U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

DOE's Minerals Sustainability

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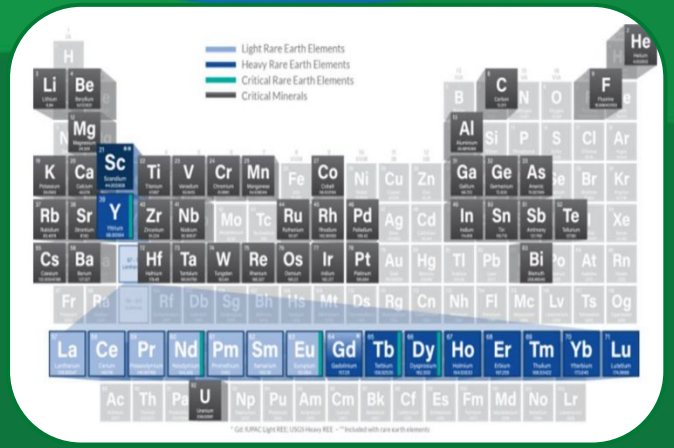


Critical Minerals & Materials (CMM) Vision & Strategy

Vision:

- Build reliable, resilient, affordable, diverse, sustainable, and secure **domestic critical mineral and materials supply networks**.
- Support the clean energy transition and decarbonization of the energy, manufacturing, and transportation economies.
- Promote safe, sustainable, economic, and environmentally just solutions to meet current and future needs.

CMM Strategies:

https://www.energy.gov/critical-minerals-materials

Critical Materials Collaborative (CMC) helps coordinate efforts

CMC Mission

Building a robust **innovation ecosystem**

Training the critical materials leaders and workforce across multiple sectors

Enabling **industry adoption** of novel, cutting-edge technology

Laying the **scientific and technological groundwork** needed to address emerging challenges

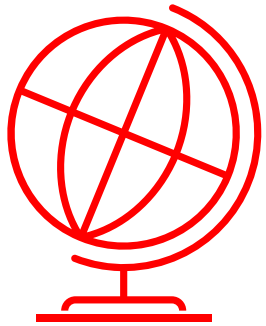
Four Main Sources for Supply Diversification

