

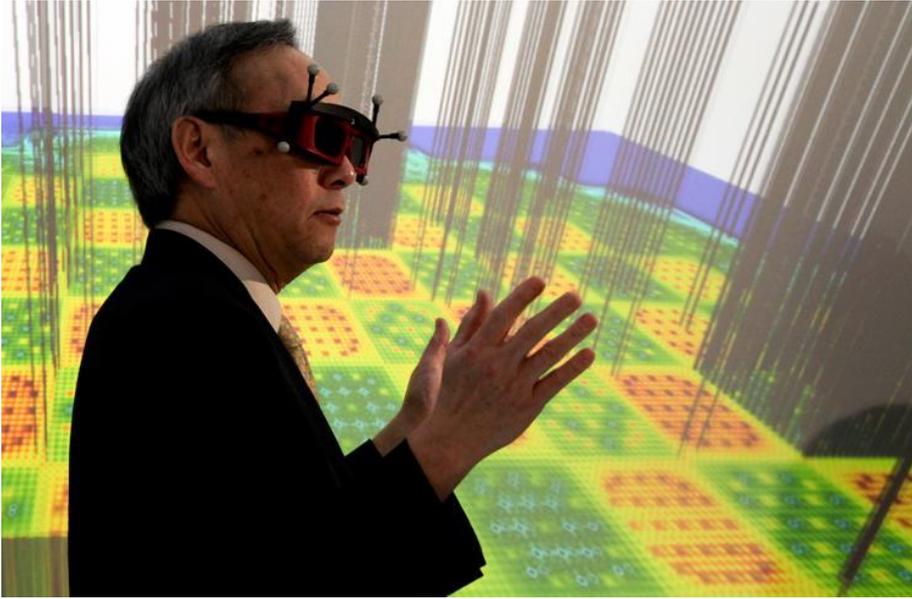


Critical Materials Institute



U.S. DEPARTMENT OF
ENERGY

What are Energy Innovation Hubs?



Integrated research centers that combine basic and applied research with engineering to accelerate scientific discovery in critical energy issue areas.

- Leadership is vested in scientists who are given the authority to assign funds where they are most effectively used
- \$20M - \$25M per year, for 5 years, renewable for an additional five.

- CASL: Consortium for Advanced Simulation of Light-Water Reactors
- EEB: Energy Efficient Buildings Hub
- JCAP: Joint Center for Artificial Photosynthesis
- JCESR: Joint Center for Energy Storage Research
- CMI: Critical Materials Institute

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.



Critical Materials are Not New



- “The stone age did not end because we ran out of stones” – Steven Chu.



- 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 was unavailable.

