NATIONAL CENTER FOR POLICY ANALYSIS

Critical Minerals: Rare Earths and the U.S. Economy

Backgrounder No. 175 by Ann Norman, Xinyuan Zou and Joe Barnett September 2014

Rare earths are 17 elements in the Earth's crust used in a variety of applications, from hybrid cars and x-ray units to cell phones and wind turbines. When it comes to little-known resources, rare earths are probably the world's most important — they are small but necessary components of a vast range of consumer goods that account for hundreds of billions of dollars in gross domestic product.

Dallas Headquarters:
14180 Dallas Parkway
Suite 350
Dallas, TX 75254

www.ncpa.org

Washington Office:
600 Pennsylvania Ave., SE
Suite 400
Washington, DC 20003
202.830.0177

National Center for Policy Analysis

Yttrium, for example, is used in cancer treatment drugs and camera lenses, while scandium is a critical part of televisions and energy-efficient lighting. World demand for these elements is high and growing, as applications for rare earths cover a large swath of industries.

Unfortunately, the United States is largely dependent on China for these critical minerals, posing a serious threat to the American economy. With few suppliers, disruptions in the Chinese rare earth market lead to price fluctuations, with ripple effects across rare earth-dependent industries. Notably, the United States has a considerable rare earths supply; what it lacks is an efficient permitting process to attract investment and promote extraction. As a result, significant portions of the American economy are reliant on China, based on these largely unknown — but highly critical — minerals.

