History of Rare Earths

ENORMOUSIMPACT

First discovered in the 18th century, rare earth elements are integrated into today's modern life. Most are unaware of the critical impact they have in advancing society. Rare earth materials are essential to a variety of industries including those that support a clean energy future.

1788

Term "rare earth" coined – An unusual black rock unearthed by a miner in Ytterby, Sweden was called "rare" and "earth", the then term for rocks that could be dissolved in acid.

1794 – Yttria Discovered - Chemist Johan Gadolin discovered four elements (yttrium, ytterbium, terbium, and erbium) from the unknown "earth" yttria, named after the town where it was discovered, Ytterby.

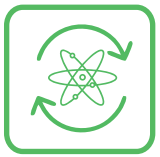
1803-1828

Discovery of Cerium and Thorium –Jöns Jacob Berzelius isolated and named cerium in 1803 and thorium in 1828.

1839 – More Rare Earths Discovered - Swedish chemist Carl Gustaf Mosander began to systematically analyze the mixed rare earths, discovering and naming lanthanum, erbium, and terbium.

Mid-1800s – Spectroscopy Developed - Chemists Gustav Kirchhoff and Robert Bunsen developed spectroscopy to identify elements by examining light spectra.

1880-1930s



Commercialization of Rare Earths – Carl Auer von Welsbach works with rare earth elements resulting in new commercial applications.

1913 – Lanthanides Discovered - British physicist Henry Moseley determined there were 15 elements in the lanthanide series.

1939 – Rare Earths in the Atomic Age - Scientists discover the nuclear fission of uranium—an insight leading to the atomic bomb, associating rare earth elements in fission products.

1950s

Rare Earths in Color TVs – Searching for uranium in the United States led to the development of the Mountain Pass Mine in California's Mojave Desert.

In the early 1950s, extracted europium was used to produce red phosphors for new color television technology.

1960s

Rare Earths in the Arms Race – In the 1960s U.S. Air Force researchers developed samarium-cobalt magnets for powerful radar instruments. Soviet metallurgists used scandium to make aluminum stronger and lighter in the 1980s, which increased the performance of MiG-29 fighter planes.

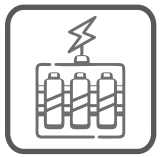
Laser research led to the development of yttrium-aluminum-garnet lasers used for laser rangefinders or target designators for guided weapons.

Late 1970s

China Develops its Rare Earths Industry – Communist China began manufacturing and global trade capabilities as a way to secure political stability, establish domestic prosperity, and overcome the catastrophic events of 20th-century history.

Between 1978 and 1995 China's annual production of rare earth elements increased by an average of 40% per year.

1980s-1990s



Rare Earths for Rechargeable Batteries – Battery research in the 1980s led to the development of the nickel–metal hydride battery, which used lanthanum and neodymium. These batteries could be recharged repeatedly while holding a large energy volume (size).

They became popular for use in portable electronics in the 1990s are widely used in hybrid cars.

1990s

Magnequench Rare Earth Magnets – General Motors patented neodymium-iron-boron magnets in the 1980s and created a company, Magnequench, that produced lightweight, powerful, permanent magnets used in power windows, door locks, windshield wiper motors, and electric engine starters.

Magnequench also sold tiny magnets for computer hard drives, as personal computer use became widespread in homes and offices duringthe 1990s.

2000s-2010s

Rare Earth Elements in Electronics – In the 1990s Bell Labs used erbium to boost the signal in fiber-optic cables. This was leveraged to create a global network of fiber-optic cables carrying cheap long-distance calls and internet data.

2010 - Rare Earth Crisis – In 2010 an international incident between China and Japan caused a trade embargo by China, spiking the price of rare earth metals substantially.

2020s

Rare Earths and Critical Materials Today – Rare earths and critical materials are essential in efforts to reduce greenhouse-gas.

Wind farms continues to drive demand for neodymium and dysprosium used in wind turbines, while electric vehicles increase demand for rare earth magnets and batteries.