Recycling

Secondary & Unconventional Feedstocks

Minerals Sustainability Focus

New Domestic Mining



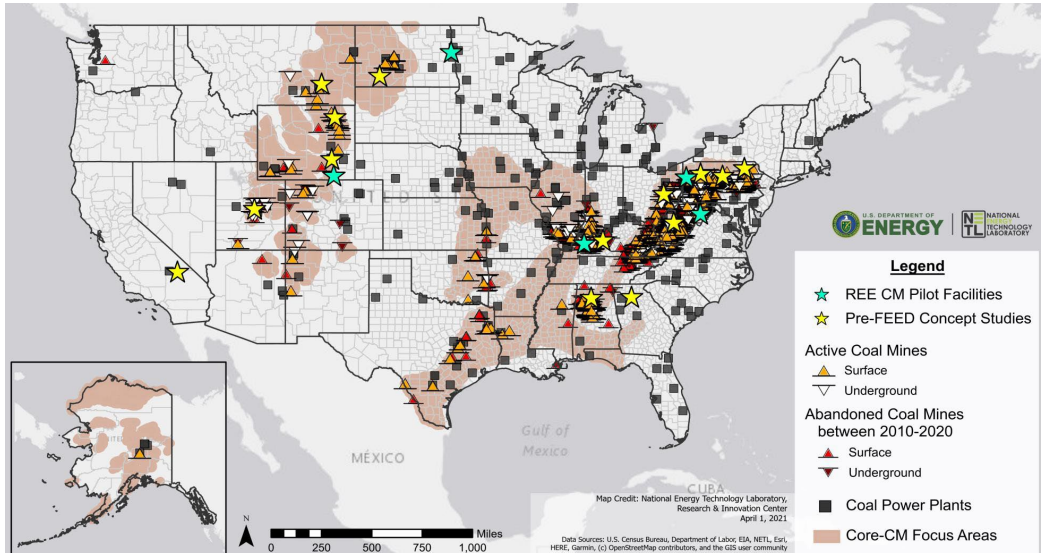
International Sources

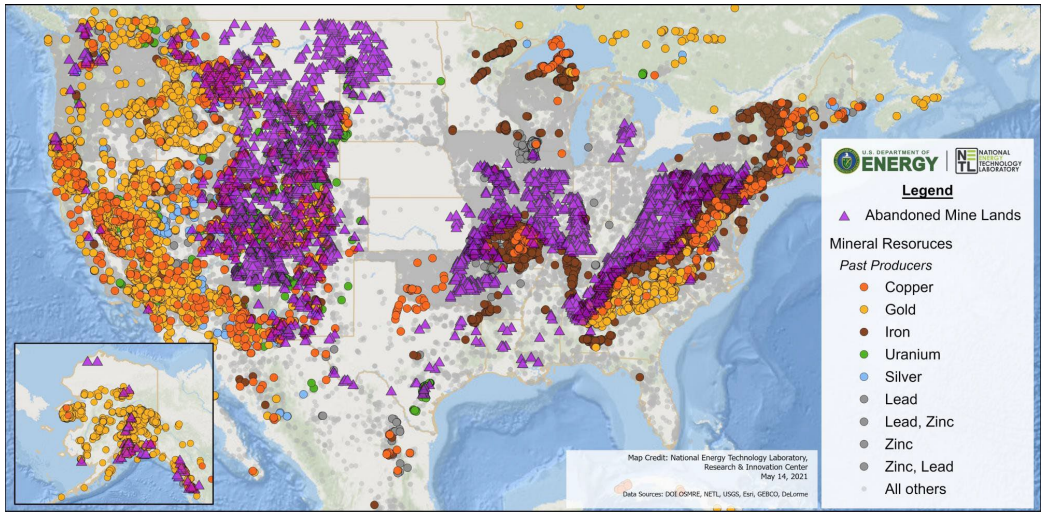
Program Goals

- By 2035, enable unconventional and secondary sourcing for half of domestic rare earth element (REE) needs
  - *Demonstrate **sufficient resources** usable from domestic unconventional (e.g., coal-based, AMD, produced water) feedstocks*
  - *Generate a National Prospectus for REE and other critical minerals*
    - *Regional resource assessments*
    - *Standardize approaches*
    - *Best practices*
  - Demonstrate economically competitive and environmentally **sustainable extraction and processing technologies**
  - Support development of **sustainable international standards** for supply chains
- Develop technologies for value-added carbon products
  - Energy materials
  - High value carbon products
  - High volume carbon products

