Critical Materials Institute

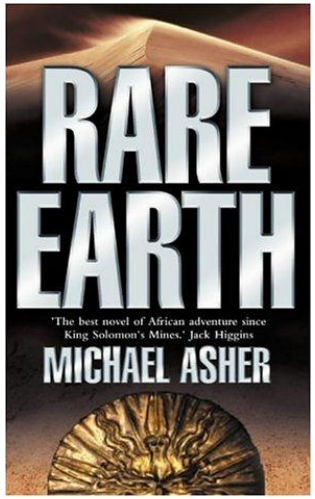
AN ENERGY INNOVATION HUB

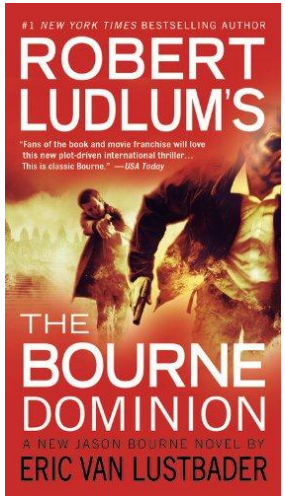
Critical Materials for Energy Systems Manufacturing

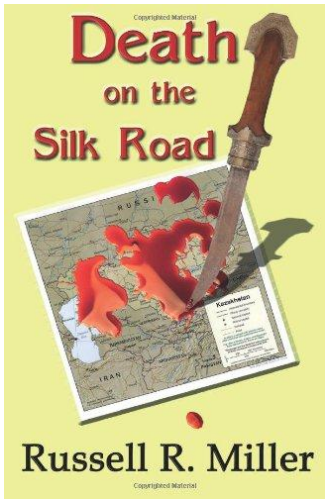
Alex King

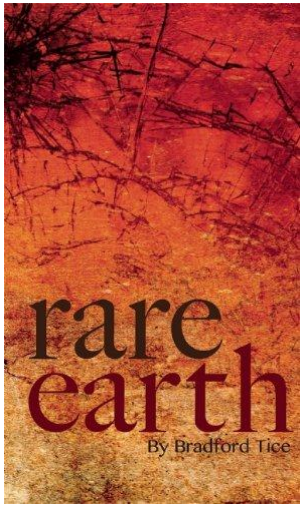
U.S. DEPARTMENT OF ENERGY

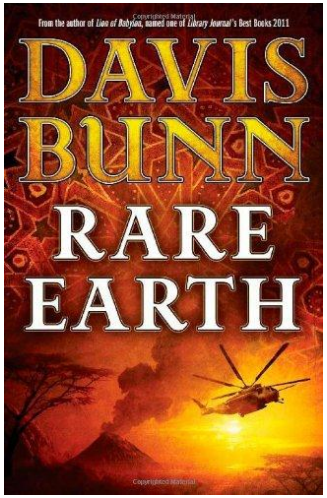
The hottest new literary sub-genre?