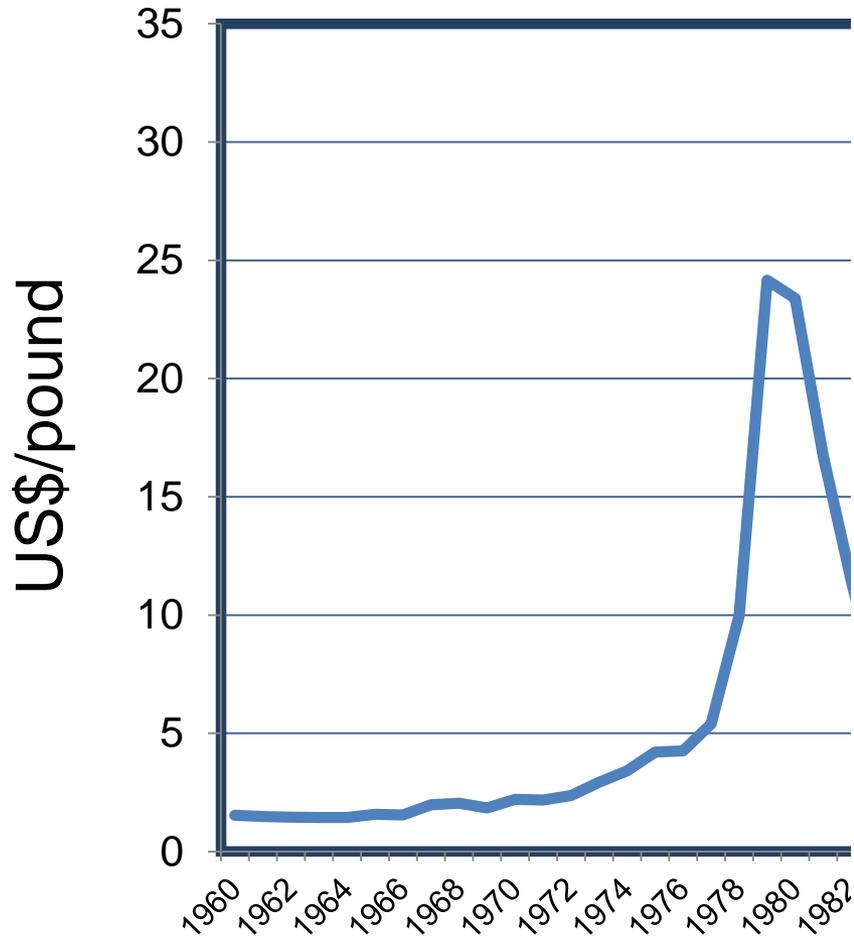
The Bronze Age Collapse

~1200 BC

- **Bronze becomes unavailable**
 - Possibly because Cyprus is overtaken by war, making copper inaccessible.
- **Responses include**
 - Recycling
 - Source Diversification
 - Materials Substitution
- **Results**
 - Collapse of civilization; collapse of trade
 - Strengthening of Egypt, which had alternative sources in Africa
 - Eventual emergence of the iron age



Annual Average Cobalt Prices



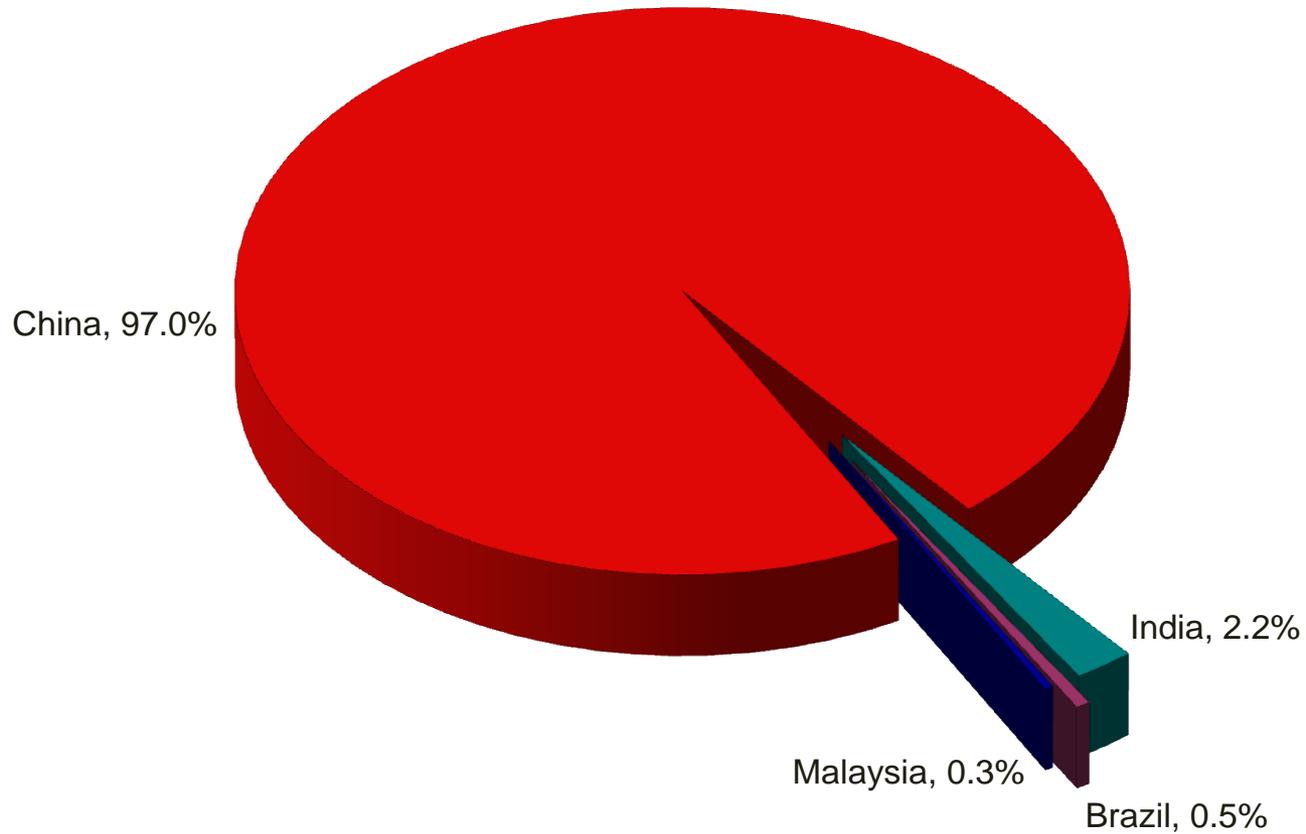
Materials criticality is affecting us today

- 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.



