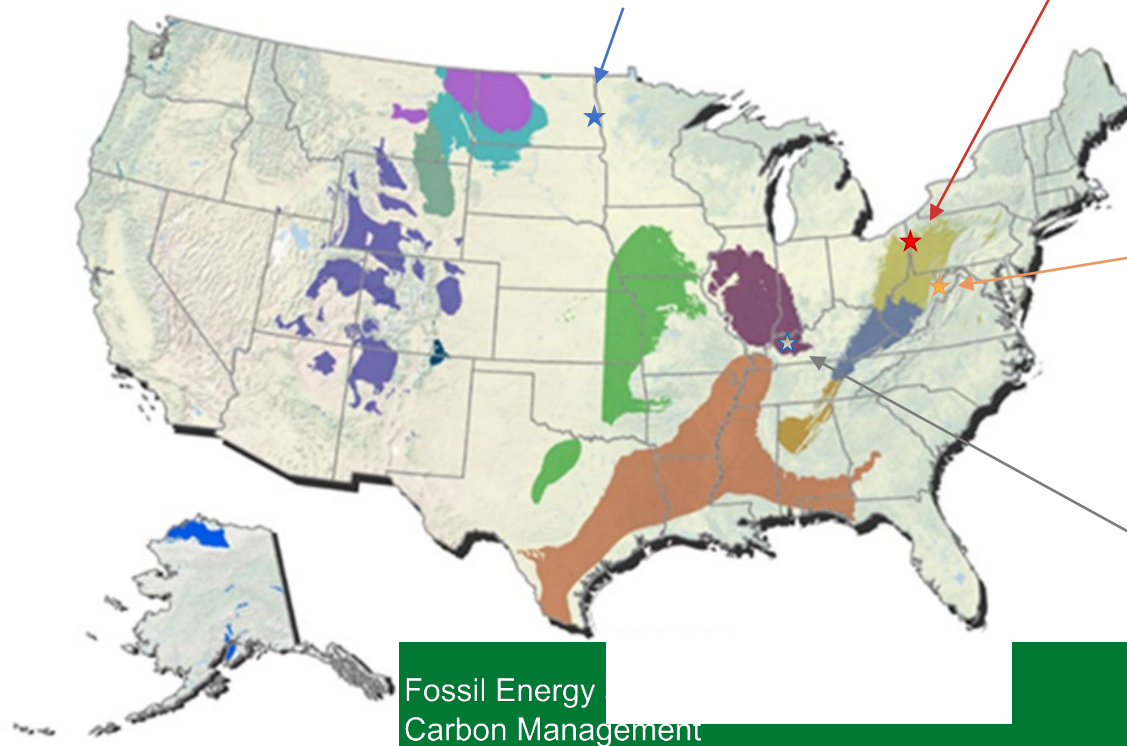
- Produced REE pre-concentrates from **AMD and sludge materials** with ~100% REE recovery, 45% is HREEs

2018	2019	2020	2021
44 g 95 – 99% purity		Field pilot Under Construction to start up January 2022	



- Produced quantities MREOs in its *modular* pilot-scale facility **from coal refuse materials**

2018	2019	2020	2021
0.6 kg 80% purity	1.5 kg > 90% purity	0.41 kg 98% purity	Pilot processing to begin in fall

