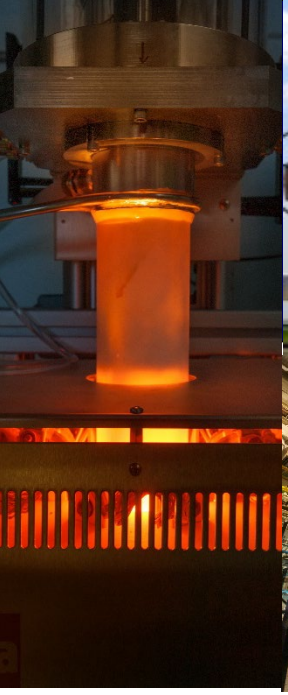
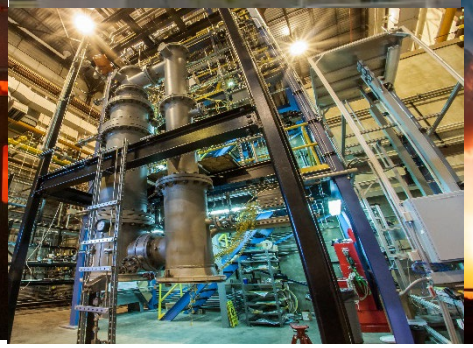
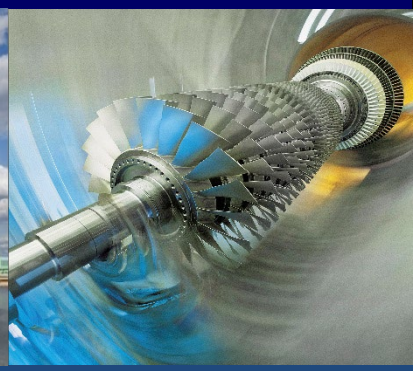