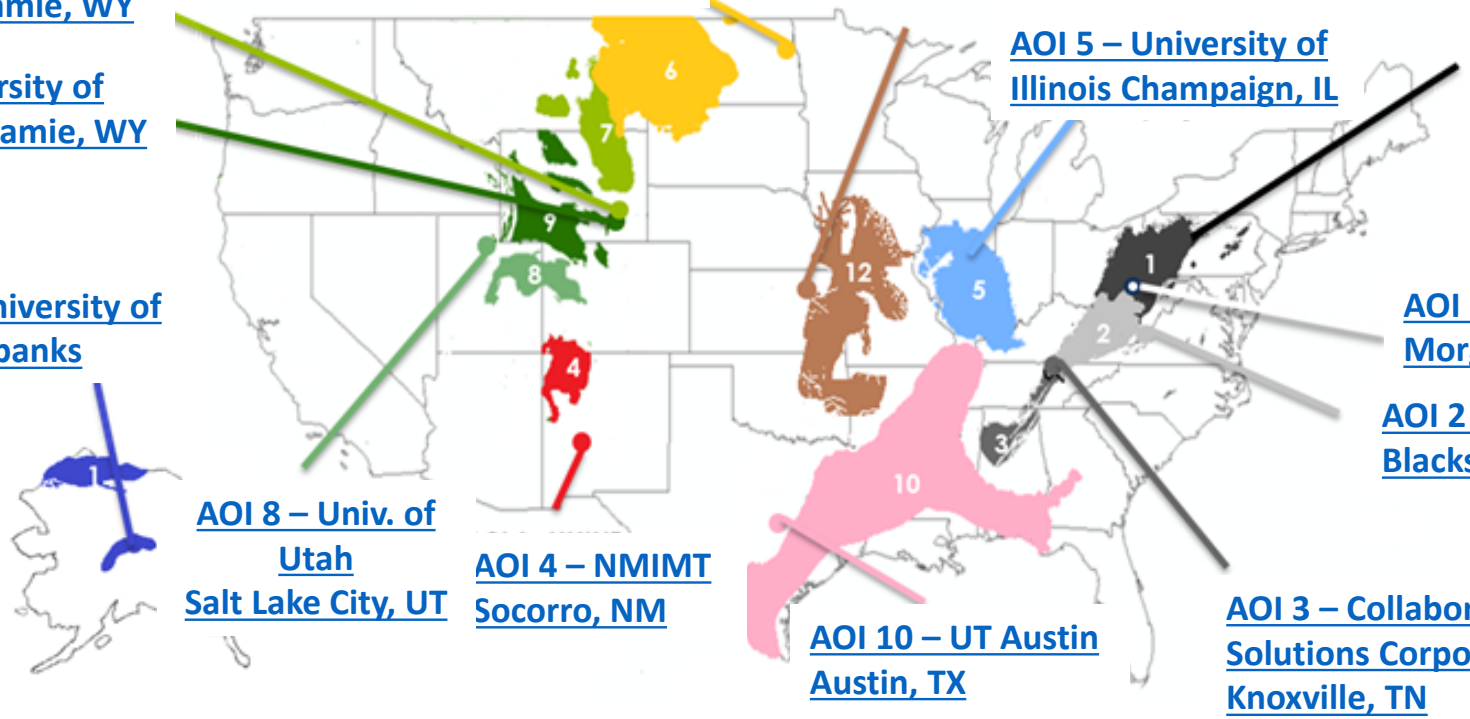
High-level Estimates from Unconventional, Secondary Sources

- **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
- **Additional opportunities from produced water, phosphate sludge, metal mine wastes, etc.**





CORE-CM: Developing National Prospectus by Assessing Regional Opportunities



- 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

Critical Minerals Processing Development (2014-2023)

PROSPECTING

PROCESSING

PRODUCTION

Coal Refuse

AMD

Fly Ash

TRL 3-5

2016: FOA-1202
Conventional REE Separation & Recovery – 80-90% Purity

2016: RFP 9067 & 2017: RFP 10982
Field Prospecting

2017: FOA-1718
Transformational Separation

TRL 5-7

2019: 3 First-of-a-Kind Bench & Small Pilot-Scale REE Facilities

2020: FOA-2003
REE System Optimization & Efficiency Improvements – CM Production

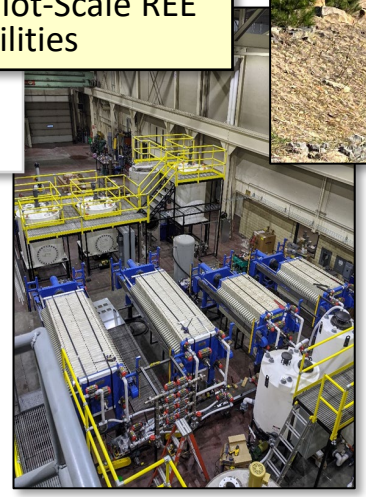
2020 & 2021: RFP
Concept & Feasibility Studies

2021: FOA-2346
CORE-CM Phase 1

2021: FOA-2404
Advanced Processing Phase 1

TRL 5-7

2021 & 2022: 2 Additional First-of-a-Kind Small Pilot-Scale REE & CM Facilities



Lignite

AMD

2023: FOA-2618
REE Demonstration Facility (Phase 1)

