

Overview of DOE-NETL's REE & CM Program



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***U.S DOE's Workshop on REE &
CM Production from
Domestic Coal-Based
Resources***

***Washington DC
December 11, 2019***

Annual Global Rare Earth Market

- ~\$5B in 2015 (~149,000 tonnes/yr)

U.S. Consumes

- 11% (\$550M) or ~16,000 tonnes/yr (~4.4 tonnes/day) in 2015

Approximately 750M Tons of Coal Burned in U.S. Annually

- ~75M tons of coal ash generated
- Average concentration of ~470 ppm REE+Y, yields ~31,980 tonnes of REE+Y annually

Lynas Advanced Materials Plant, Malaysia

- Capacity: 22,000 tonnes/yr REO (Nd/Pr, Ce, La..)
- Capital Cost: \$546M (2011)

Magnet Industry – International Consumption (2015)

- 21,727 tonnes/yr Nd_2O_3
- 5,542 tonnes/yr Pr_6O_{11}

Feasibility of Recovering Rare Earth Elements (REEs)

FY14 to perform an **assessment and analysis of the feasibility of economically recovering rare earth elements** from coal and coal by-product streams, such as fly ash, coal refuse, and aqueous effluents

FY15 to continue **activities to economically recover rare earth elements** from coal and coal by-product streams, such as refuse, and aqueous effluents

FY16-FY18 to expand its **external agency activities to develop and test commercially viable advanced separation technologies** at proof-of-concept or pilot scale that can be deployed near term for the **extraction and recovery of rare earth elements and minerals from U.S. coal and coal by-product** source showing the highest potential for success

FY19-FY20 to continue its **external agency activities to develop and test advanced separation technologies** and **accelerate** the advancement of commercially viable technologies for the **extraction and recovery of rare earth elements and minerals from U.S. coal and coal by-product** sources

Mission

Development of an economically competitive and sustainable domestic supply of rare earth elements (REEs) and critical materials (CMs) to assist in maintaining our Nation's economic growth and National Security

Objectives

- Recovery of REEs from coal and coal by-product streams, such as coal refuse, clay/shale over/under-burden materials, aqueous effluents, power generation ash
- Advance existing and/or develop new, second-generation or transformational technologies to improve process systems economics, and reduce the environmental impact of a coal-based REE value chain

Goals

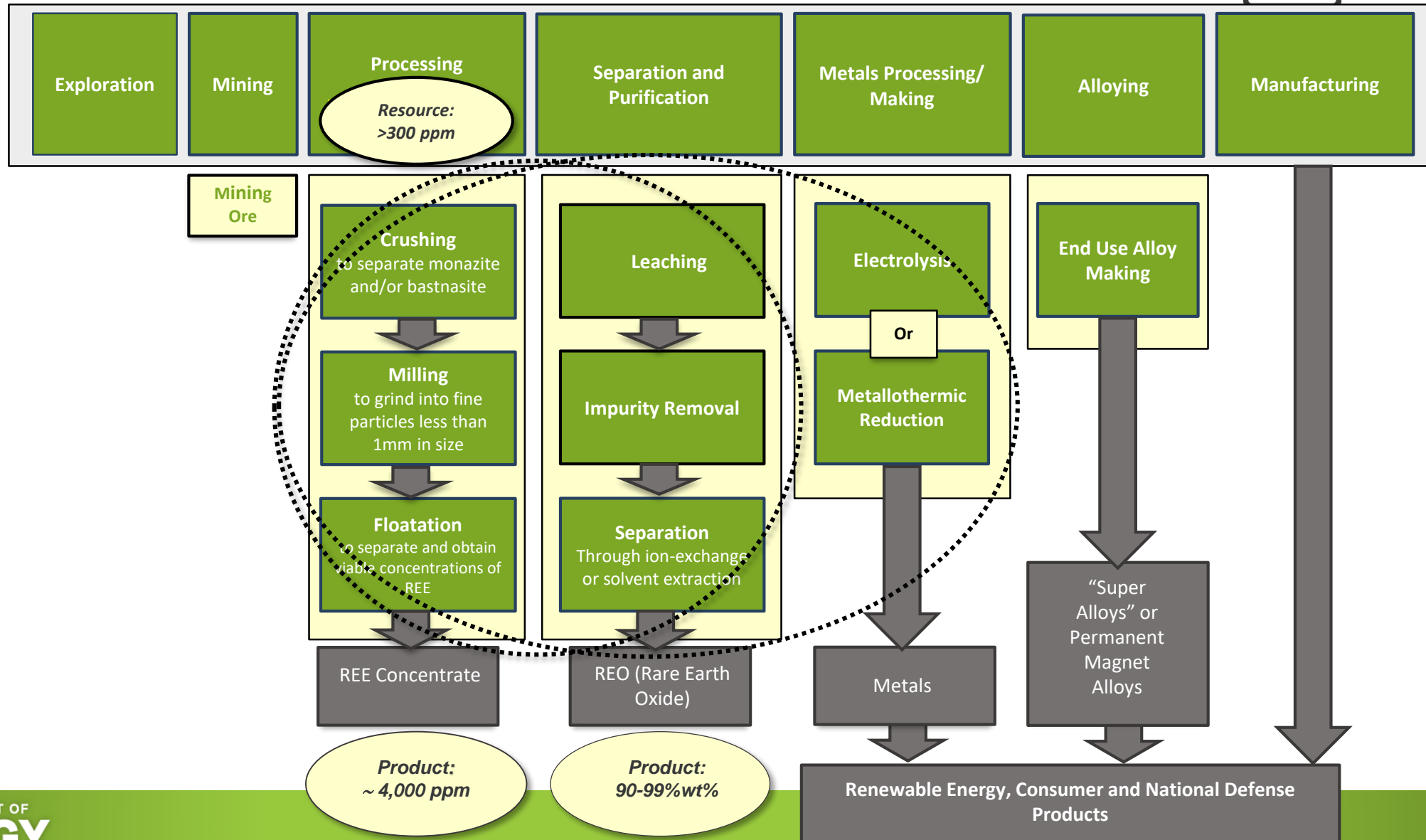
- Validate the technical and economic feasibility of small, domestic, pilot-scale, prototype facilities to generate, in an environmentally benign manner, high purity 90-99 wt% (900,000-990,000 ppm), salable, rare earth element oxides (REOs) from 300 ppm coal-based resources.