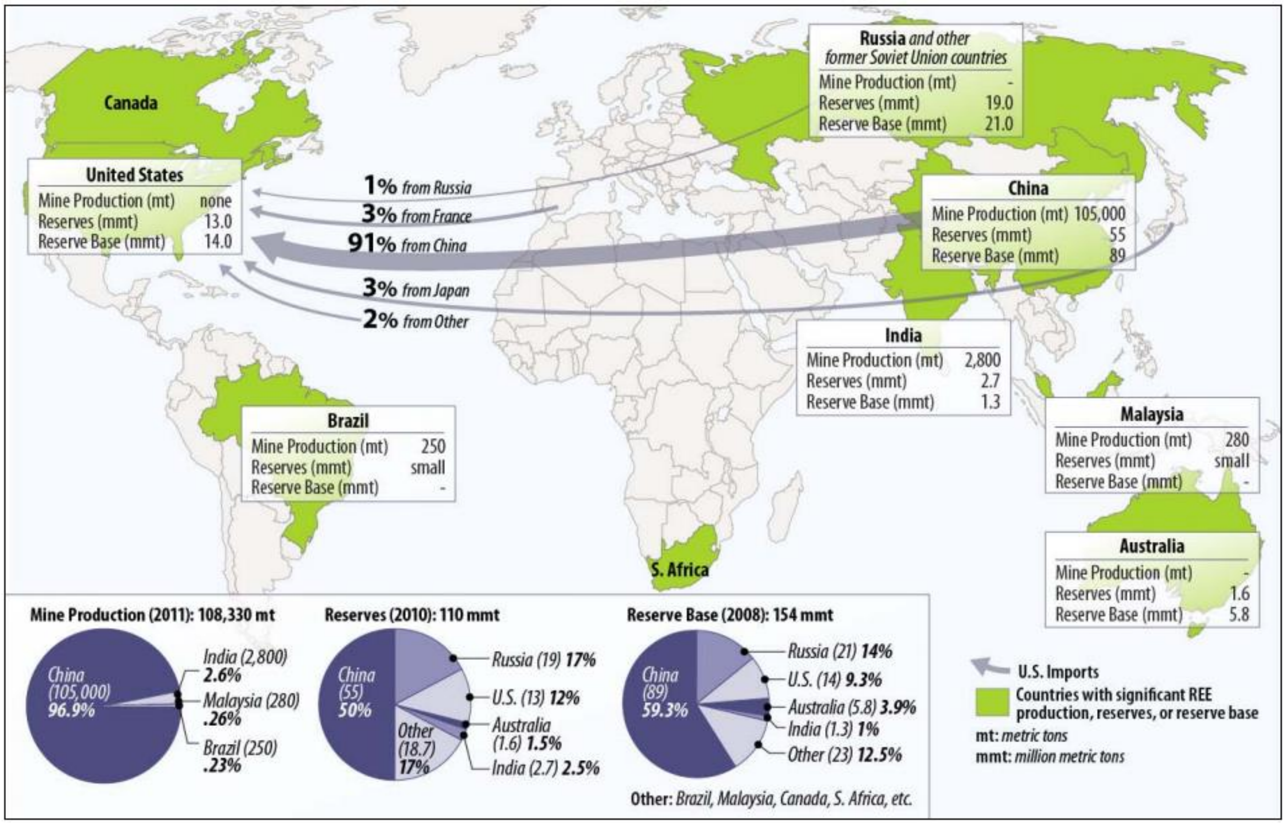
Supply of Rare Earths

Despite their name, rare earths (REs) are relatively abundant; even the two least common REs are almost 200 times more abundant than gold.[1] However, REs are generally not concentrated together, making extraction expensive and often uneconomical.[2] While the United States holds 13 percent of the world's rare earth reserves, China dominates the industry, with an estimated 50 percent of global RE reserves and 95 percent of all RE production.[3]

Moreover, China's dominance does not stop with extraction. After rare earths are mined, they must be separated, refined into metals, alloyed, and the products containing them must be manufactured. China also dwarfs other countries in these supply chain activities, producing 89 percent of rare earth metal alloys, and three-fourths of the world's permanent magnets.[4]

The United States was once self-sufficient in rare earths. From 1965 to 1985, U.S. industry performed all stages of rare earths processing, and California's Mountain Pass mine ranked as the world's leading producer of REs. But problems with the mine led to its closure in 2002, and three major

Figure I
Rare Earth Elements: Global Production, Reserves and U.S. Imports



Source: Marc Humphries, "Rare Earth Elements: The Global Supply Chain," Congressional Research Service, December 16, 2013, page 11. Available at http://fas.org/sgp/crs/natsec/R41347.pdf.

rare earths manufacturers closed their American facilities soon after.[5] China's dominance over the rare earths industry began to grow in the 1990s, swelling to a near monopoly today.[6]

In 2010, the Mountain Pass mine in California resumed activities and became fully operational in 2013.[7] Today, it is the only producing RE mine in the United States. But ramping up U.S. mining activity is just one part of the rare earths puzzle, as the United States largely lacks the capacity to process the raw materials into finished components.[8] The Government Accountability Office say rebuilding a domestic rare earths supply chain could take up to 15 years.[9]

Other countries with rare earths production or known reserves include Canada, Russia, France, Japan, India, Brazil, Malaysia, South Africa and Australia.[10] The United States imports rare earths from several of these countries, but from 2008 to 2013, 91 percent of American imports came from China. [See Figure I.]

Economic Importance and Demand

Rare earths are critical components of many products, including magnets, material additives and batteries, and they support a wide variety of end-market technologies used in medicine, electric and hybrid vehicles, lighting, communications systems and defense. [See Table I.]

Uses of Rare Earths. To get a sense of various RE uses and applications, consider the array of products that utilize these elements:[11]

- Rare earths are widely used in pharmaceuticals. Cerium oxalate is used to treat motion sickness, while lanthanum nitrate is used as an antiseptic and cerium-141 is used in medical research.
- Fertilizers with rare earth components improve cotton and oil-plant crops. They increase chlorophyll content and the photosynthesis rate, raise plant yields and improve nutrient uptake.
- The aircraft and shipbuilding industries used gadolinium to find undetected flaws in fuselages and hulls.
- Cerium oxide is the most efficient polishing agent for most forms of glass and is used to polish corrective lenses, televisions and computer monitors.
- Batteries containing rare earths represent 32 percent to 35 percent of the battery industry. Lanthanum, which is widely used in laptop computers, allows for extended battery life.
- Rare earth magnets reduce power use, as well as the size and weight of products. They are used in everything from power steering to brakes, laser gun sights, fax machines, headphones and HVAC (heating, ventilation and air conditioning) pumps.