TRL 7-8

2027-2028: First-of-a-Kind REE Demonstration Facility

1,000 tonnes MREO/yr & CMM through Metals Refining

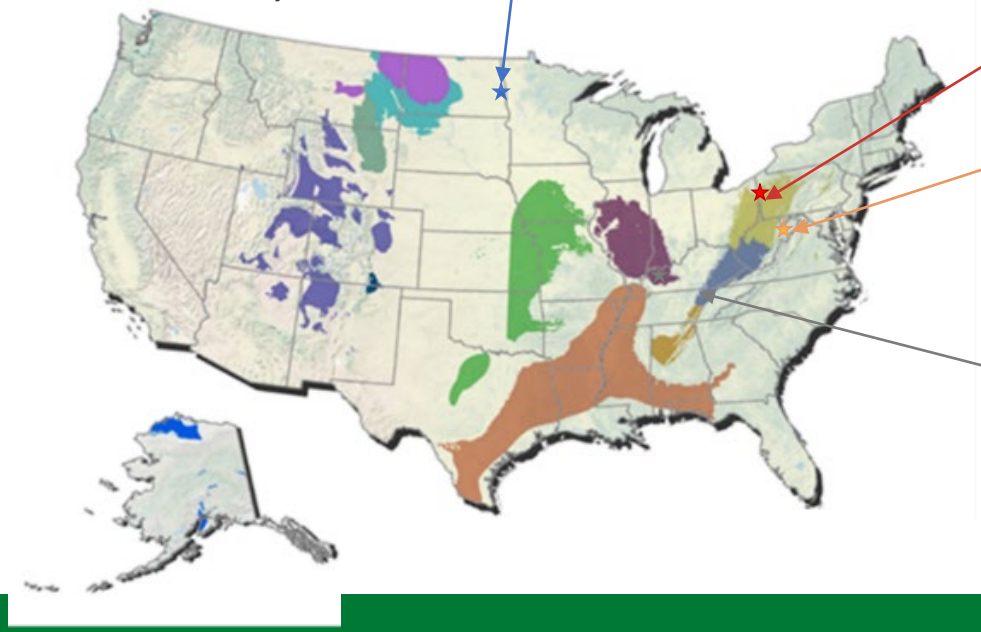
2015 2020 2025

Small-Scale Pilot Facilities

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

- *Location*: Grand Forks, ND
- *Feedstock*: Lignite
- *Operation Period*: Not yet in operation, Period of Performance ends 06/30/2024
- *Production rate of highest grade/purity*: 140 g/week (85% REO; 88% REO/CM)*
- *Separation Beyond MREO/MRES*: Planned, but not yet achieved.
- *CMM Produced*: Ge (60% by weight) – Planning for Ga

** Data from bench-scale system*



- *Location*: Lexington, KY (Physical Separation); Sharon, PA (Chemical Processing)
- *Feedstock*: Post-combustion fly ash from two KY power plants
- *Operation Period*: November 2019 – March 2022
- *Production of highest grade/purity*: 16 g >90% REY oxide, 22 g of >85% REY oxide
- Separation Beyond MREO/MRES: Sc, Al only
- *CMM Produced*: 1 g Sc salt (>85%), 101 g Al (>70% oxide)

- *Location*: Mt. Storm, WV
- *Feedstock*: Acid Mine Drainage
- *Operation Period*: October 2022 – September 30, 2023
- *Production rate of highest grade/purity*: 82 g MREO/hr, 2.8 kg 95% LREO, 2.5 kg 65% HREO
- Separation Beyond MREO/MRES: Partially
- *CMM Produced*: Ni+Co, Mn, Zn

- *Location*: Webster County, KY
- *Feedstock*: Course Refuse and Lignite
- *Operation Period*: July 2021 – July 2022
- *Production of highest grade/purity*: 0.72 kg >80% REO (with coal refuse)
- Separation Beyond MREO/MRES: N/A
- *CMM Produced*: 0.3 kg (8% Co, 30% Ni); 0.27 kg (22% Mn)

BIL--Rare Earth Element Demonstration Facility ($140M)

Phase 1 Awards

Start: Summer 2023. Duration: 18 month
Includes: FEED studies, NEPA, community engagement
Feedstock types: coal mine waste, acid mine drainage

1) Recovery and Refining of Rare Earth Elements from Lignite Mine Wastes — University of North Dakota (Grand Forks, North Dakota)

2) AMDREE: Integrated Treatment of Acid Mine Drainage and Rare Earth, Critical Materials Production — West Virginia University (Morgantown, West Virginia)