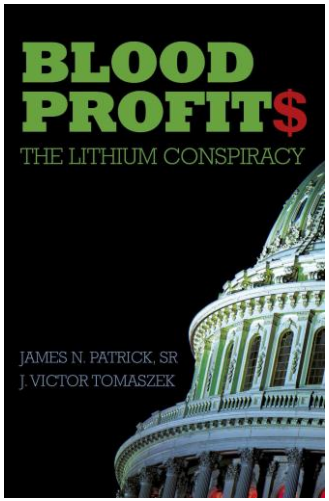


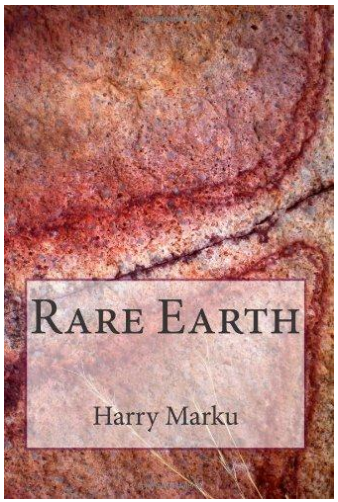


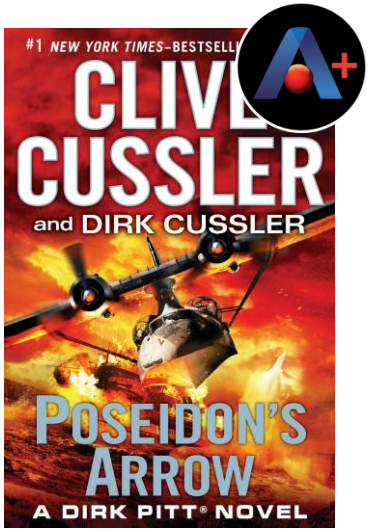


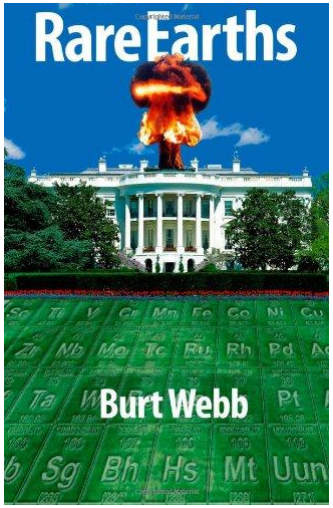


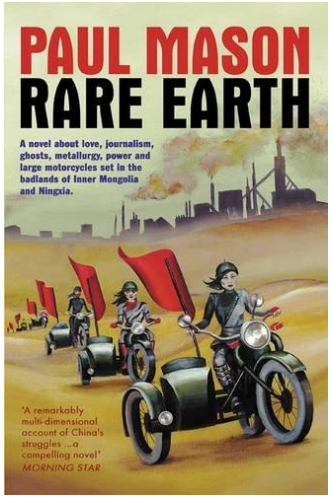


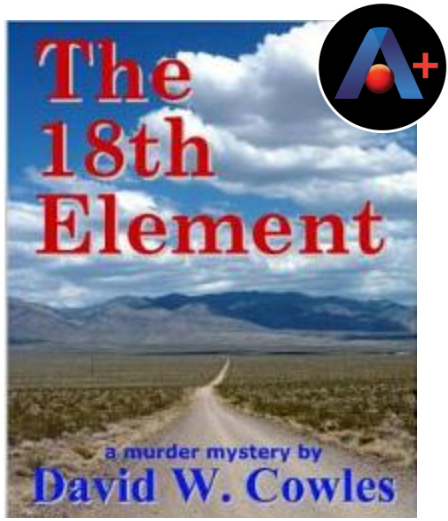












Critical materials are not new

- "The stone age did not end for lack of stone" – *Sheik Ahmed Zaki Yamani*.

- The copper age replaced the stone age because copper was better for some things.