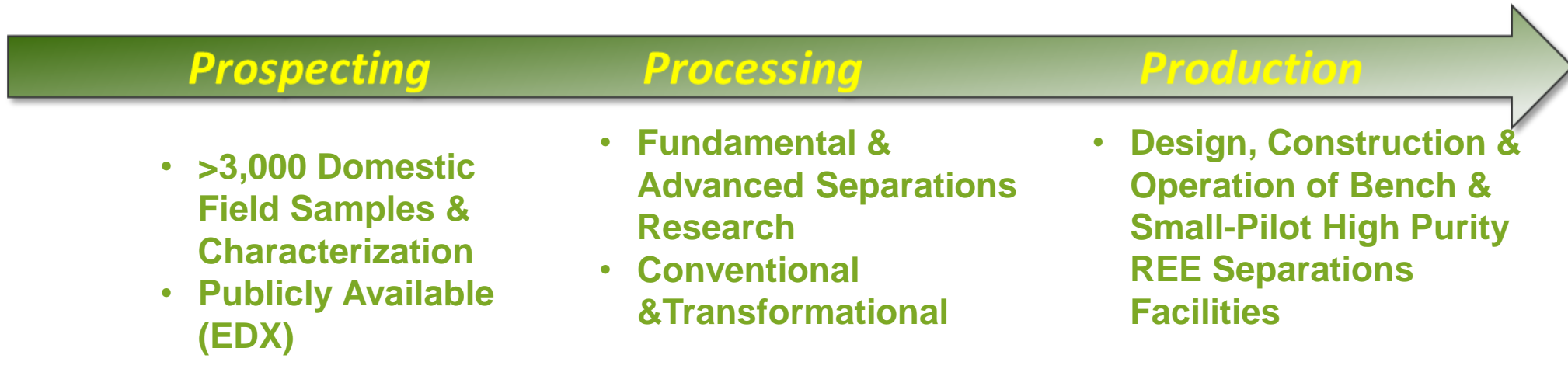
Feedstock Materials

- Run-of-Mine Coal
- Overburden & Underlying Clays/Shales/Sediments
- Coal Prep Plant Refuse
- Power Generation Ash
- Acid Mine Drainage Sludge