Phase 2: Construction of Demonstration Facility

350-1,000 tonnes MREO/yr & CM through Metals Refining

Standards Development/Engagement

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

FECM/MSD engages in ISO efforts to improve sustainability in global CM 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

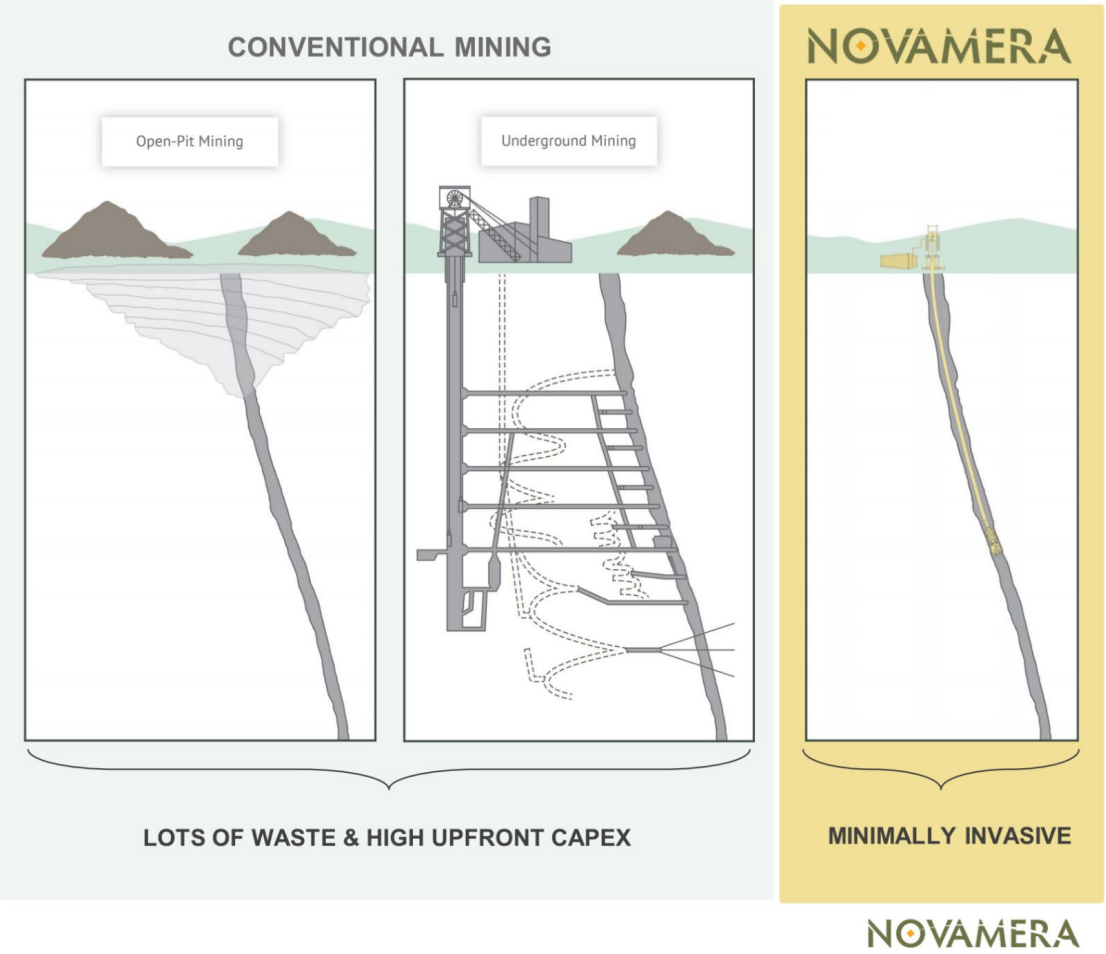
Working with EPA on certification standards for federal procurement

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

Future Mining RDD&D for precision extraction

Opportunity to capitalize on recent efforts to revolutionize mining technology

- Take a “surgical” approach
  - No removal of overburden
  - No big hole to be filled
  - No workers underground
  - Minimized impact on water (aquifers, rivers, streams)