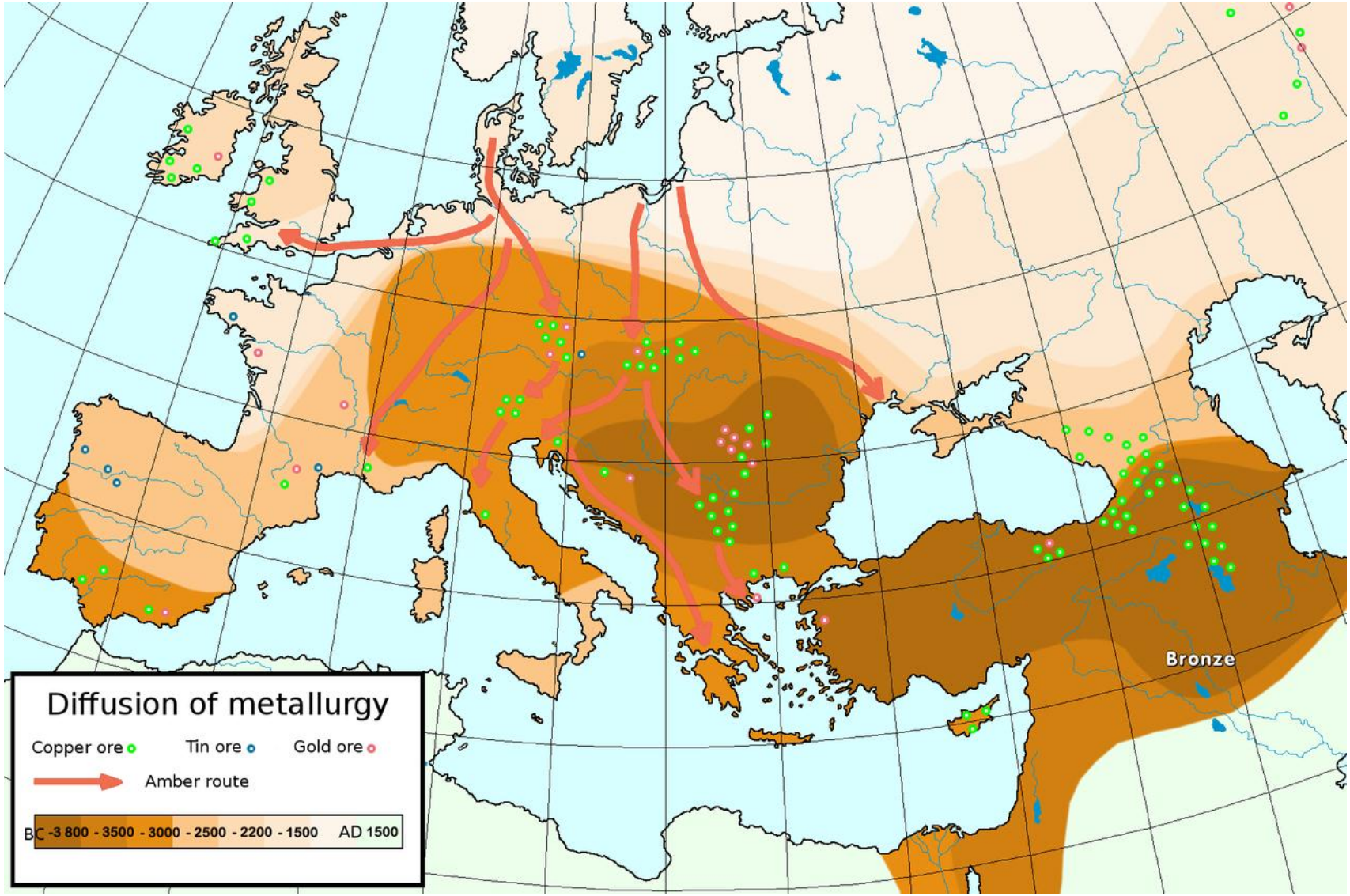
- The bronze age replaced the copper age because bronze was better than copper.

- But the bronze age was not replaced by the iron age. It ended because copper became unavailable.

Iron vs. Bronze, 1200 BC

- Processing
  - Bronze is manufactured at lower temperatures
- Hardness
  - Bronze is better, because no effective hardening mechanisms are yet available for iron.
- Corrosion
  - Bronze is better
- Cost
  - Iron is nine times more expensive than gold