U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Critical Minerals Program

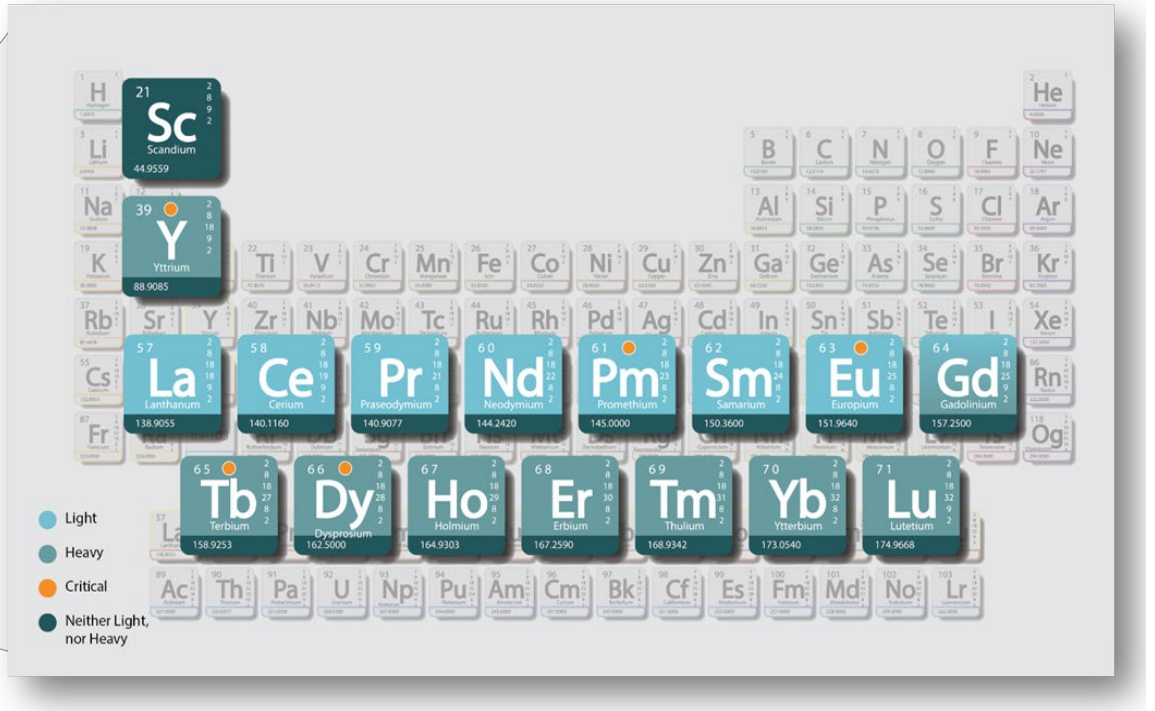
Traci Rodosta
Program Manager

August 2020

WHAT ARE CRITICAL MINERALS AND RARE EARTH ELEMENTS (REE)?

Mineral Commodity	Top Producer
Aluminum	China
Antimony	China
Arsenic	China
Barite	China
Beryllium	U.S.
Bismuth	China
Cesium/Rubidium	Canada
Chromium	So. Africa
Cobalt	Congo
Fluorspar	China
Gallium	China
Germanium	China
Graphite (natural)	China
Helium	U.S.
Indium	China
Lithium	Australia
Magnesium	China
Manganese	China
Niobium	Brazil
Platinum metals	So. Africa
Potash	Canada
Rare earth elements	China
Rhenium	Chile
Scandium	China
Strontium	Spain
Tantalum	Rwanda
Tellurium	China
Tin	China
Titanium	China
Tungsten	China
Uranium	Kazakhstan
Vanadium	China
Zirconium, Hafnium	Australia

REE are chemical elements/metals found in low concentrations throughout the Earth's crust, making them hard to recover.



WHY ARE CRITICAL MINERALS AND REE IMPORTANT?

MAGNETICS

Computer Hard Drives
Disk Drive Motors
Anti-Lock Brakes
Automotive Parts
Frictionless Bearings
Magnetic Refrigeration
Microwave Power Tubes
Power Generation
Microphones & Speakers
Communication Systems
MRI

Nd Tb Dy Pr

DEFENSE

Satellite Communications
Guidance Systems
Aircarft Structures
Fly-by-Wire
Smart Missiles

Nd Eu Tb Dy Y Lu Sm Pr La

CERAMICS

Capacitors
Sensors
Colorants
Scintillators
Refractories

Nd Y Eu Dy Lu Gd La Ce Pr

CATALYSTS

Petroleum Refining
Catalytic Converter
Fuel Additives
Chemical Processing
Air Pollution Controls

Nd La Ce Pr

METAL ALLOYS

NiMH Batteries
Fuel Cells
Steel
Super Alloys
Aluminum/Magnesium

Nd Y La Ce Pr

GLASS & POLISHING

Polishing Compounds
Pigments & Coatings
UV Resistant Glass
Photo-Optical Glass
X-Ray Imaging