World Rare Earth Production in 2008

124,000 metric tons of contained rare-earth oxide (REO)



Most solutions take effect “tomorrow”

- Mine development, *where there is a known resource*, takes at least 10 years.
- Deployment of substitute materials, *when there is an existing option*, takes an average of 4 years.
- Development and deployment of *new* substitute materials takes an average of 18 years.

The Ames Laboratory is the world's leading rare earth research center

Rare Earths

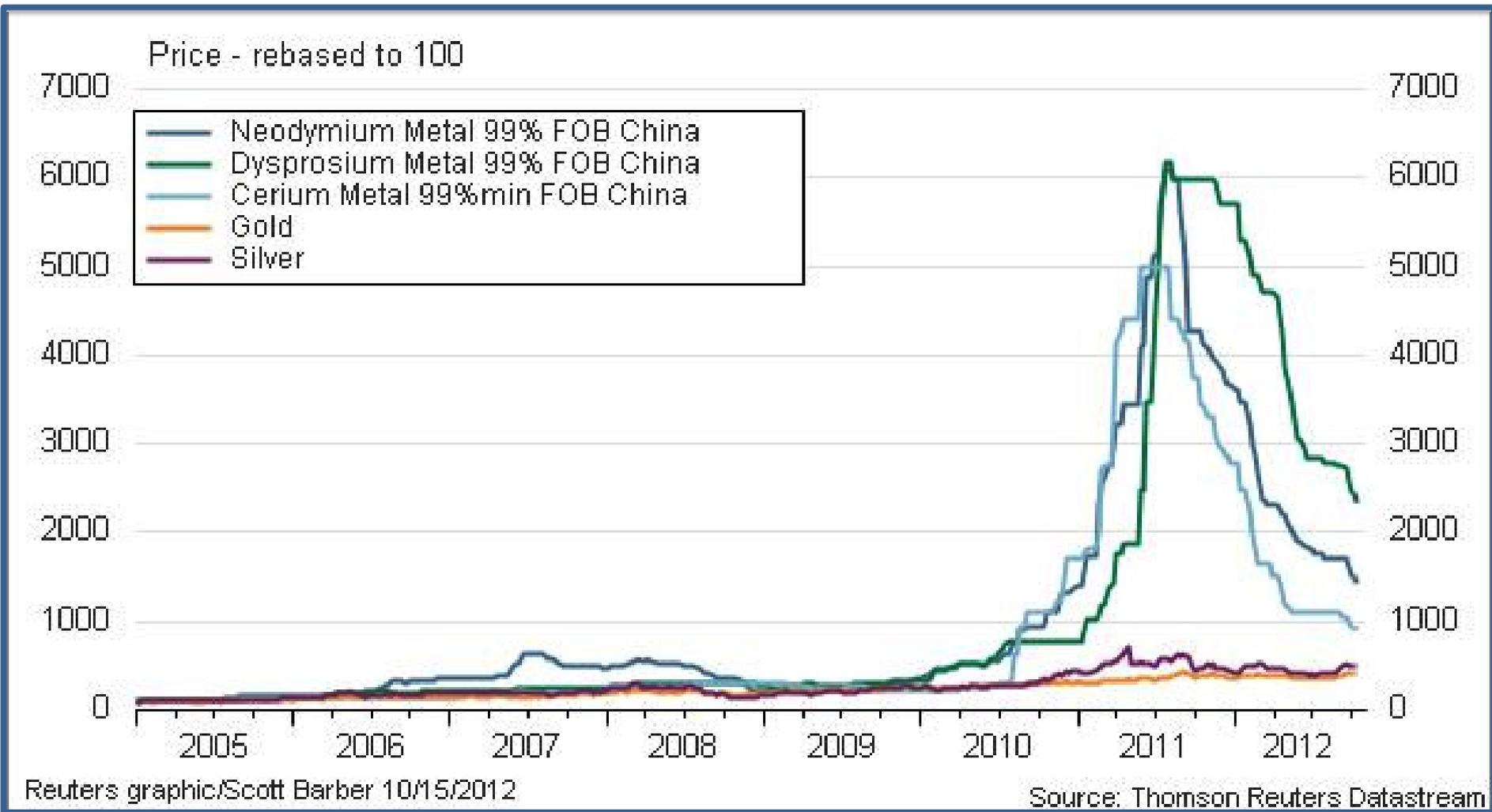
- Research
- Knowledge resources
- High-purity metals & materials