Research into new methods to recover rare earths from electronic waste will reduce the amount of metals that need to be mined.

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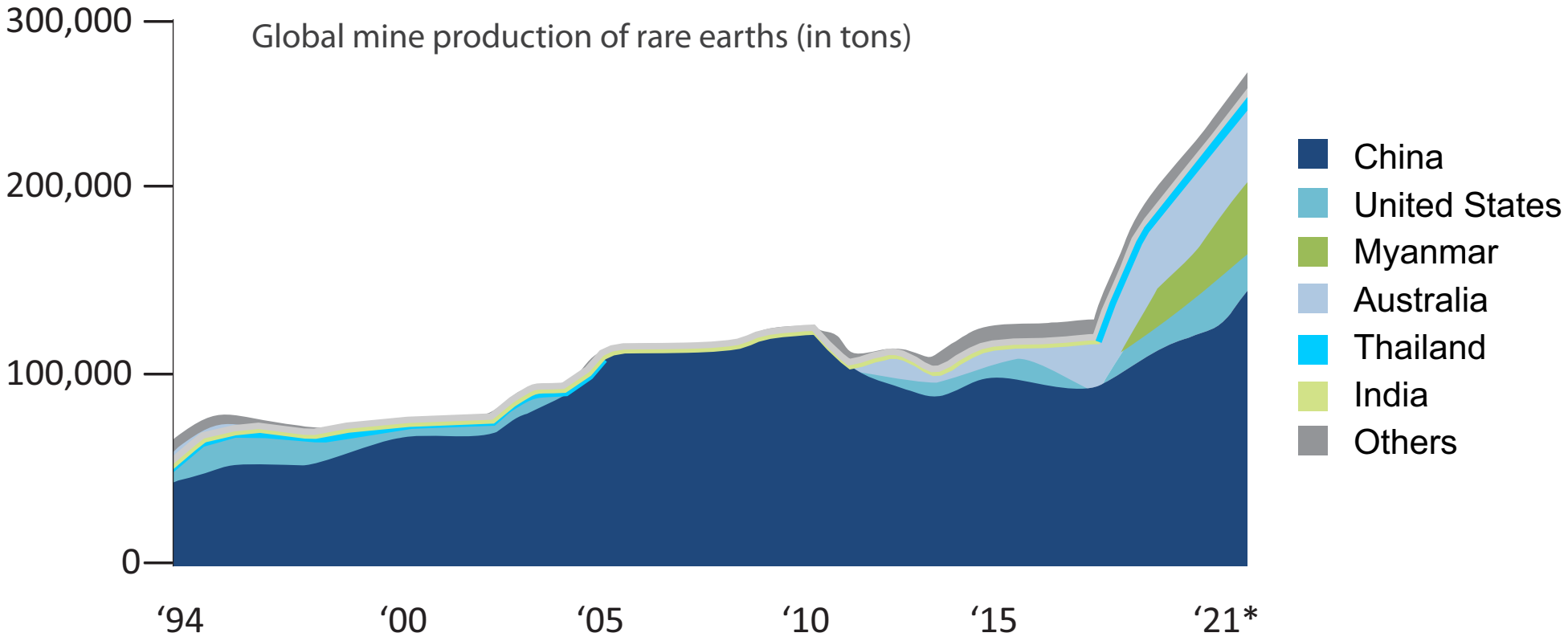
Science History Institute, 2020.

China's Rare Earth Monopoly is Diminishing

In recent years, several nations have picked up production and new players have entered the market.