Bronze age trade and industry



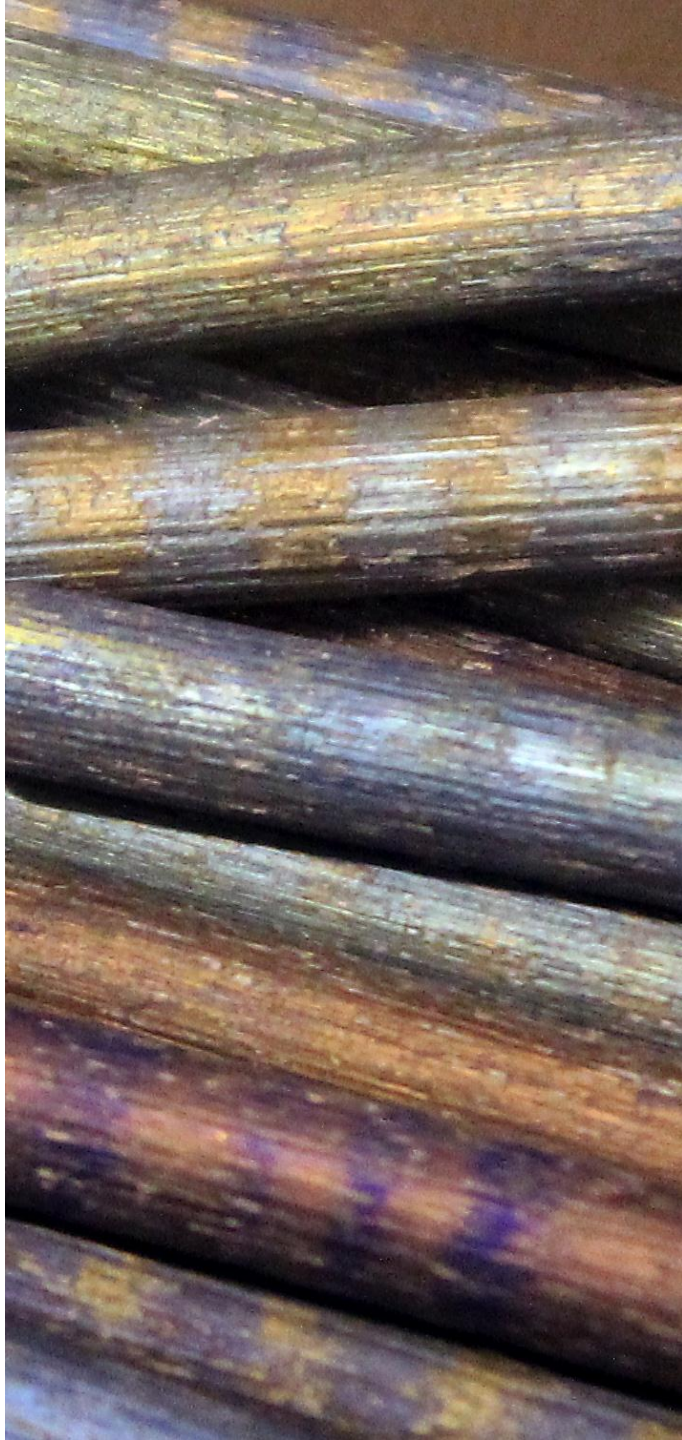
Wikipedia (After M. Otte (2007) Vers la Préhistoire, de Boeck, Bruxelles)

The Bronze Age Collapse ~1200 BC

- "Global" events
  - Natural disasters: earthquakes, climate change, famine
  - Wars, revolts, invasions
  - Collapse of trade; collapse of civilization
- Bronze becomes unavailable
  - Possibly because Cyprus is overtaken by war, making copper inaccessible.
- Responses include
  - Recycling
  - Source diversification
  - Materials substitution: eventual emergence of the iron age

What is a “Critical Material?”

- Any substance used in technology that is subject to supply risks, and for which there are no easy substitutes.
- Or, in plain English – stuff you really need but can’t always get.
- The list of materials that are considered critical depends on *who*, *where* and *when* you ask.
- CMI focuses on clean energy technologies, in the US, over the next 10 to 15 years.