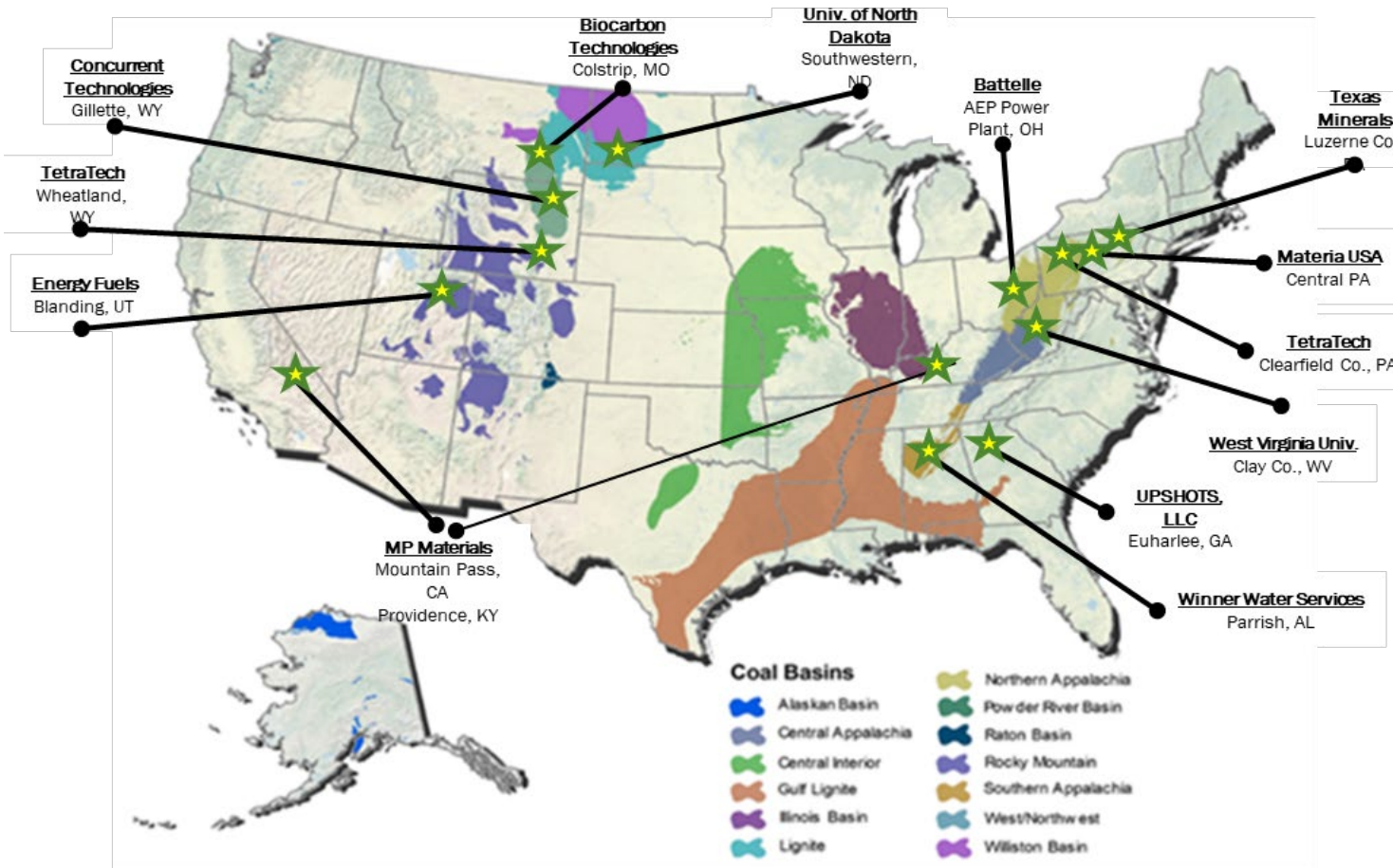


# Feasibility (Pre-FEED) Studies

*Large scale projects to produce 1-3 metric tons/day of mixed REO/RES and other critical minerals.*

*13 projects selected for the Concept Phase of the pre-FEED studies*

*8 projects were selected from concept phase to perform a more detailed pre-FEED study*