Documented production only, some estimations

*estimated

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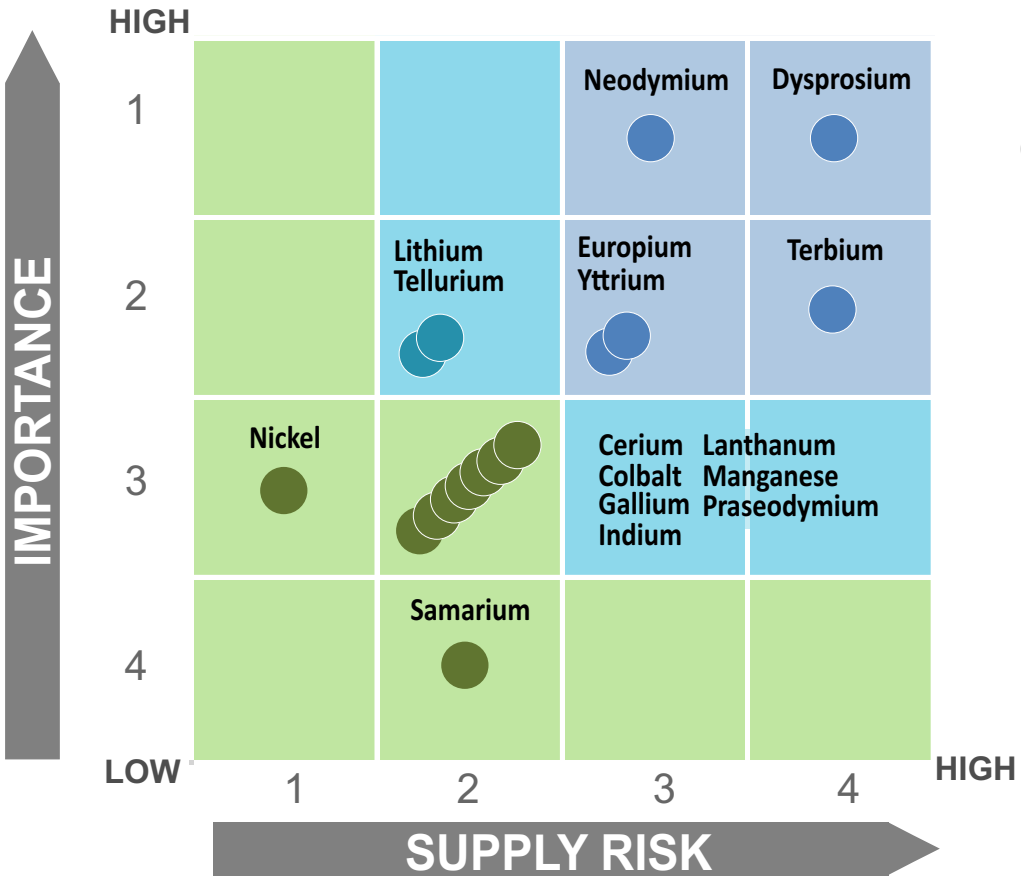
Source: United States Geological Survey, Statista.

Critical Elements Example: Green Energy

Essential Rare Earth Elements (REEs) are a group of 17 elements that are vital for renewable energy and energy storage.



CLASSIFICATION

Critical	Near-Critical	Not Critical
Lithium		Batteries
Cobalt		Batteries
Nickel		Batteries
	Yttrium	Industrial
	Cerium	Industrial
	Praseodymium	Industrial
	Tellurium	Steel
	Manganese	Steel
	Neodymium	Technology
	Dysprosium	Technology
	Europium	Technology
	Terbium	Technology
	Gallium	Technology
	Indium	Technology
	Lanthanum	Technology
	Samarium	Technology