REE Program – Value Chain



REE Program Focus – Coal-Based Materials



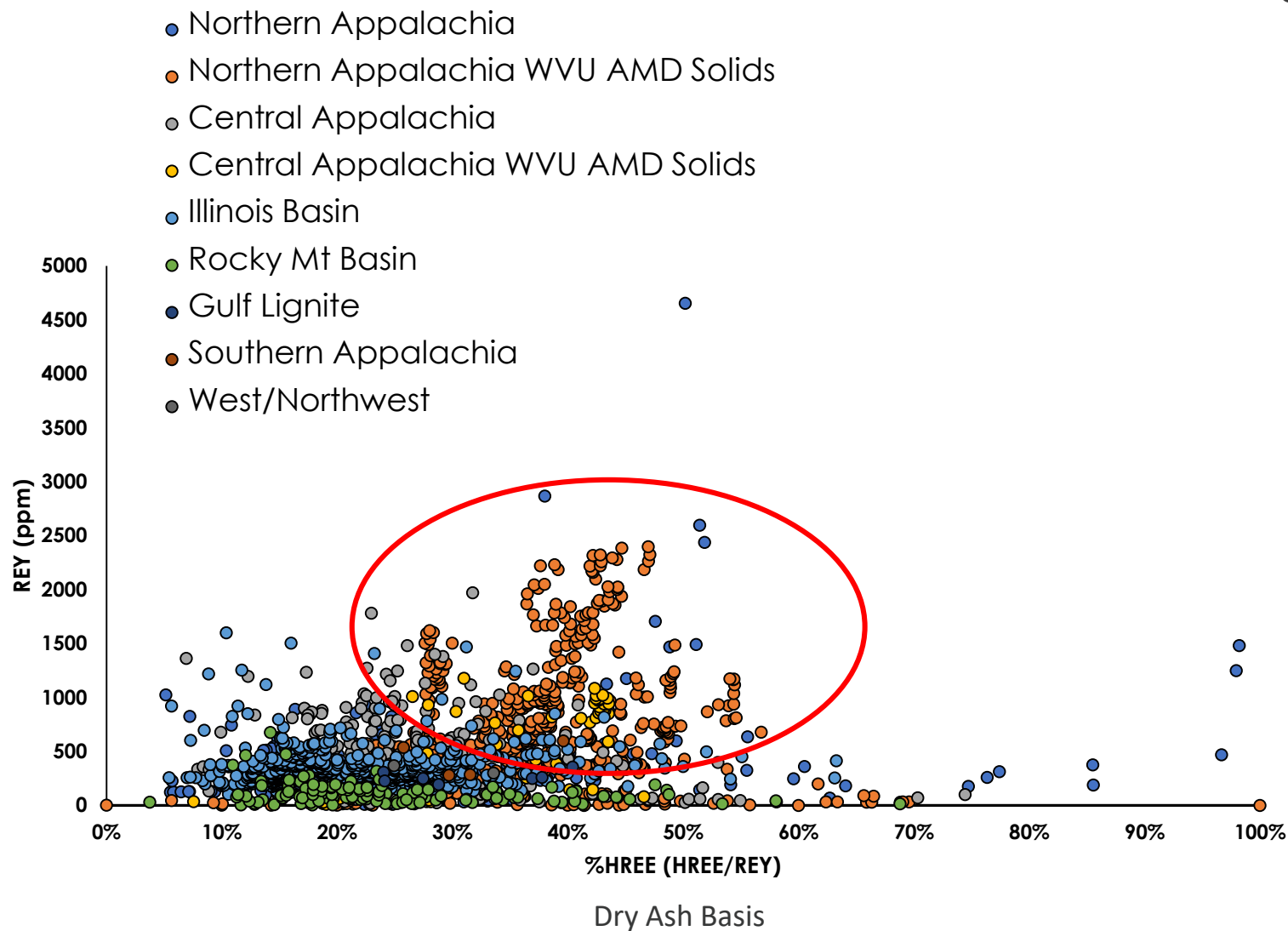
Stakeholders – 25-30 Active Projects (FY18-FY19)

- **NETL Research & Innovation Center (RIC)**
 - *Geospatial Modeling, Sensors, Separations, Techno-Economic Analyses, REE Embedded Database*
- **National Labs: LANL, LLNL, INL, PNNL**
 - *Field Sensors, Technology Transfer*
- **Universities**
 - *Separations Processing*
- **Industry – Small Business**
 - *Sensors (2017), Separation (2018), Metalization (2019)*