Hardly exhaustive, this list illustrates the global economic scope of RE chemistry and demonstrates the unique capabilities of these elements. [See Table II.]

About 133,600 tons of REs were produced worldwide in 2010. World demand for rare earths is an estimated 136,100 tons per year and is expected to rise to 160,000 tons by 2016.[12]

U.S. Rare Earths Industry.[13] The U.S. rare earths mining industry is relatively small. In 2013, the value of North American rare earths shipments (the net selling value of products shipped from a mining or manufacturing business) totaled $795 million. [See Table III.] However, the value of REs to the American economy is quite significant, due to their widespread use in many common products. For example [see Table IV]:

- REs support more than $39 billion in revenue from intermediate products such as catalysts, polishing powders and glass additives. These industries employ 101,800 Americans and generate more than $6.1 billion in payroll.
- End-market products and technologies, including oil refining processes and wind power, use rare earths to generate over $259 billion in revenue. These industries support 433,500 jobs and $27.2 billion in payroll.
- In total, REs support more than $298 billion in revenue from downstream economic activity — 535,000 American jobs and more than $33 billion in payrolls.

RE elements provide important components for an array of applications: They have magnetic, luminescent and electrochemical properties that make for faster, more durable, high-performing, energy-efficient, lightweight products. As the American Chemistry Council reports, “Rare earth-enabled products and technologies help to fuel global economic growth, maintain high standards of living, and create

Table I

Basic Rare Earth Materials and Component Parts Using Rare Earths	End Market Products Using Rare Earths
Alloys	*Arthritis medicines*
Batteries	*Microphones*
Catalysts	*Cameras*
Ceramics	*MRIs*
Controls	*Consumer electronics*
Glass additives	*Night vision goggles*
Lasers	*HVAC systems*
Magnets	*Hybrid vehicles*
Metallurgical additives	*Lighting*
Phosphors	*Pacemakers*
Polishing powders	*Printers*
Sensors	*Televisions*
Transducers	*Wind turbines*

Source: “The Economic Benefits of the North American Rare Earths Industry,” Report by the American Chemistry Council for the Rare Earth Technology Alliance, April 2014. Available at http://www.rareearthtechalliance.com/Resources/The-Economic-Benefits-of-the-North-American-Rare-Earths-Industry.pdf.