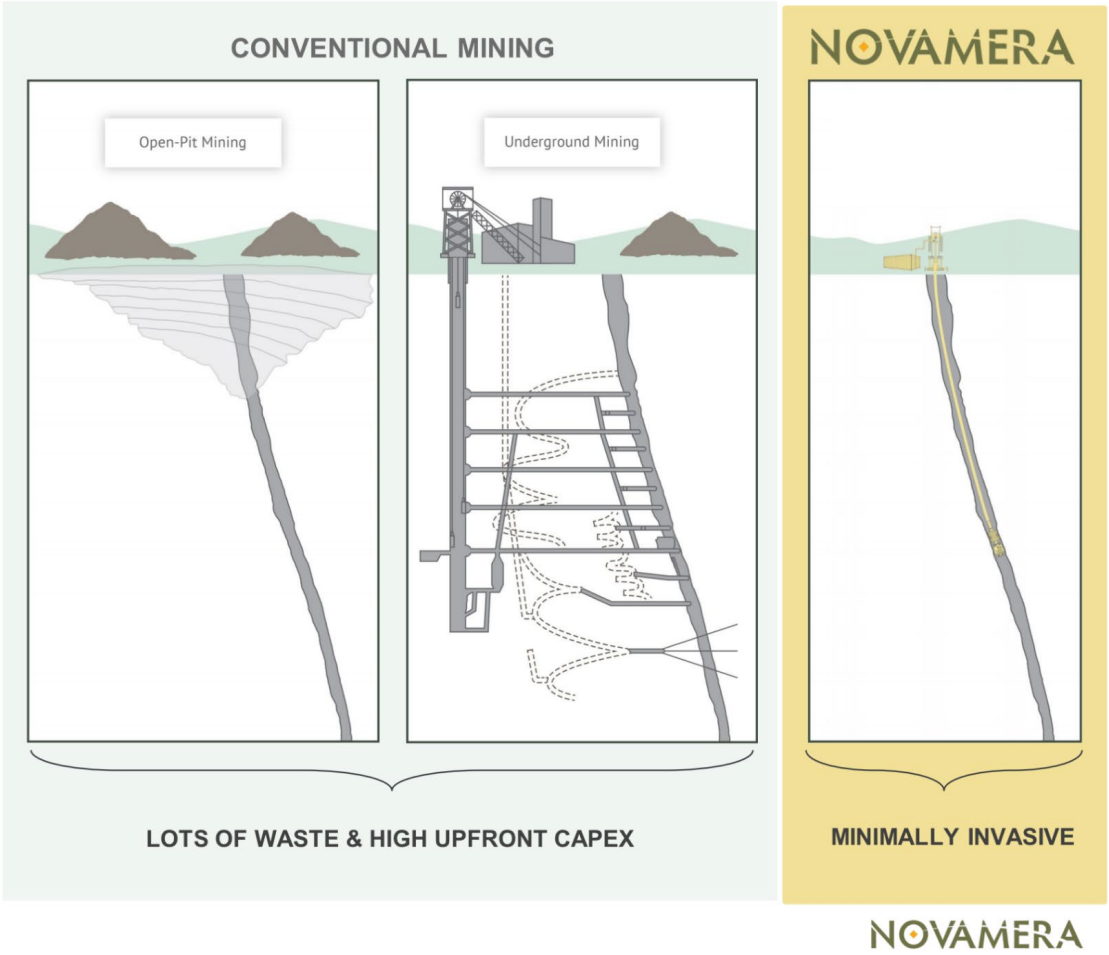


Novamera is a gold mining/drilling company that is applying a similar approach now

Mine of the Future RDD&D for precision extraction

Opportunity to capitalize on recent efforts to revolutionize mining technology

- RDD&D areas needed
  - Advanced drilling technologies
  - Novel geophysics
  - Digital subsurface applications (autonomous ops, robotics, real-time extraction)
  - In-situ mineral extraction (e.g., bio)
  - Novel processing
  - Tailings management
  - Marine mineral production
  - Mineral traceability