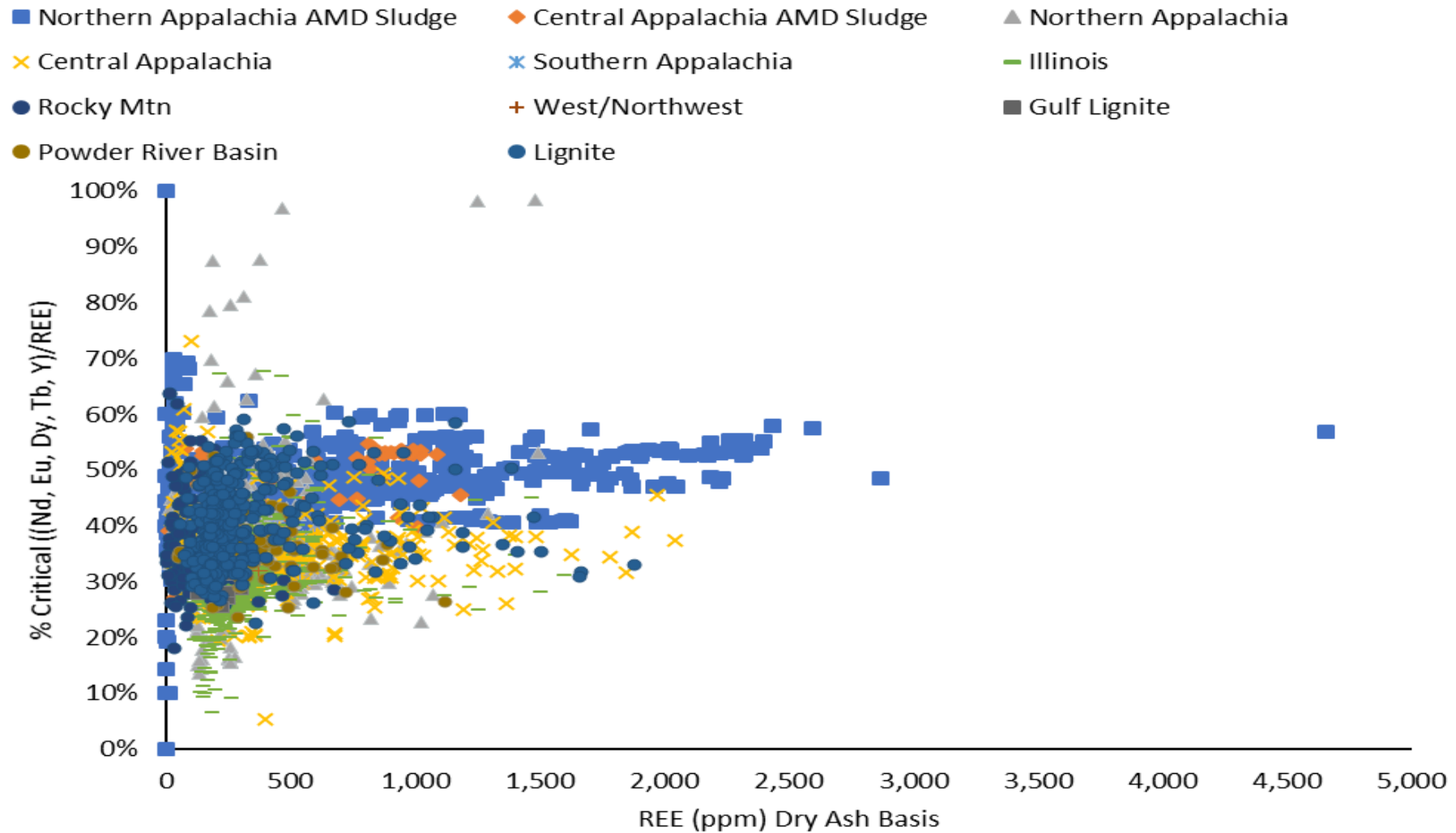
Program Direction

- **Economic & Process Efficiency Improvement**
- **Addressing Technology Gaps**
- **Metalization**
- **Accelerating Development**
- **REE-CM Co-Production**

REE Program - Prospecting



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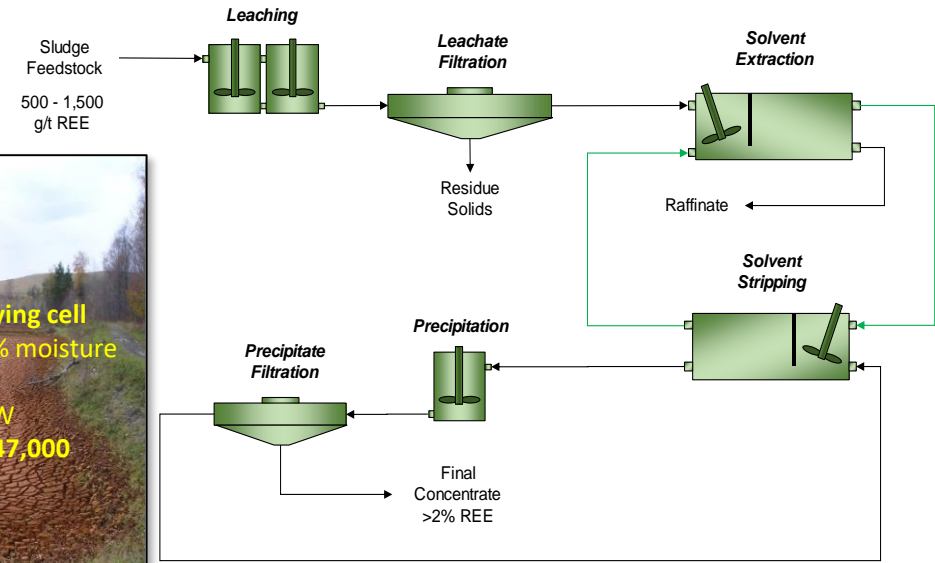


