

Securing Our Competitiveness

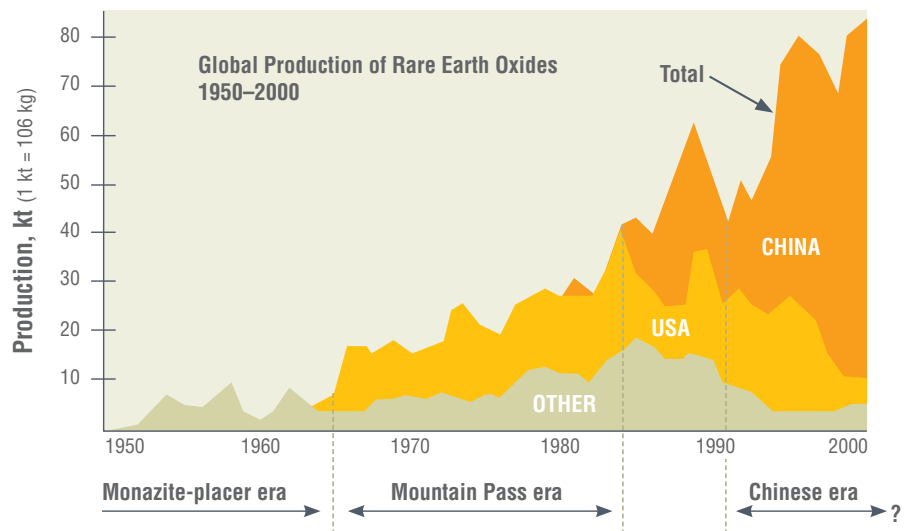
Sustained investment in scientific research and education is critical for energy solutions of the future

Current funding: DoD, DoE, NSF

Rare Earth Elements (REEs) are critical to our energy future

- Thin film semiconductors
- Advanced batteries
- Permanent magnets
- Phosphors

But: Current foreign dominance in REE production can lead to an uncertain future



A sustainable US competitive position requires continued, increased investment in scientific research