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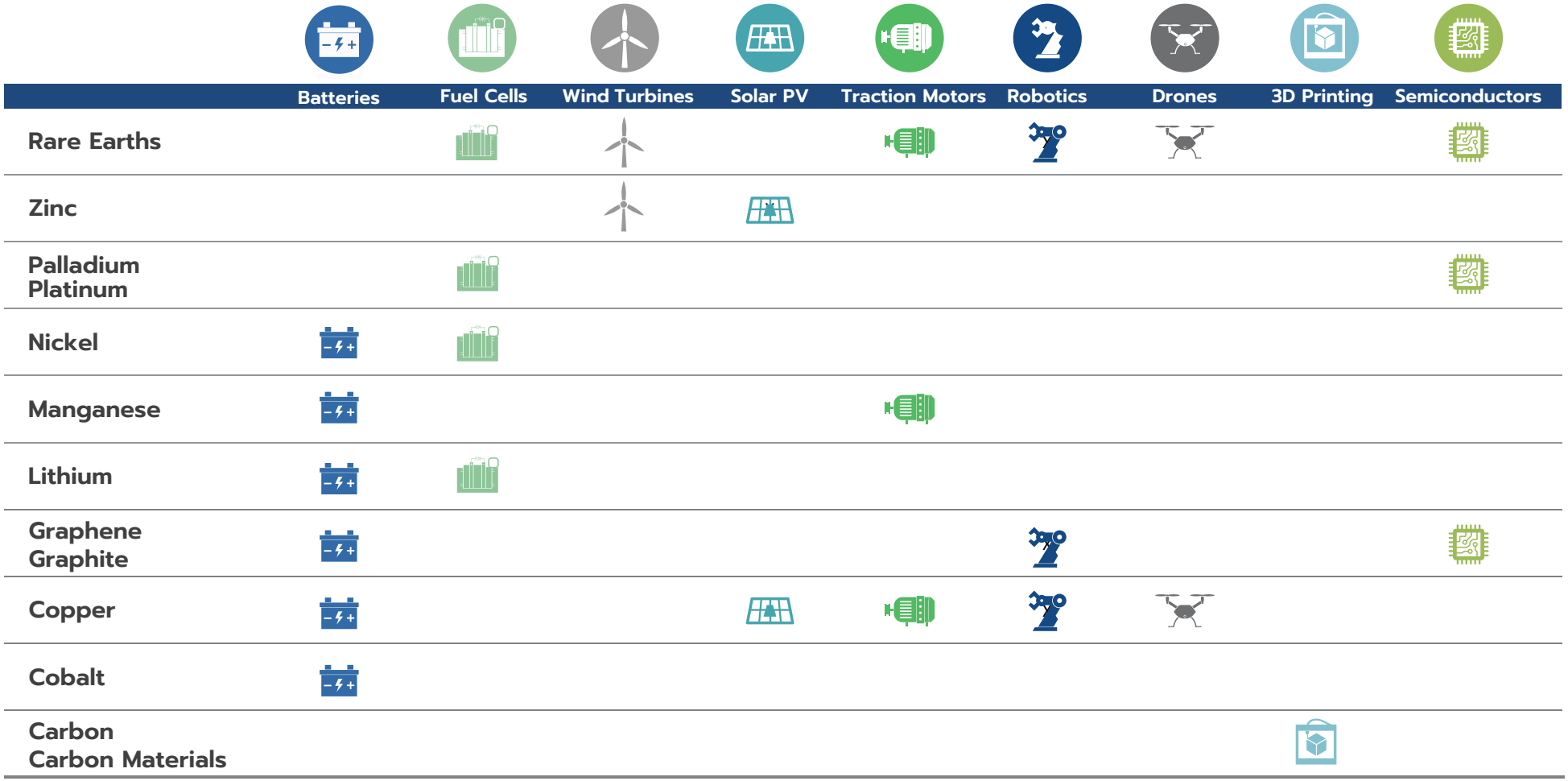
Source: EQM Indexes, University of Michigan

Critical Materials in Technology

Strategic technologies and sectors depend on critical raw materials.



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Source: EQM Indexes, European Commission

The 50 Materials Critical to the U.S.

STRATEGIC NEEDS AND USAGE ARE EVOLVING


COMMUNICATIONS


ELECTRONIC DEVICES


ENERGY STORAGE


INFRASTRUCTURE


MILITARY


SEMI-CONDUCTORS

The new 2022 updated list of commodities deemed critical to the U.S. economy and national security now includes 17 rare earth metals broken out individually.