REE Program – Bench-Scale Processing



West Virginia University

Acid Mine Drainage (AMD)
July 2018 Commissioned Facility
~100% REE Recovery from Feedstocks
Production of ~96% REO



Courtesy of Paul Ziemkiewicz, WVU

REE Program – Bench-Scale Processing

University of North Dakota

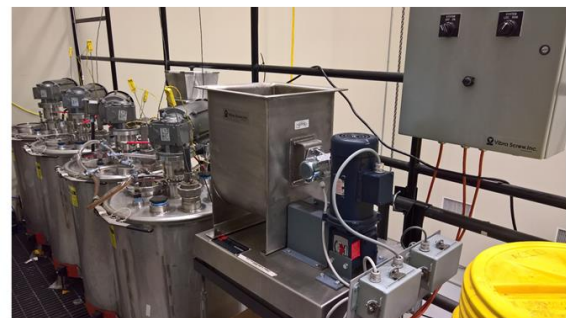
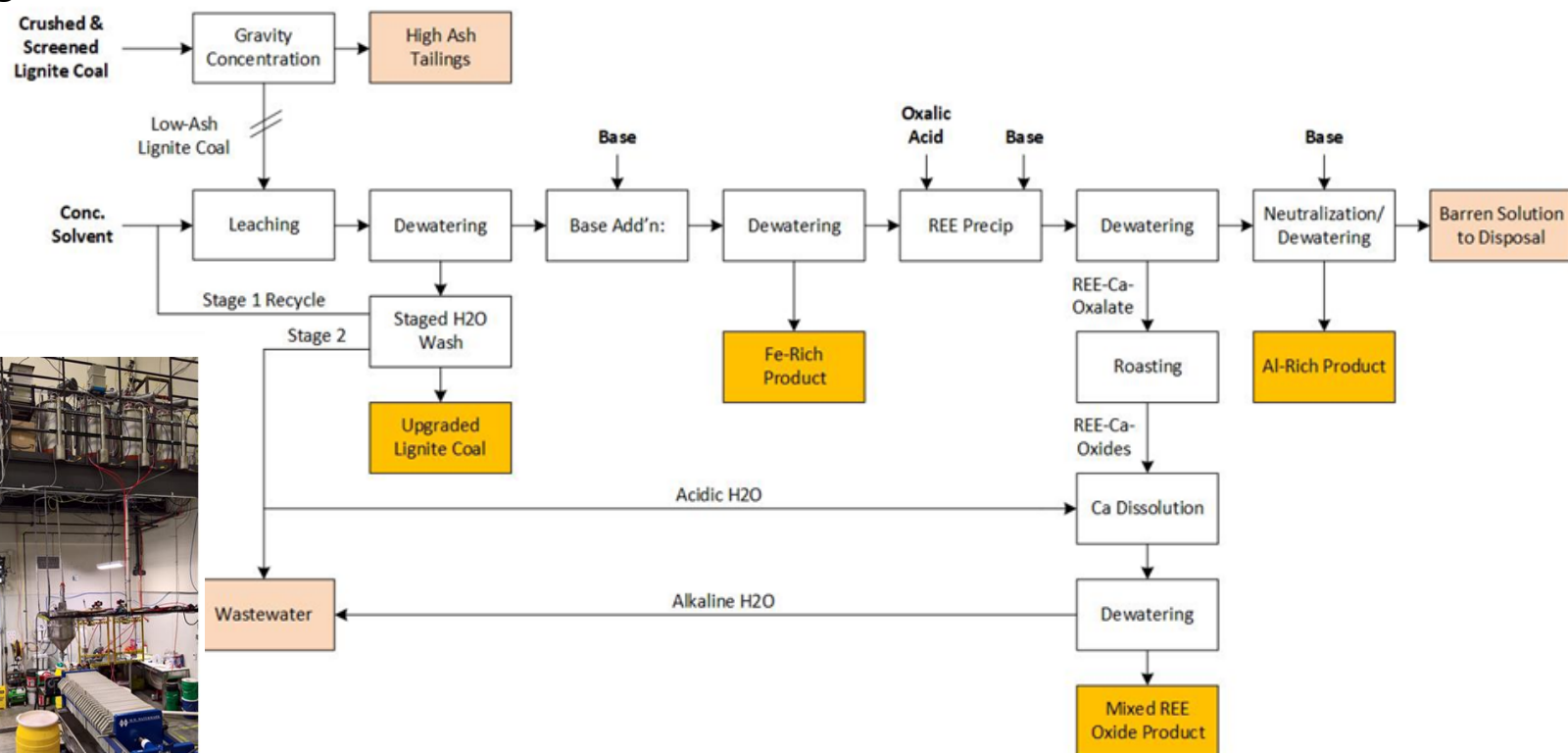
Low-Rank Coals – Lignite