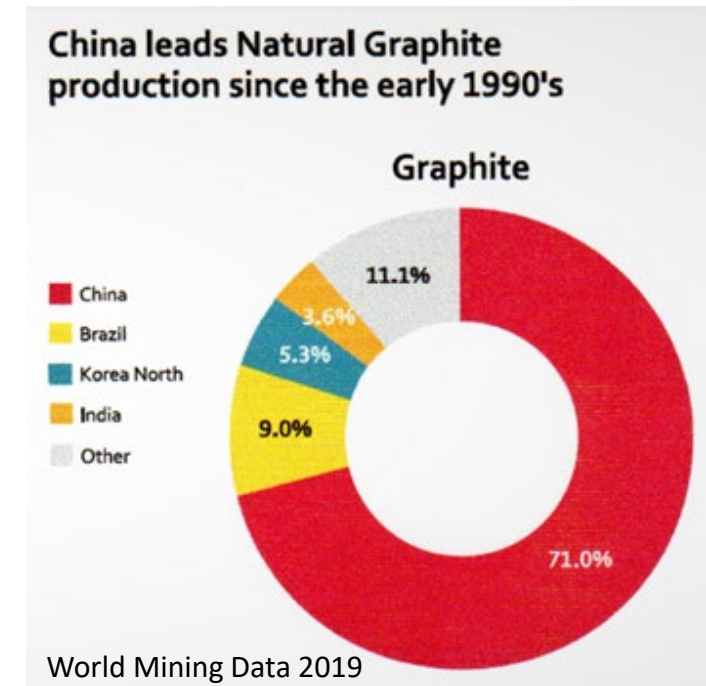
Contractor	Location
West Virginia University	Morgantown, WV
MP Mine Operations LLC	Mountain Pass, CA
Energy Fuels	Lakewood, CO
University of North Dakota	Grand Forks, ND
Winner Water Services	Sharon, PA
Tetra Tech – PA	Pittsburgh, PA
Texas Minerals Resource Corp	Sierra Blanca, TX
Materia USA LLC	Inwood, NY

# Graphite is critical to the future energy transition

*The U.S. imported 58,000 tons of natural graphite in 2019 – Predominantly from China*

World Mine Production & Reserves for U.S. & 4 Top Countries – Graphite (tons)			
	Mine Production		Reserves
	2018	2019	
U.S.	-----	-----	NA
China	693,000	700,000	73,000,000
Mozambique	104,000	100,000	25,000,000
Brazil	95,000	96,000	72,000,000
Madagascar	46,900	47,000	1,600,000
World Total (rounded)	1,120,000	1,100,000	300,000,000

<https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-graphite.pdf>



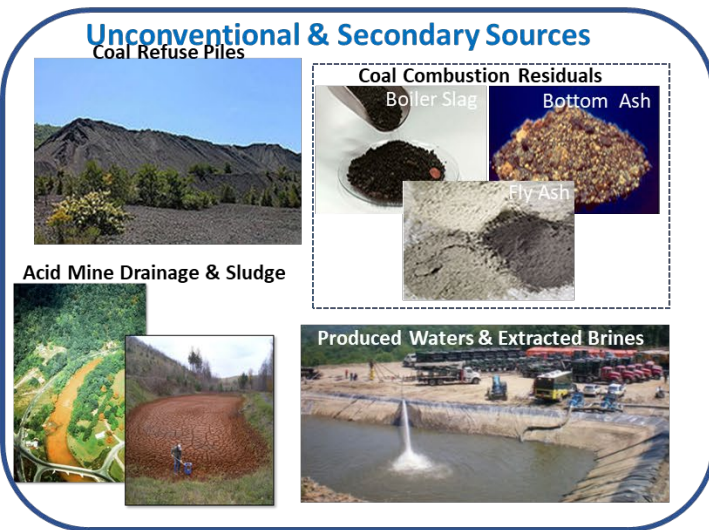
**3 billion tons of minerals and metals, including graphite, will be needed to deploy clean energy**

- Recycling and reuse is not be enough to meet the demand
- Production would need to ramp up more than 450% by 2050

# Waste Minimization and Circularity

Reclaiming, recycling  
waste materials

Maximizing use of  
feedstock materials



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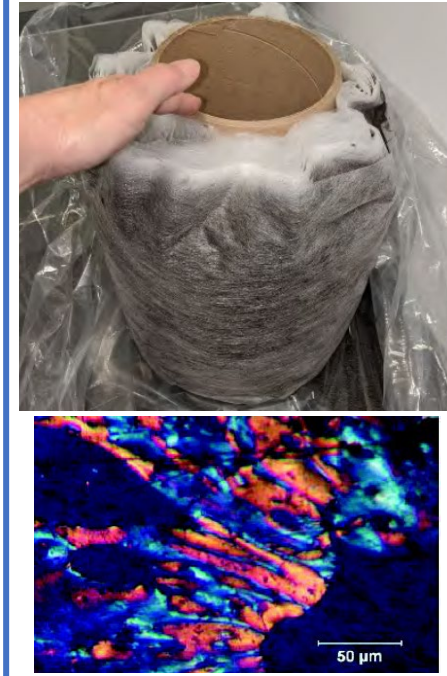
# Carbon Ore Processing Opportunities