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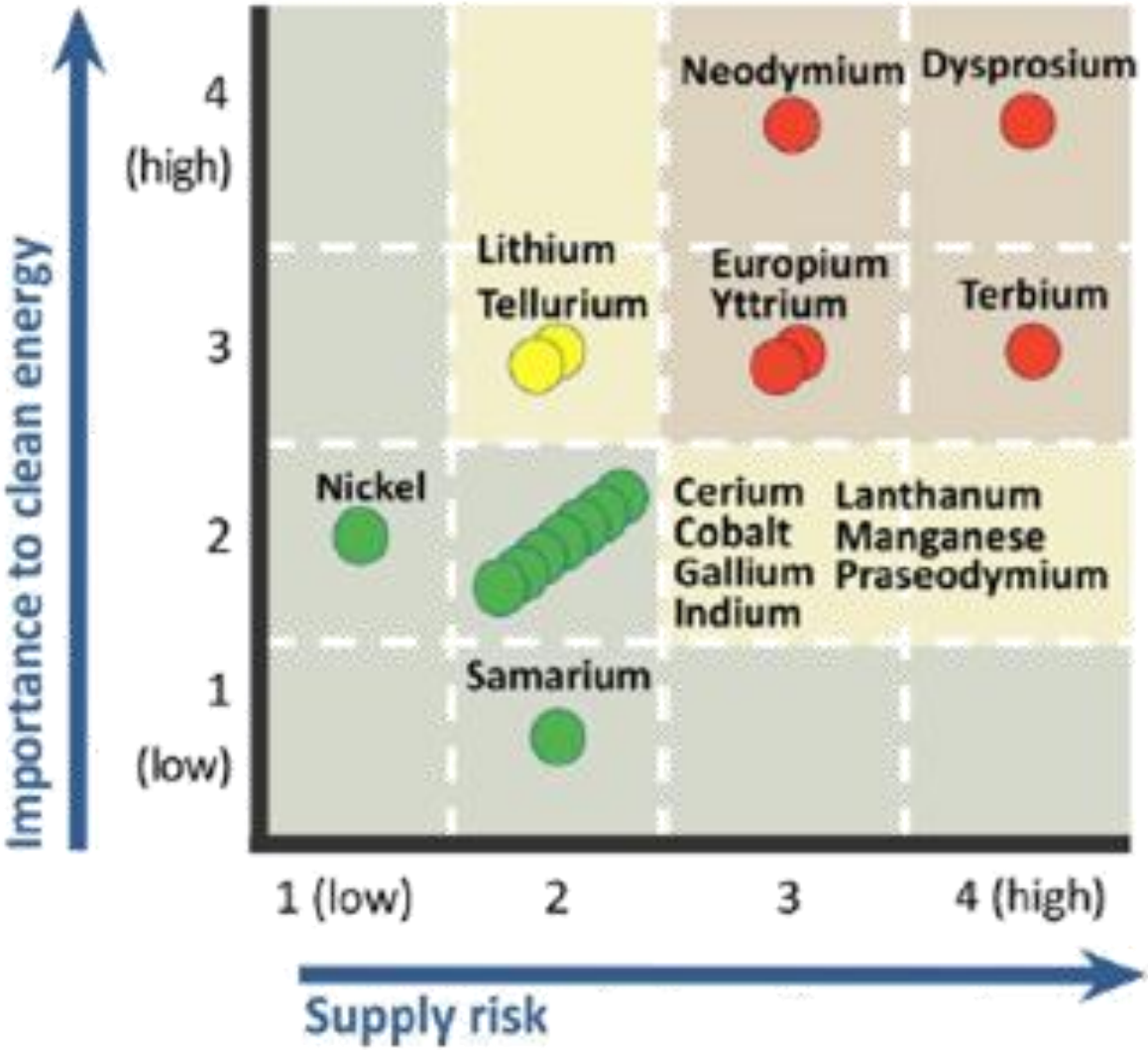
Materials criticality is affecting us *today*

- The target date for transition to high-output T5 fluorescent lamps has been delayed by two years because manufacturers claim that there is a shortage of Eu and Tb for the phosphors.