High Organic REE Association

One-Step Selective Mineral Acid Leaching Process

~43% REE Recovery

Production of ~65% REO



Courtesy of Nolan Theaker, UND



REE Program – Modular Pilot-Scale Processing



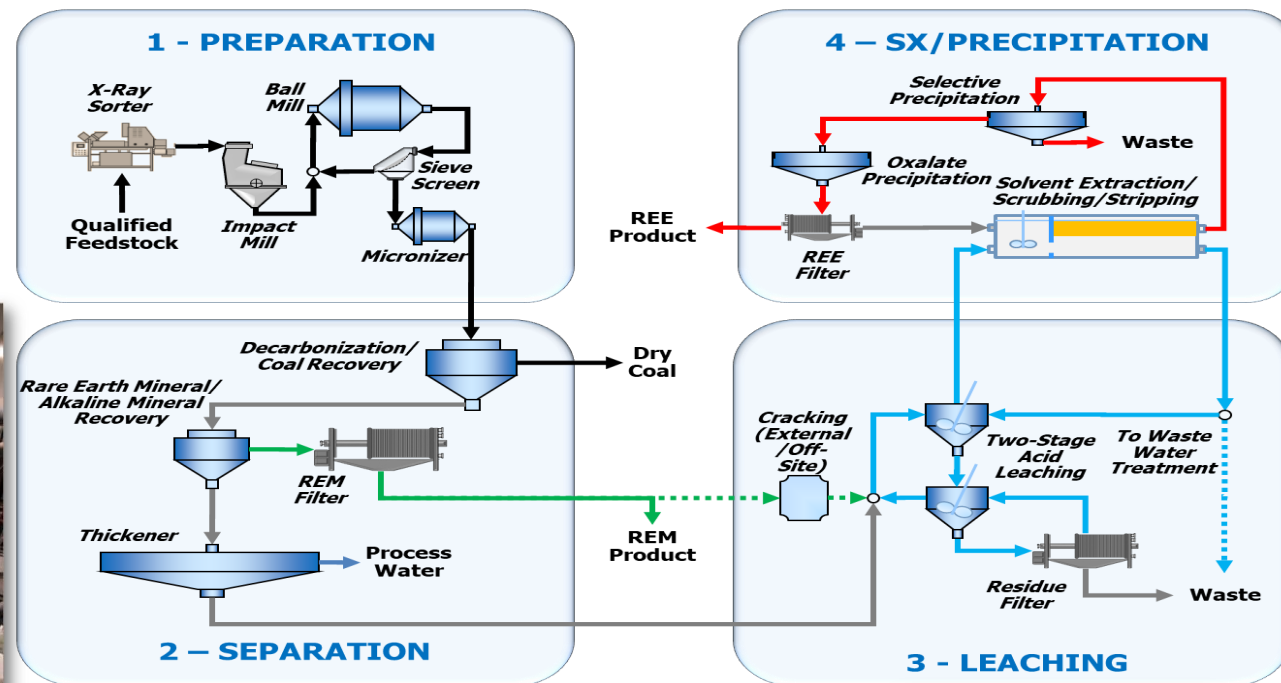
University of Kentucky

Coal Refuse – Central Appalachian & Illinois Coal Basins
 Initiated Operation in June 2018
 Production of REE in October/November 2018
 80-90% REE Concentrate Produced



Courtesy of Rick Honaker, University of Kentucky, Roe-Hoan Yoon, Virginia Tech

Youtube video link:
<https://www.youtube.com/watch?v=jR70j-MzWNE>



REE Program – Pilot-Scale Processing

Physical Sciences Inc. (PSI) Center for Applied Energy Research (CAER) Winner Water Service (WWS)