Nd Gd Er Ho La Ce Pr

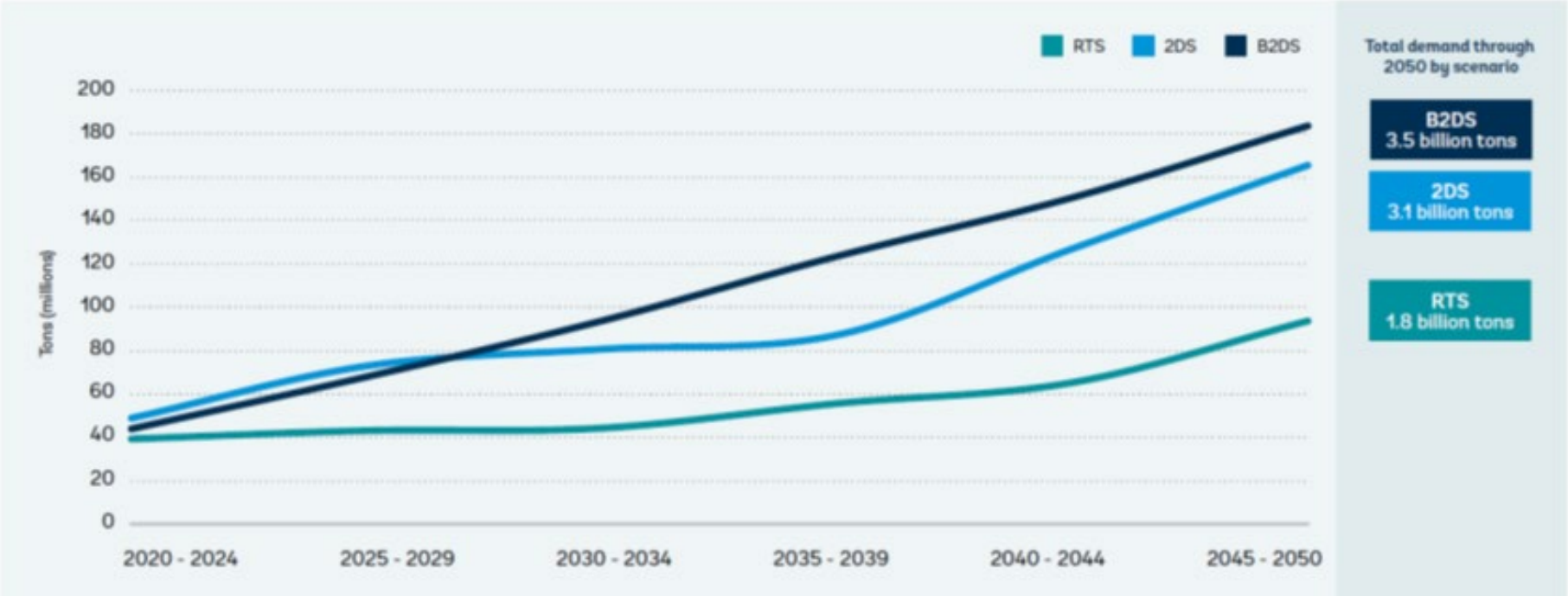
PHOSPHORS

Display phosphors-
CRT,LPD,LCD
Fluorescents
Medical Imaging
Lasers
Fiber Optics

Nd Eu Tb Y Er Gd Ce Pr

CLEAN ENERGY TECHNOLOGIES AND CRITICAL MINERALS

Figure ES.1 Projected Annual Average Demand of Minerals up to 2050 Under the IEA Energy Technology Perspective Scenarios