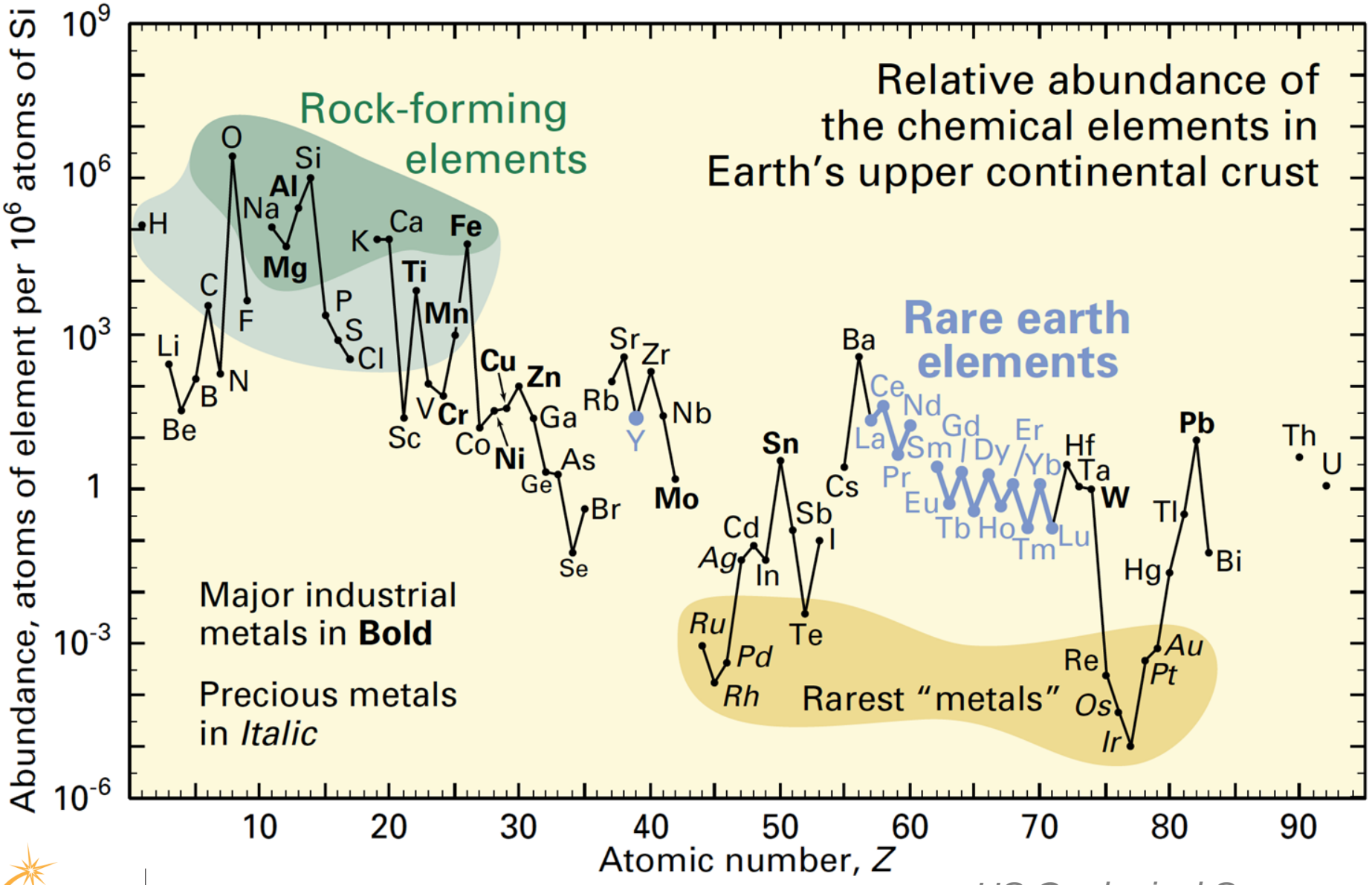
- Utility-scale wind turbine installations are overwhelmingly gearbox-driven units, despite the high failure-rate of the gearboxes, because of the cost and unavailability of Nd and Dy required for direct-drive units.

How is criticality assessed?