THE Ames Laboratory
Creating Materials & Energy Solutions
U.S. DEPARTMENT OF ENERGY

The image shows a periodic table with a red border highlighting the rare earth elements. The highlighted elements are Scandium (Sc, 21), Yttrium (Y, 39), and the Lanthanide series (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and the Actinide series (Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr). The Ames Laboratory logo and name are also present.

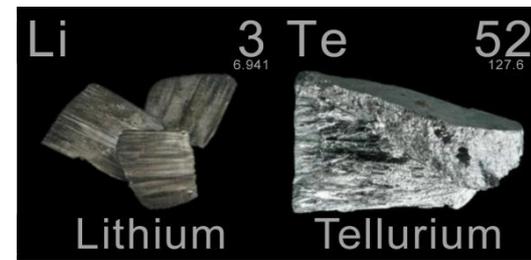
1 H Hydrogen	2 He Helium															
3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon									
11 Na Sodium	12 Mg Magnesium	13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon									
19 K Potassium	20 Ca Calcium	21 Sc Scandium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon			
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium		

Rare Earth Prices compared to Gold & Silver



The Mission of CMI

Eliminate materials criticality as an impediment to the commercialization of clean energy technologies for today and tomorrow.



Four CMI Outcomes



Workers at Acciona Wind Power in West Branch, Iowa assemble a casing around the nacelle of a wind turbine. Credit Clay Masters / IPR

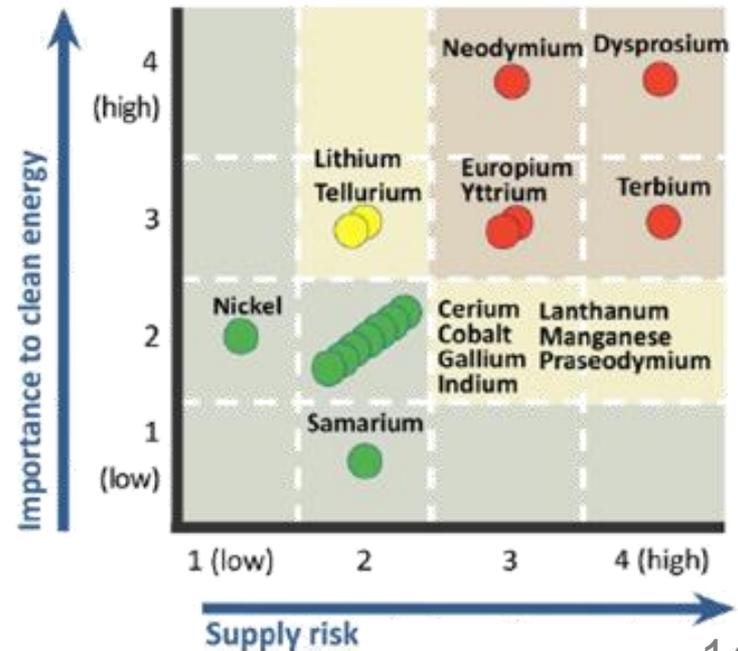
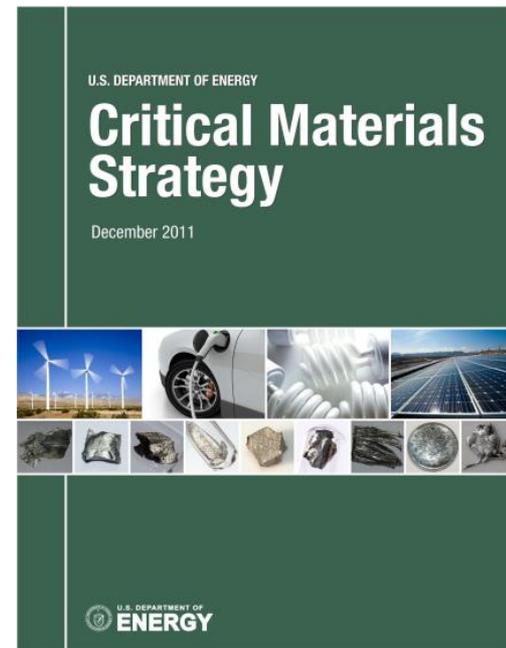
- Materials supply chains assured for clean energy manufacturing in the US
 - Current critical materials issues solved
 - Future criticality issues identified and averted
- Supplies of technical talent and expertise assured
- Critical materials information provided to researchers, producers & OEMs
- Federal critical materials research efforts coordinated for maximum impact