Advanced processing of carbon ore for the development of high value carbon products

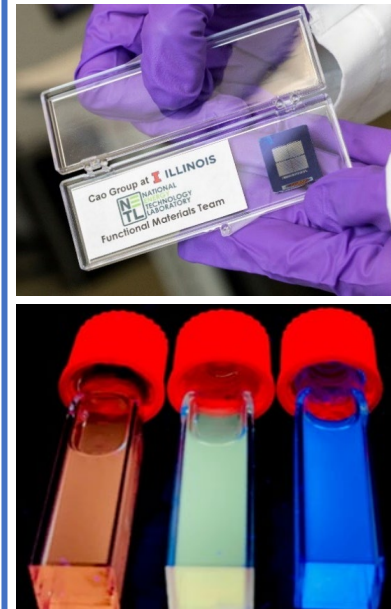
## Next-Gen Construction & Infrastructure Materials



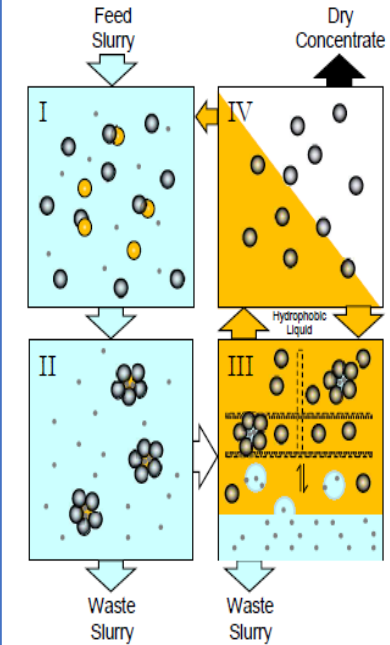
## Carbon Fibers from Coal Tar Pitch



## Nanomaterials



## Waste Recovery



- Generated predominantly from *coal waste and refuse*– toward remediation
- Enable domestic manufacturing of strategic materials to encourage job creation
- Ensure the health and safety of the environment and people around the use and disposal of carbon-based products