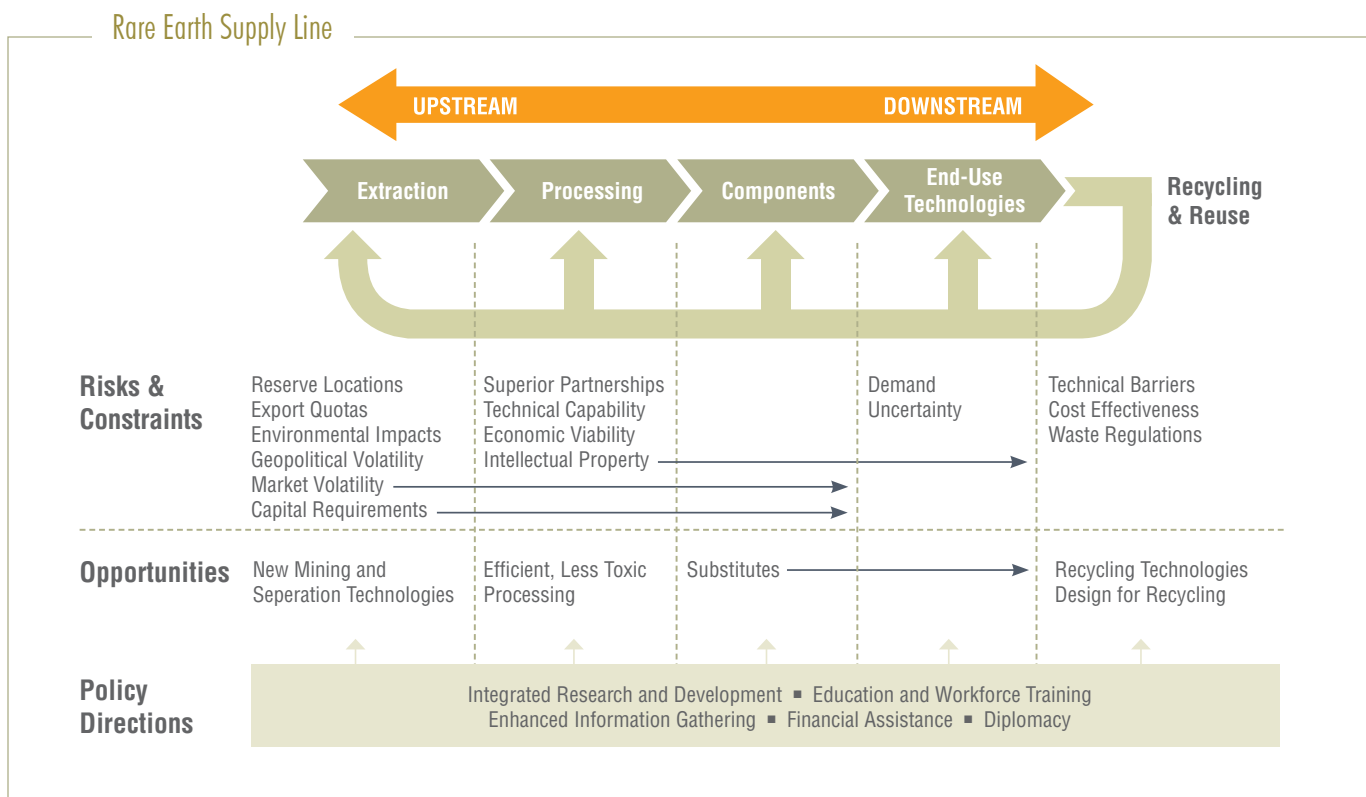
Develop Talent

Supply Line Enabling
(ex. mining, processing, recycling)

Substitution Research

The federal government has a crucial role in providing scientific research and educational support for programs through the DoD, DoE, NSF, as well as related programs in the national laboratories.

Recent reports released by the **Materials Research Society/American Physical Society** and the **Department of Energy** identify a complex global supply chain for **Energy Critical Elements (ECEs)** that could threaten America's competitiveness in the rapidly-growing technology marketplace. Near term investment in RESEARCH and EDUCATION is crucial to long term sustainability.



▼ ECEs and REEs are Pervasive in the US Economy

There is an increasingly urgent focus on a class of critical/strategic materials being used in consumer, industrial, and defense applications. These “Energy Critical Elements” are often the essential components that make the end-product unique in performance.

Many clean energy technologies—including wind turbines, electric vehicles, photovoltaic solar cells, and fluorescent/LED lighting—now employ materials which are at risk of near term supply disruptions, and in need of alternatives to ensure long term availability.

When widely deployed, these materials and their associated technologies have the capacity to transform the way energy is produced, transmitted, stored and conserved. To meet our energy needs and reduce our dependence on fossil fuels novel energy systems must be scaled from laboratory, to demonstration, to widespread use.

Future investments by the federal government to support basic research in Energy Critical Elements are needed to maintain the projected growth of the ECE domestic markets.



▼ ECE Energy Applications

Lithium (Li) batteries will power hybrid and electric vehicles

Market: currently just under **\$1B** (2010); estimated to grow to **\$50–100B** by 2015

Neodymium (Nd) permanent magnets drive wind turbine engines

Market: Nd magnets comprise 90% of **\$9B** rare earth magnet market—an important piece of the **\$45B** global wind turbine market, predicted to be **\$60B** domestically by 2015

Tellurium (Te) is a requirement for efficient thin film solar panels

Market: Cadmium Telluride (CdTe) will take a large share of the **\$40B** (2010), **\$80B** (2015) PV market

Indium (In) is an important element in light emitting diode (LED) lighting

Market: High Brightness LEDs make up **\$5–10B** of **\$100B** of the current general illumination market; **\$15B** by 2013

Terbium (Tb) is used in new compact fluorescent (CFL) lights replacing incandescent

Market: Majority share of transforming market—at least **\$80B** in the near term



Global competitors have shown a willingness to make investments necessary to secure strategic materials and support the valued added processing and creation of new finished products. In the case of REEs, the US previously performed all stages of the rare earth element material supply chain. China is now the predominant source of rare earth ores and processing, generating a potential dominant position with respect to global supply and prices.