1. **Aluminum**
   USE: almost all sectors of the economy
2. **Antimony**
   USE: lead-acid batteries and flame retardants
3. **Arsenic**
   USE: semi-conductors
4. **Barite**
   USE: hydrocarbon production
5. **Beryllium**
   USE: an alloying agent in aerospace and defense industries
6. **Bismuth**
   USE: medical and atomic research
7. **Cerium**
   USE: catalytic converters, ceramics, glass, metallurgy, and polishing compounds
8. **Cesium**
   USE: research and development
9. **Chromium**
   USE: primarily in stainless steel and other alloys
10. **Cobalt**
    USE: used in rechargeable batteries and superalloys
11. **Dysprosium**
    USE: in permanent magnets, data storage devices, and lasers
12. **Erbium**
    USE: in fiber optics, optical amplifiers, lasers, and glass colorants
13. **Europium**
    USE: in phosphors and nuclear control rods
14. **Fluorspar**
    USE: the manufacture of aluminum, cement, steel, gasoline, and fluorine chemicals
15. **Gadolinium**
    USE: medical imaging, permanent magnets, and steelmaking
16. **Gallium**
    USE: integrated circuits and optical devices like LEDs
17. **Germanium**
    USE: fiber optics and night vision applications
18. **Graphite**
    USE: lubricants, batteries, and fuel cells
19. **Hafnium**
    USE: nuclear control rods, alloys, and high-temperature ceramics
20. **Holmium**
    USE: permanent magnets, nuclear control rods, and lasers
21. **Indium**
    USE: liquid crystal display screens
22. **Iridium**
    USE: coating of anodes for electrochemical processes and as a chemical catalyst
23. **Lanthanum**
    USE: produce catalysts, ceramics, glass, polishing compounds, metallurgy, and batteries
24. **Lithium**
    USE: rechargeable batteries
25. **Lutetium**
    USE: in scintillators for medical imaging, electronics, and some cancer therapies
26. **Magnesium**
    USE: an alloy and for reducing metals
27. **Manganese**
    USE: steelmaking and batteries
28. **Neodymium**
    USE: permanent magnets, rubber catalysts, and in medical and industrial lasers
29. **Nickel**
    USE: make stainless steel, superalloys, and rechargeable batteries
30. **Niobium**
    USE: mostly in steel and superalloys
31. **Palladium**
    USE: catalytic converters and as a catalyst agent
32. **Platinum**
    USE: catalytic converters
33. **Praseodymium**
    USE: permanent magnets, batteries, aerospace alloys, ceramics, and colorants
34. **Rhodium**
    USE: catalytic converters, electrical components, and as a catalyst
35. **Rubidium**
    USE: research and development in electronics
36. **Ruthenium**
    USE: as catalysts, as well as electrical contacts and chip resistors in computers
37. **Samarium**
    USE: permanent magnets, as an absorber in nuclear reactors, and in cancer treatments
38. **Scandium**
    USE: alloys, ceramics, and fuel cells
39. **Tantalum**
    USE: electronic components, mostly capacitors and in superalloys
40. **Tellurium**
    USE: solar cells, thermoelectric devices, and as alloying additive
41. **Terbium**
    USE: permanent magnets, fiber optics, lasers, and solid-state devices
42. **Thulium**
    USE: various metal alloys and in lasers
43. **Tin**
    USE:protective coatings and alloys for steel
44. **Titanium**
    USE: a white pigment or metal alloys
45. **Tungsten**
    USE: primarily used to make wear-resistant metals
46. **Vanadium**
    USE: primarily used as alloying agent for iron and steel
47. **Ytterbium**
    USE: catalysts, scintillometers, lasers, and metallurgy
48. **Yttrium**
    USE: ceramic, catalysts, lasers, metallurgy, and phosphorus.
49. **Zinc**
    USE: primarily used in metallurgy to produce galvanized steel
50. **Zirconium**
    USE: the high-temperature ceramics and corrosion-resistant alloys

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USGS National Minerals Information Center