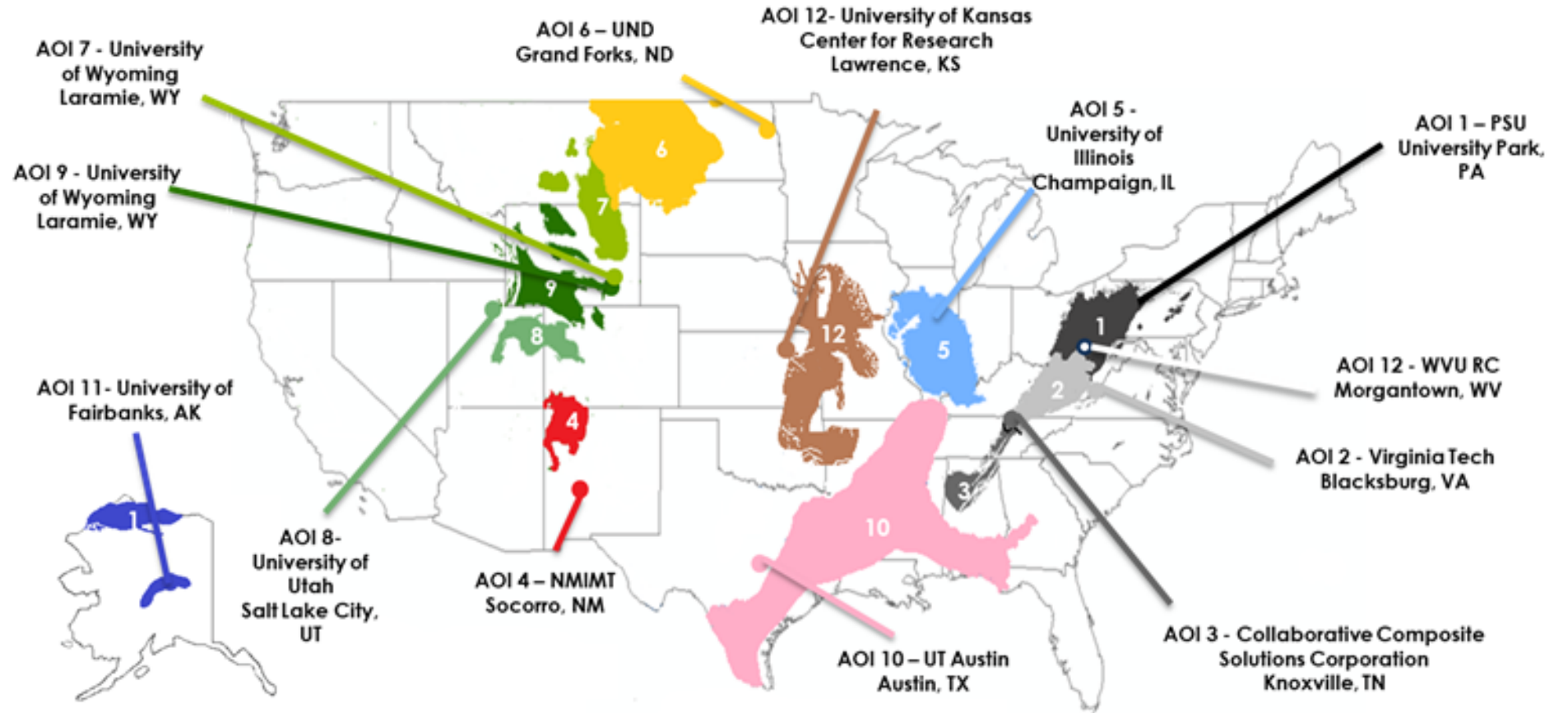


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# Opportunities for Technical Assistance

- CORE-CM Initiative
- LEAP programs



# MSD-Related BIL provisions

FECM-responsible, Critical Material-related (~\$1B)

- 40205 (c) – REE Demonstration Facility **FOA released 9/19**
- 41003 (b) – Rare Earth Minerals Security
- 41003 (c) – Critical Material Innovation, Efficiency, and Alternatives **RFI closed 9/09**
- 41003 (d) – Critical Material Supply Chain Research Facility

Battery-specific (\$3B)

- 40207(b) – Battery Materials Processing Grants **(First set of FOAs returned)**

Mining-specific (unfunded so far)

- 40210 – Critical Minerals Mining and Recycling Research **(nominally \$400M)**

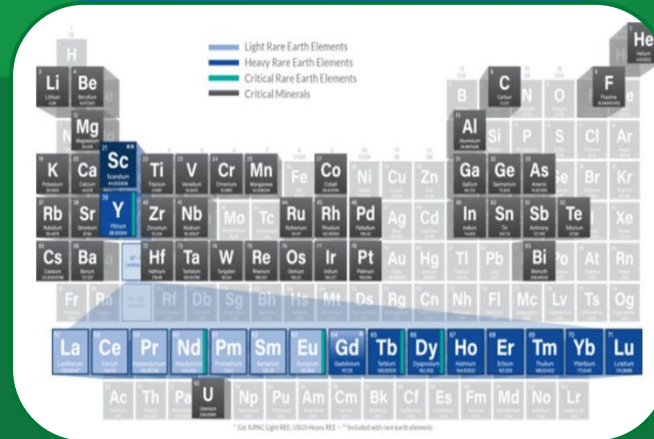
REE Demo FOA: : [Funding Notice: Bipartisan Infrastructure Law - Rare Earth Element Demonstration Facility | Department of Energy](#)



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# Questions?





**Responsible stewardship of critical materials is a domestic and international issue requiring high environmental standards across the entire supply chain**

DOE engages in ISO efforts to improve sustainability in global critical material supply chains

- ISO TC 298 Rare Earth Elements
  - U.S. proposed developing a sustainability standards for rare earth mining, separation and processing to include environmental, economical and societal impacts
  - Working Group 5 has been established specifically for sustainability, and will be beginning work soon
- ISO TC 333 Lithium
  - New technical committee that is still developing strategic business plan, but is meant to include the full supply chain, excluding LIB as end products
  - Sustainability proposal put forth by the U.S. and is currently posted for a 12-week ballot

OSTP NSTC CMS, International Bilaterals/Trilateral interactions are opportunities to coordinate responsible development of supply chains