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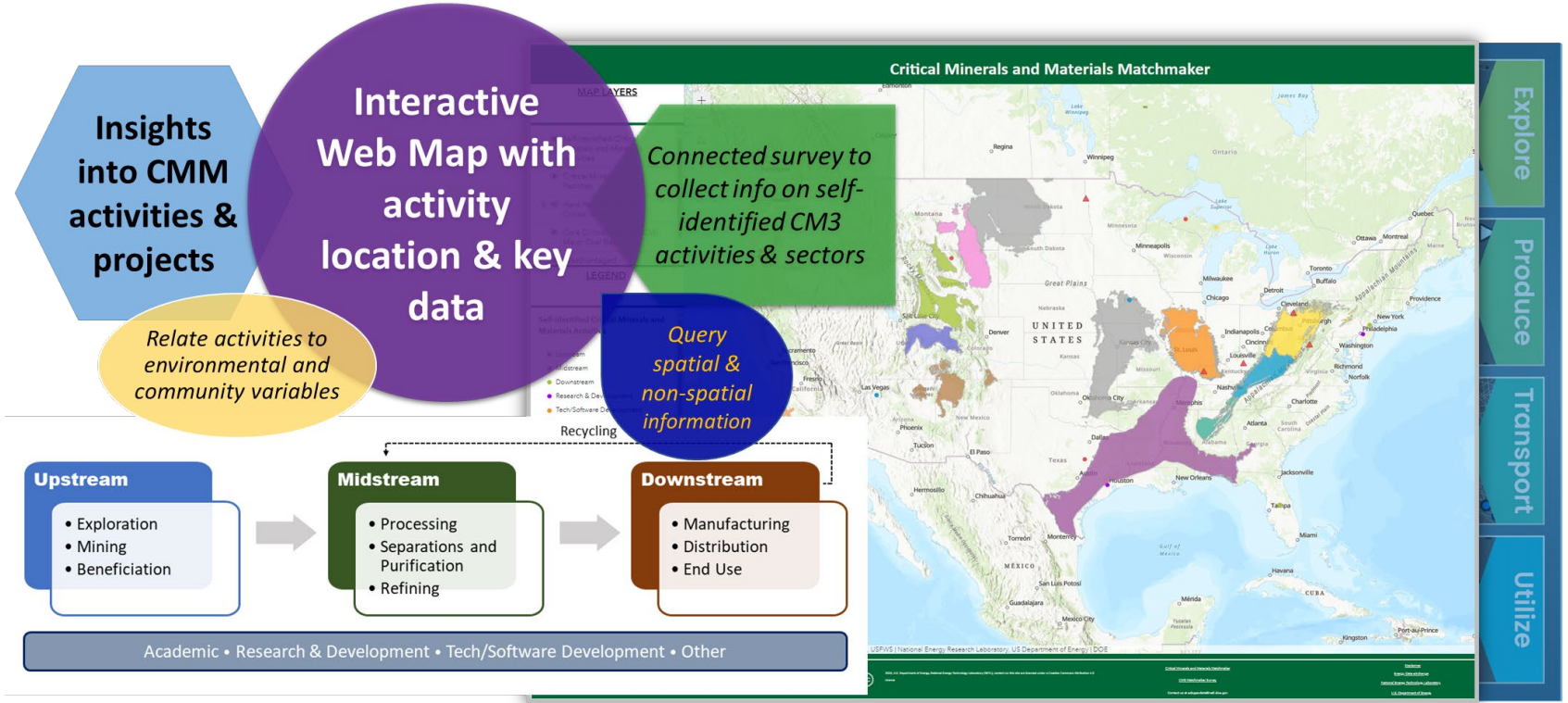
Critical Minerals & Materials Matchmaker (CM3)

NETL-developed application to connect stakeholders (e.g., communities, regulators, industry and research) - Accelerating domestic critical mineral commercialization efforts



CM3 Includes:

- energy.gov hosted website (https://www.energy.gov/fecm/cm3)
- Link to an online survey that allows for self-identification of CMM activities
- Host a web-based exploration application that allows users to find & visualize information from verified CMM activities

Interactive Demo: Wednesday, April 3, 5pm

Jennifer Bauer and Neyda Maymi, National Energy Technology Laboratory

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Questions?