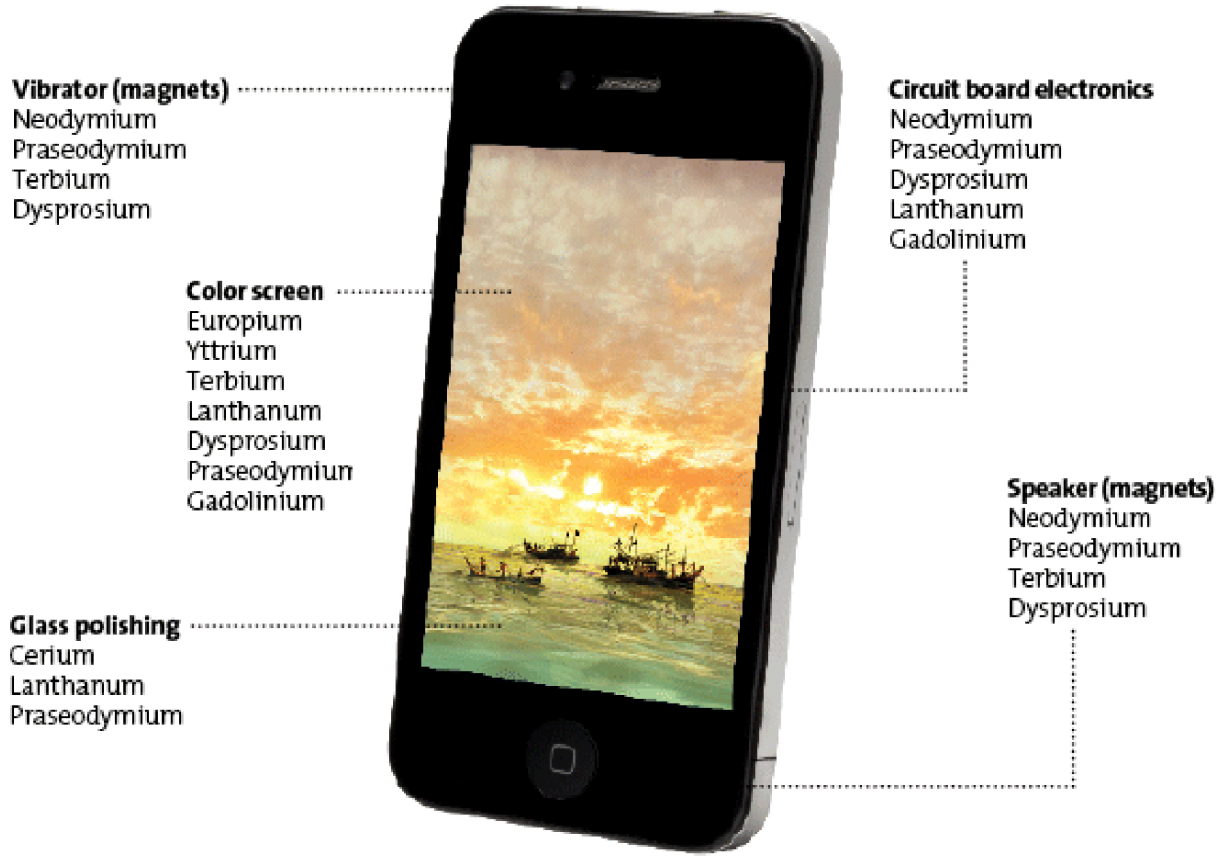


- **A global study funded through the World Bank predicts key minerals for clean energy technology could grow over 450% by 2050**
- **Estimates over 3 billion tons of minerals and metals could be needed**
- **100% recycling will not be enough – requiring additional mineral extraction and processing**

http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

CRITICAL MINERALS AND MANUFACTURING

The total value of REE in a cell phone is about $15
The value of the phone is hundreds of dollars



FEDERAL STRATEGY – CRITICAL MINERALS

The President issued Executive Order (EO) 13817, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* address strategic vulnerabilities in critical minerals supply chains

Two deliverables

- **Critical Minerals Lists – published by Department of the Interior in May 2018**
- **Report to President – published by Department of Commerce in June 2019.**

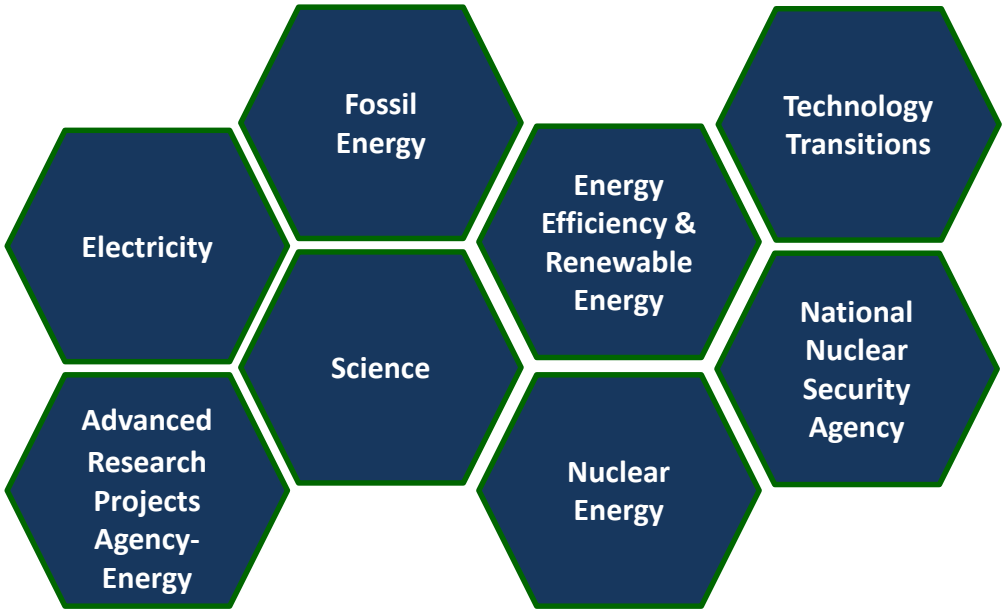
Interagency Coordination

- **National Science and Technology Council (NSTC) Subcommittee on Critical Minerals**