Table II
Applications of Rare Earths

Element	Symbol	Light/Heavy	Common Uses
Scandium	Sc	Light	Scandium is often used to strengthen metals and is found in televisions and fluorescent lighting.
Lanthanum	La	Light	Lanthanum is used in wastewater treatment and petroleum refining, as well as telescope lenses, hybrid engines, and night vision goggles.
Cerium	Ce	Light	Cerium is used to reduce automotive emissions and polish computer chips and glass.
Praseodymium	Pr	Light	Praseodymium is used in rare earth magnets, which are used in wind turbines, among other applications. Praseodymium also strengthens other metals.
Neodymium	Nd	Light	Neodymium is used to create permanent magnets which fill nearly all modern vehicles, as well as aircraft and hand tools. It is an important component of computer discs and headphones, as well as lasers.
Promethium	Pm	Light	Promethium is used in pacemakers, watches, and compact fluorescent bulbs.
Samarium	Sm	Light	Samarium can kill cancer cells when used in radiation treatments. It is also used in nuclear reactors.
Europium	Eu	Light	Europium colors television sets and computer screens.
Gadolinium	Gd	Light	Gadolinium is especially useful in health care, as it can target tumors, enrich MRIs and even aid in diagnosing cancer.
Yttrium	Y	Heavy	Yttrium is in a vast array of products, including cancer treatment drugs, surgical arthritis medication, superconductors, light bulbs and camera lenses.
Terbium	Tb	Heavy	Terbium is found in x-ray screens, color televisions and fluorescent lighting, and it is a critical part of many defense technologies.
Dysprosium	Dy	Heavy	Dysprosium allows magnets to operate at high temperatures. It can be found in nuclear reactors, energy-efficient vehicles and hard computer disks.
Holmium	Ho	Heavy	Holmium can add color to glass, and it is used in microwave equipment as well as nuclear control rods.
Erbium	Er	Heavy	Erbium amplifies wavelengths, making it an important part of fiber optic communications systems. Many lasers use erbium.
Thulium	Tm	Heavy	Thulium is used in x-rays as well as lasers.
Ytterbium	Yb	Heavy	Ytterbium is used in cancer treatments. It can strengthen stainless steel and monitor earthquakes.
Lutetium	Lu	Heavy	Lutetium is important in petroleum refining and can be used to identify the age of items such as meteorites.

Source: “The Economic Benefits of the North American Rare Earths Industry,” Report by the American Chemistry Council for the Rare Earth Technology Alliance, April 2014, pages 2-4. Available at http://www.rareearthtechalliance.com/Resources/The-Economic-Benefits-of-the-North-American-Rare-Earths-Industry.pdf.

products that help to save lives."[14] [For the distribution of rare earth elements by application, see Table V.]

"Criticality" Assessments of Rare Earths

The National Research Council of the U.S. National Academies (NRC) has developed a criticality matrix to measure exactly how important minerals are to the U.S. economy. Criticality is a function of the *risk* of a supply disruption combined with the *impact* of that disruption — a mineral's supply risk depends upon its availability, while the impact of supply restrictions is a function of the element's importance in use and the existence of substitutes.

Risk of Supply Disruption. The risk of a supply disruption depends upon a number of factors, including:[15]

- Concentration of supply
- Geologic availability
- Increases in demand
- Political environment

Currently, the dominant factor in the United States is the first — supply concentration — as China's grip on the RE industry leaves the United States reliant on imports and Chinese trade policy. The NRC scored the supply risk for all RE applications high, the uppermost ranking within the criticality matrix. Indeed, the RE giant has begun to limit exports of its rare earths; in 2013, China's RE export quota was 31,438 metric tons, down from 50,145 metric tons in 2009 and 61,560 metric tons in 2006.[16]

In 2012, non-Chinese producers were responsible for just 15,000 metric tons of the 110,000 tons of rare earths produced globally that year.[17] With increasing demand both worldwide and in China, a Congressional Research Service report projects that to supply world demand in 2016 will require non-Chinese sources to produce 30,000 to 80,000 metric tons of REs.[18]

Heavy versus Light Rare Earths. China is also the source of the majority of the world's so-called "heavy" REs (HREEs) — scarcer and more valuable than "light" rare earths (LREEs), and more difficult to process.[19] The heavy and light categories refer to the elements' atomic numbers, though they also distinguish the minerals by abundance. Known HREE reserves in the United States are very small; yet, demand for heavy rare earths is on the rise. According to the United Nations, China's HREE supply could be depleted within two decades.[20]

Notably, China has proved willing to use its rare earths prowess as a weapon. Japan imports half of all of China's rare earths shipments. During a diplomatic dispute with Japan, China halted its RE supply to its neighbor nation for two months.[21] Fortunately, according to an official with a Japanese trading house, the country's manufacturers typically have three to five months' worth of rare earths stockpiled.[22]

Impact of Supply Disruption. Not only are REs widely used, they have few substitutes. For example:[23]

- Europium is used as a red phosphor in color cathode ray tubes and liquid crystal displays. It costs an astounding $2,000 per kilogram, and there is no substitute.
- Erbium is used in fiber-optic

Table III
North American Rare Earth Materials Shipments

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Shipments (million $)	$107	$114	$116	$118	$145	$204	$127	$225	$957	$923	$795

Note: This table depicts the net sales value of products shipped from a mining or manufacturing business.