Coal Ash from Eastern Kentucky Coal

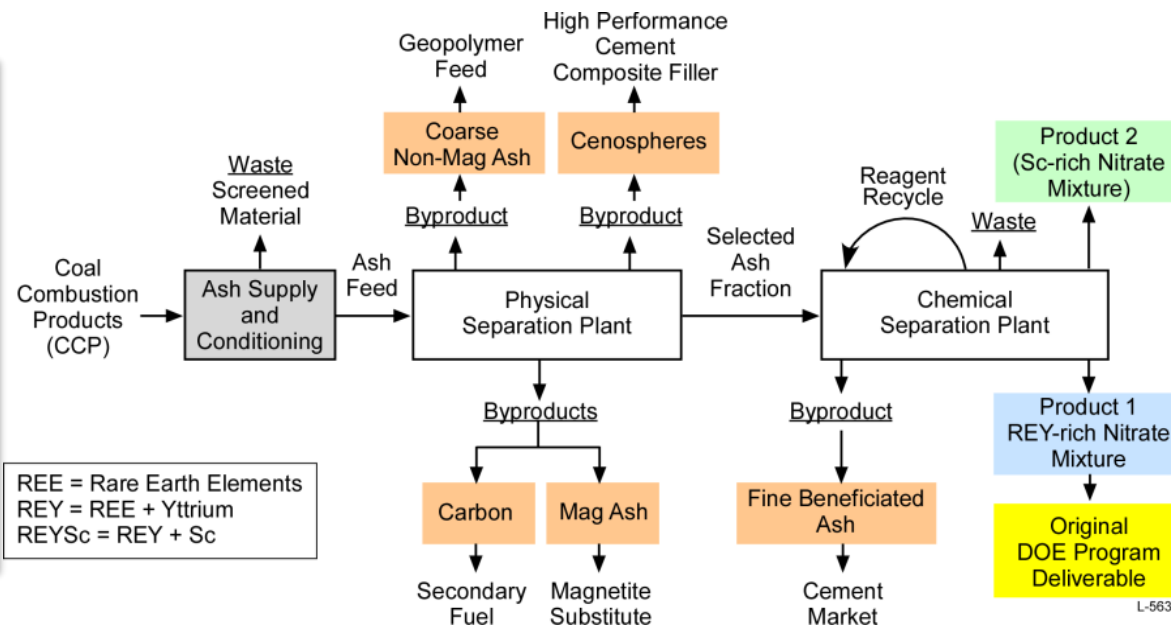
Physical Processing Pilot: 0.4 tpd Operational – CAER

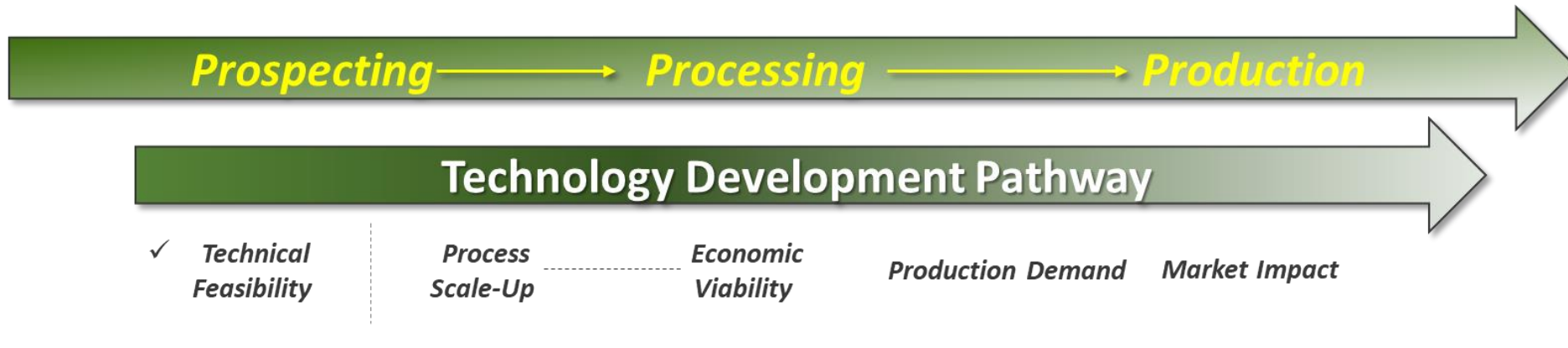
Micro-Pilot Plant: 0.5 kgpd Operational – PSI