Three-D Approach

- Diversify supply
- Develop substitutes
- Drive reuse, recycling, and efficient use of materials in manufacturing

Essentially following DOE's Critical Materials Strategy, but applying it very selectively

Medium Term Outlooks:
2015 – 2025



Two Guiding Principles

- Produce more

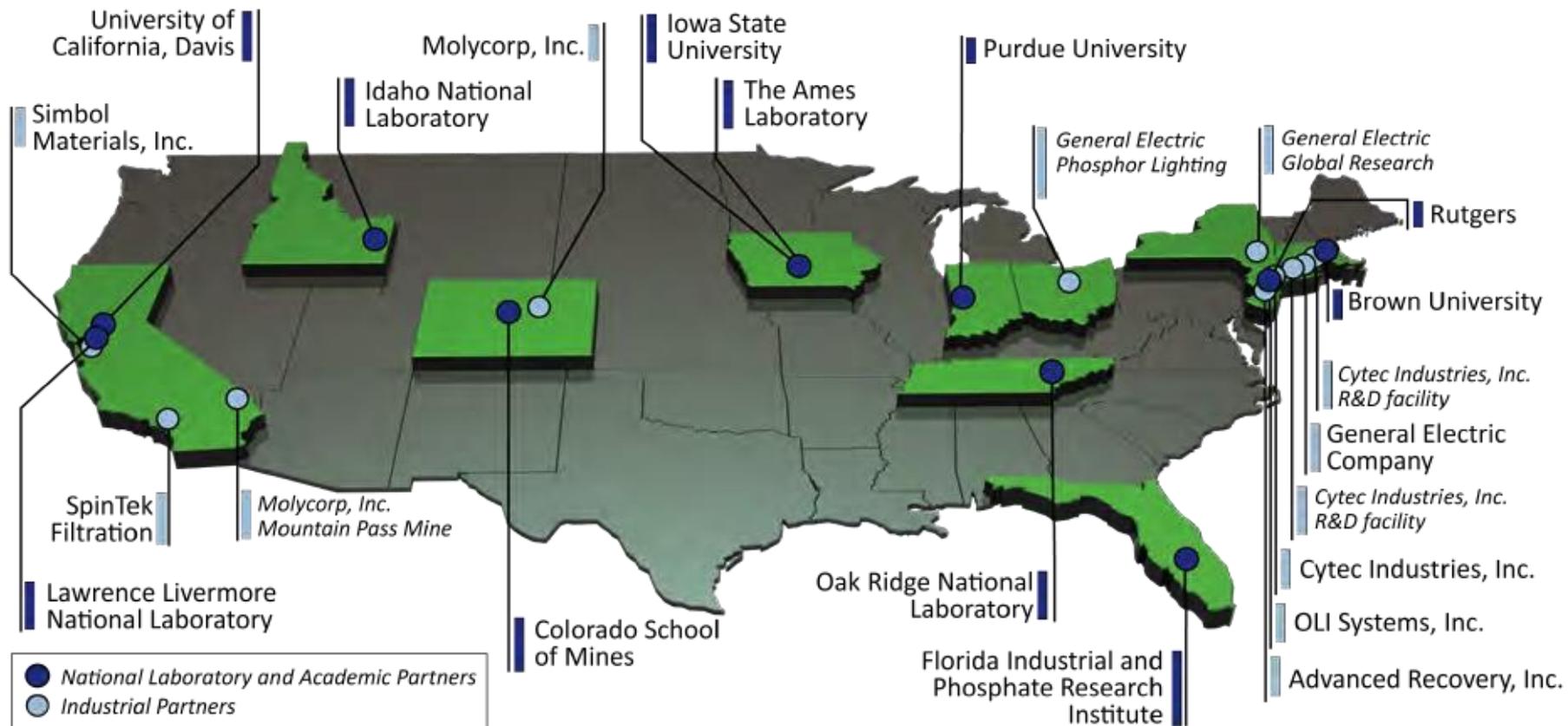


- Use less



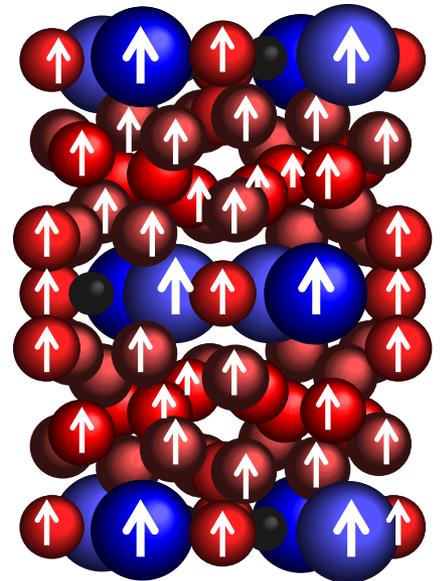
- We have to address the entire materials lifecycle, going from birth through death, and beyond, to include resurrection.

One Integrated Team



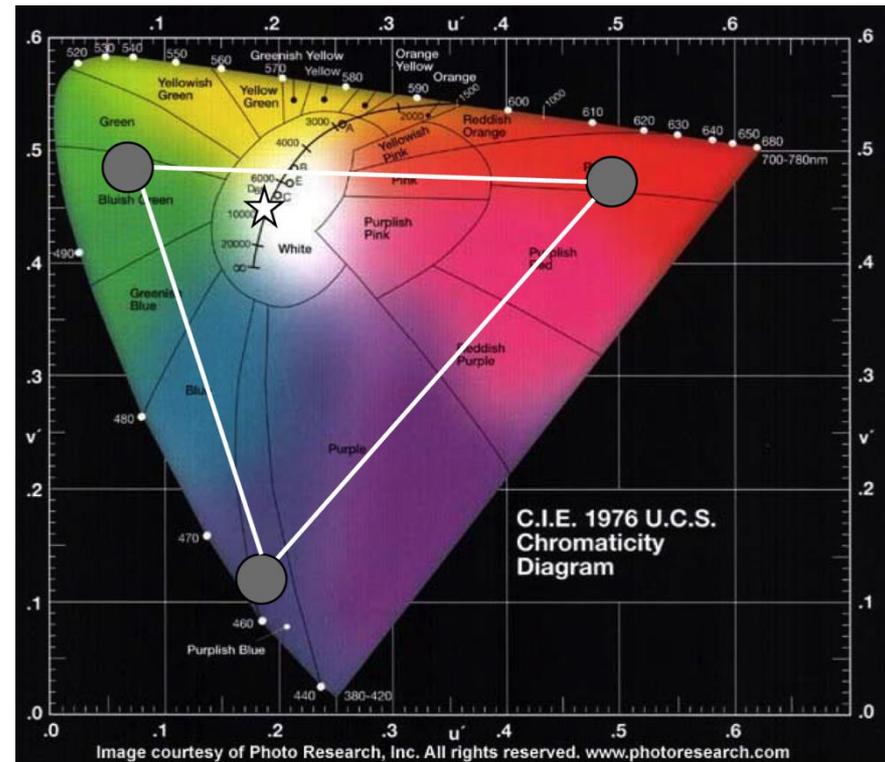
Neodymium

- Used for high-performance magnets
- Traditional uses:
 - Hard disk drive spindle motors
 - Portable electronics - loudspeakers & microphones
 - Small motors in vehicles
- Emerging uses:
 - Traction motors in electric vehicles
 - Wind turbine generators



Terbium & Europium

- Provide green and red light emission
- Traditional uses:
 - CRTs
 - Long-tube fluorescent lamps
 - Flat panel color displays and TVs
- Current uses:
 - Compact fluorescent lamps
 - Personal electronics
- Future uses:
 - LED lighting
 - OLED displays



Thank You!

Questions?