Additional competitors will emerge in these dynamic markets in the years to come and a shortage of ECEs could significantly inhibit the adoption of otherwise game-changing energy and defense related products. If this were to happen it could significantly limit the competitiveness of US industries, the domestic scientific enterprise, and eventually diminish the quality of life in the US.



Possible Energy-Critical Elements (ECEs)

Legend:

- Rare Earth Elements (Purple)
- Platinum Group Elements (Blue)
- Photovoltaic ECEs (Green)
- Other ECEs (Orange)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
H Hydrogene 1.00794	He Helium 4.0026																			
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Li Lithium 6.941	Be Beryllium 9.01218																			
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Na Sodium 22.98977	Mg Magnesium 24.305																			
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
K Kalium 39.098	Ca Calcium 40.078	Sc Scandium 44.9559	Ti Titane 47.867	V Vanadium 50.942	Cr Chrome 51.996	Mn Calcium 54.938	Fe Fer 55.845	Co Cobalt 58.933	Ni Nickel 58.693	Cu Cuivre 63.546	Zn Zinc 65.408	Ga Gallium 69.723	Ge Germanium 72.64	As Arsenic 74.922	Se Selenium 78.96	Br Brome 79.904	Kr Krypton 83.798			
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
Rb Rubidium 85.467	Sr Strontium 87.62	Y Yttrium 88.9059	Zr Zirconium 91.224	Nb Niobium 92.906	Mo Molybdene 95.94	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.906	Pd Palladium 106.42	Ag Argent 107.868	Cd Cadmium 112.411	In Indium 114.818	Sn Etain 118.710	Sb Antimoine 121.760	Te Tellure 127.60	I Iode 126.904	Xe Xenon 131.293			
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	
Cs Cesium 132.90547	Ba Baryum 137.32	La Lanthane 138.905	Hf Hafnium 178.49	Ta Tantale 180.947	W Tungstene 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.227	Pt Platine 195.084	Au Or 196.967	Hg Mercure 200.59	Tl Thallium 204.383	Pb Plomb 207.2	Bi Bismuth 208.980	Po Polonium (209)	At Astate (210)	Rn Radon (222)			
87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	
Fr Francium (223)	Ra Radium (226)	Ac Actinium (227)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (266)	Bh Bohrium (264)	Hs Hassium (277)	Mt Meitnerium (268)												
58	59	60	61	62	63	64	65	66	67	68	69	70	71							
Ce Cerium 140.116	Pr Praseodyme 140.908	Nd Neodyme 144.242	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.925	Dy Dysprosium 162.500	Ho Holmium 164.930	Er Erbium 167.259	Tm Thulium 168.934	Yb Ytterbium 173.04	Lu Lutetium 174.967							
90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106				
Th Thorium 232.038	Pa Prasectinium 231.036	U Uranium 238.029	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)							

Possible Energy-Critical Elements (ECEs) are highlighted on the periodic table. The rare earth elements (REEs) include lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). The closely related elements scandium (Sc) and yttrium (Y) are often included as well. The REEs are considered as a family, although Pm is unstable, and Ho, Er, and Tm have no energy-critical uses at present and are omitted from our list. Y together with the Tb—Lu form the heavy rare earth elements (HREE), and Sc plus Ce—Gd constitute the light rare earths (LREE). The platinum group elements (PGEs) include ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt). Additional ECE candidates include gallium (Ga), germanium (Ge), selenium (Se), indium (In), and tellurium (Te), all semiconductors with applications in photovoltaics. Cobalt (Co), helium (He), lithium (Li), rhenium (Re) and silver (Ag) round out the list.