Chemical Processing Pilot: 0.5 tpd Operational November 2019 – WWS



Courtesy of Prakash Joshi & David Gamliel, PSI



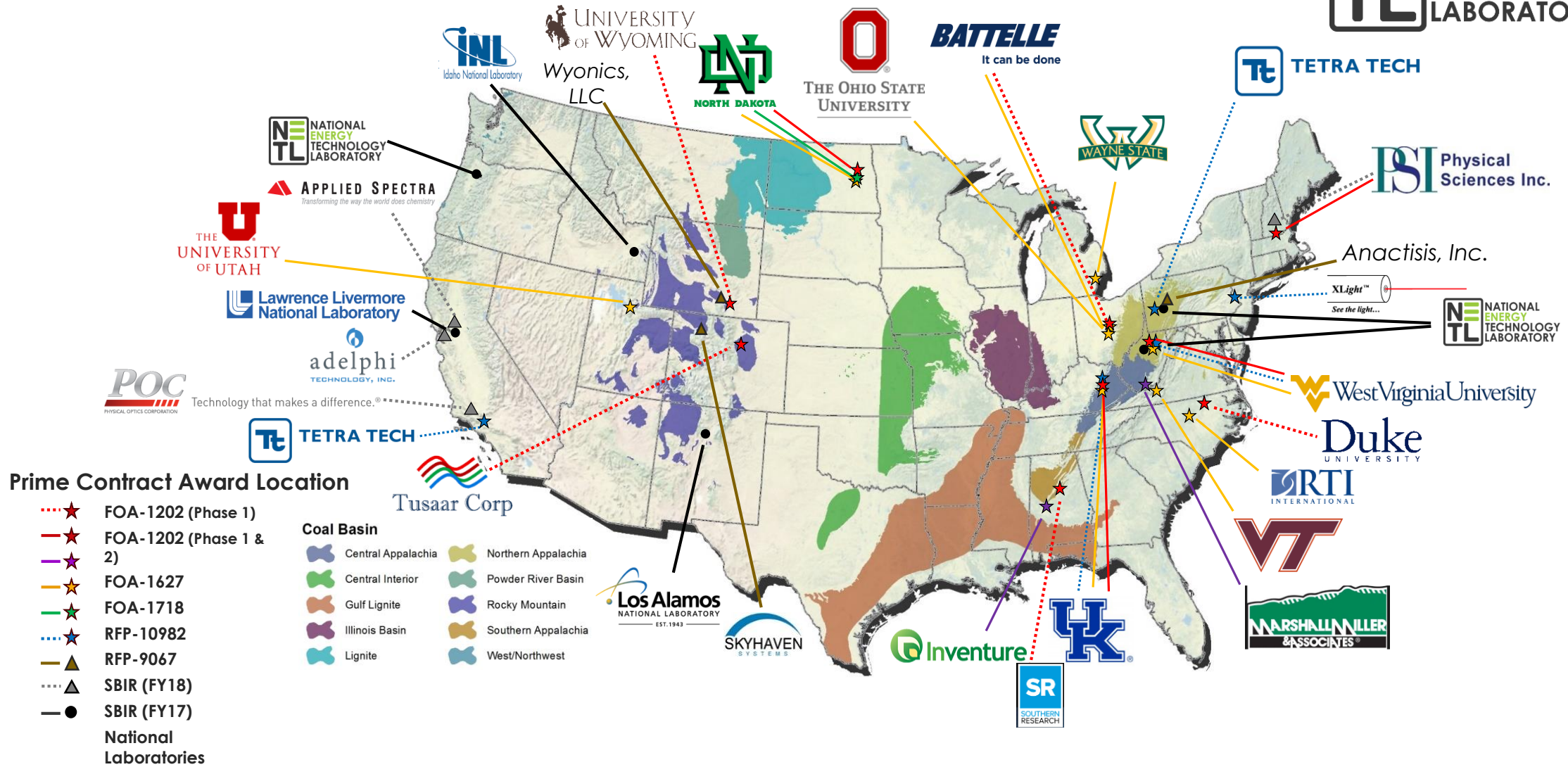


Courtesy of Inventure Renewables

Where We Are Today

- ✓ **Technical Feasibility** of Extracting REE from Coal-Based Resources Demonstrated
- ✓ **Three Domestic, First-of-a-Kind, Extraction/ Separation Test Facilities**, Producing Small Quantities of REEs from Coal-Based Materials,
- ✓ **Fully Integrated REE Program**
 - ✓ Spanning Basic/Fundamental Technology Development (TRL 1-3) through to Small Pilot-Scale Facility Validation (TRL 5-7)
 - ✓ Maintaining Broad Feedstock Base – Coal Refuse/Tailings, Clays/Shales, Power Generation Ash, Acid Mine Drainage

REE Program - Acknowledgments



REE Program – Contact Information



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National Energy Technology Laboratory

<http://www.netl.doe.gov/research/coal/rare-earth-elements/>

<https://edx.netl.doe.gov/ree/>