DOE Medium Term Outlooks: *2015 – 2025*

“Abundance” is not necessarily the issue



US Geological Survey

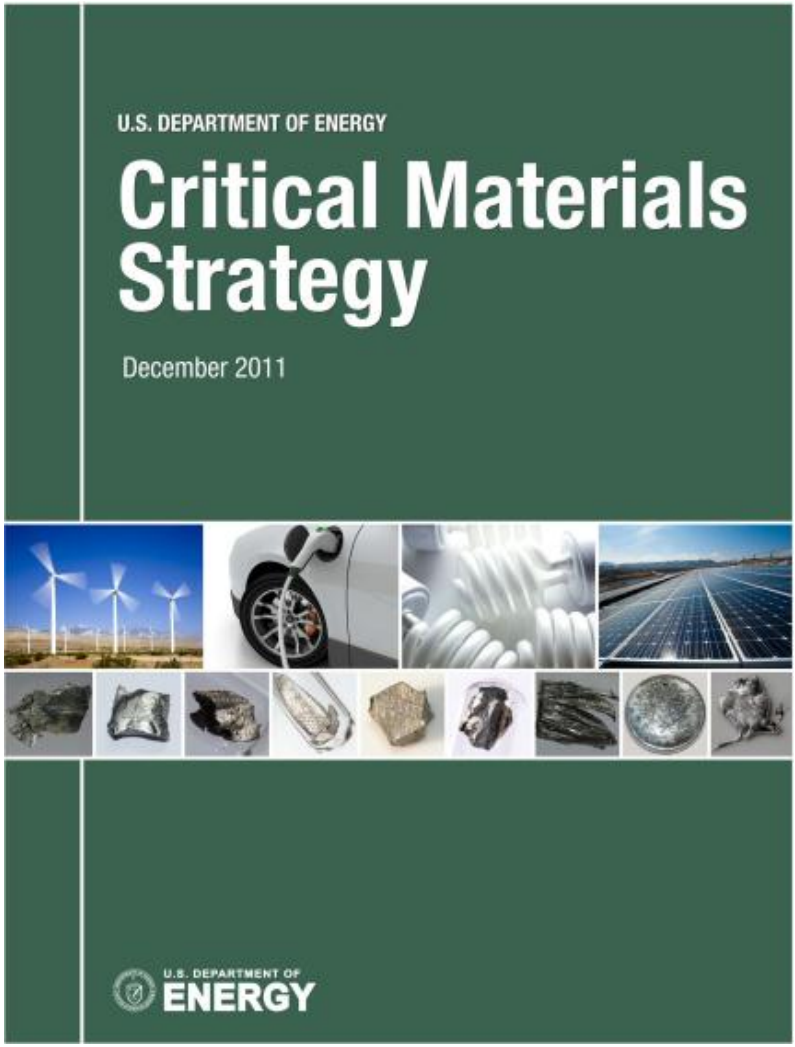
A three-pillared research strategy

Find ways to:

- diversify our sources;
- provide alternatives to the existing materials;
- make better use of the existing supplies.

Some of these approaches work better than others for specific materials.

All of them take time.



Invention disclosures

- Extraction of rare earth elements from phosphoric acid streams
- Extraction of rare earths from fly ash
- Recovery of neodymium from neodymium iron boride magnets
- Membrane solvent extraction for rare earth separations
- Selective composite membranes for lithium extraction from geothermal brines
- Methods of separating lithium-chloride from geothermal brine solutions
- Recovery of Dy-enriched Fe alloy from magnet scrap alloy via selective separation of rare earth elements
- Aluminum nitride phosphors for fluorescent lighting
- Novel surface coatings to improve the functional properties of permanent magnets

Invention disclosures – *page 2*

- Additive manufacturing of bonded permanent magnets using a novel polymer matrix
- Ceria-based catalyst for selective phenol hydrogenation under mild reaction conditions
- Recycling and conversion of samarium cobalt magnet waste into useful magnet
- Catalysts for styrene production
- Recycle of Fe Nd B machine swarf and magnets
- Task specific ionic liquids extractive metallurgy or rare earth minerals
- Separation of neodymium from praseodymium
- High throughput cost effective rare earth magnets recycling system

Take home messages

- Materials that are difficult to live without and have only a small number of suppliers should be a matter of concern to any manufacturer.

- Rare earth elements are at the top of every list of critical materials, but they are not the only ones to consider.
  - We expect other materials to be of concern to particular manufacturers.
  - We expect other materials to be critical at other times.

- The Critical Materials Institute wants to hear from you!

Thank You!

Questions?

https://cmi.ameslab.gov