DOE RESEARCH AND DEVELOPMENT PRIORITIES

Research and Development Priorities for Critical Minerals

- Diversifying supply of critical materials – including domestic production and processing
- Developing Substitutes
- Driving recycling, reuse and more efficient use



R&D is being coordinated across DOE Offices

WHAT IS A CRITICAL MINERAL SUPPLY CHAIN?

Sequence of processes involved in the production of a commodity from raw materials (feedstock) through processing to end-use

Upstream → Midstream → Downstream

Exploration-Extraction-and Beneficiation

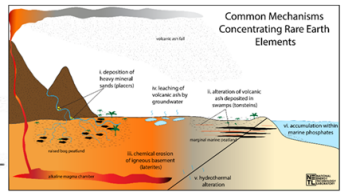
Separation and Purification

Manufacturing

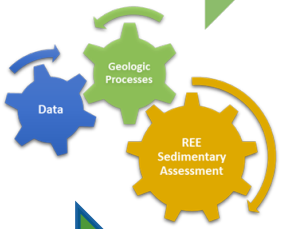
Pictures are courtesy of University of North Dakota, Three Consulting + Thorium Energy Alliance, University of Kentucky, and NETL

TECHNOLOGY DEVELOPMENT- NATIONAL ENERGY TECHNOLOGY LAB

CHARACTERIZE GEOLOGIC PROCESSES:

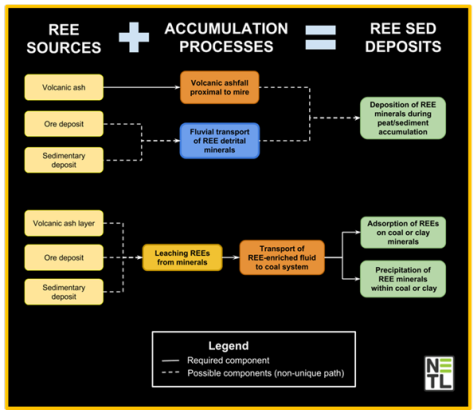


Distill geologic processes tied to REE SED systems into discrete, testable components



INTEGRATION OF GEOLOGIC PROCESSES AND DATA:

Enables testing for geologic conditions needed to accumulate REEs



Photos courtesy of B. Hedin (Pitt)

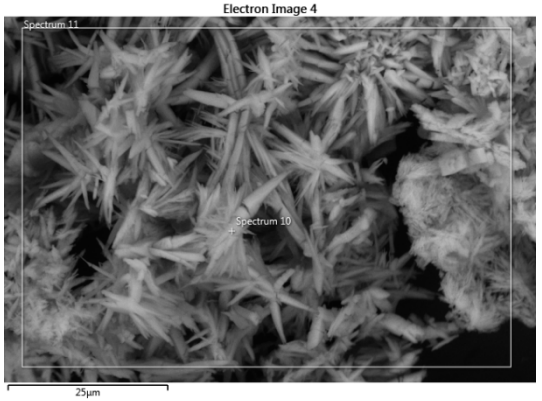
Upstream

- Exploration
- Characterization
- Mining
- Beneficiation

Midstream

- Separation
- Purification
- Metallization

SEM Image of HREE+Y oxalate precipitate



TECHNOLOGY DEVELOPMENT - FIELD VALIDATION PROJECTS

Upstream

- Exploration
- Characterization
- Mining
- Beneficiation

Midstream

- Separation
- Purification
- Metallization

QUESTIONS

Image Courtesy of National Energy Technology Laboratory