Source: "The Economic Benefits of the North American Rare Earths Industry," Report by the American Chemistry Council for the Rare Earth Technology Alliance, April 2014, page 7. Available at http://www.rareearthtechalliance.com/Resources/The-Economic-Benefits-of-the-North-American-Rare-Earths-Industry.pdf.

Table IV

United States Economic Activity Supported by Rare Earths

Industry	Revenue ($ millions)	Employment (thousands)	Payroll ($ millions)
Intermediate Products	**$ 39,196**	**101.8**	**$ 6,110**
Magnets & Magnetic Powders	$ 517	0.8	$ 46
Catalysts	$ 3,562	4.2	$ 349
Metallurgical Additives	$ 18,157	46.3	$ 2,513
Polishing Powders	$ 425	0.3	$ 20
Phosphors	$ 349	0.6	$ 44
Glass Additives	$ 378	0.5	$ 33
Ceramics	$ 818	4.8	$ 200
Batteries	$ 3,746	8.6	$ 474
Other Components & Systems	$ 11,247	35.7	$ 2,432
End-Market Products & Technologies	**$259,365**	**433.5**	**$ 27,258**
Health Care	$ 10,795	99.3	$ 5,347
Hybrid, Electric, PHEVs & Other Vehicles	$ 65,864	67.7	$ 3,818
Lighting	$ 3,340	11.8	$ 586
Communications Systems	$ 7,584	19.5	$ 1,798
Audio Equipment	$ 2,810	6.5	$ 390
Defense Technologies	$ 12,413	30.6	$ 2,758
Other Electronics	$ 27,413	49.3	$ 3,227
Advanced Optics & Other Glass Products	$ 4,560	16.3	$ 813
Oil Refining	$ 85,652	7.1	$ 823
Wind Power	$ 10,389	8.2	$ 839
Other	$ 28,546	117.1	$ 6,858
Total Downstream Customer Sectors	**$298,561**	**535.2**	**$ 3,368**

Source: "The Economic Benefits of the North American Rare Earths Industry," Report by the American Chemistry Council for the Rare Earth Technology Alliance, April 2014, page 13. Available at http://www.rareearthtechalliance.com/Resources/The-Economic-Benefits-of-the-North-American-Rare-Earths-Industry.pdf.

telecommunication cables as laser amplifiers. There is no substitute for this element, and it costs an average of $1,000 per kilogram.

- Cerium is one of the most abundant and least expensive REs, costing only a few dollars per kilogram. However, it is used to polish nearly all mirrors and lenses used today.

In fact, 44 percent of U.S. rare earths consumption is in uses for which substitution is "difficult or impossible."[24] And the only available substitutes are generally less effective than their RE counterparts, according to the United States Geological Survey.[25]

Because of the bevy of applications and the increasing American consumption of REs, the NRC concluded that a disruption in supply availability "would have a major negative impact on our quality of life," giving rare earths an impact score of 3.15 out of four.[26]

The NRC deemed rare earths, as a group, to be critical minerals. [See Figure II.]

Criticality by Industry: Defense, Energy and Electronics

While the NRC criticality matrix assessed the role of REs across the U.S. economy as a whole, a closer look at specific industries reveals just how important it is to maintain an adequate supply chain of these elements. Indeed, supply cuts could be devastating to particular producers or sectors.

Defense. A 2010 Government Accountability Office (GAO) report explained that "[d]efense systems will likely continue to depend on rare earth materials, based on their…lack of effective substitutes."[27] Moreover, the GAO wrote that the future availability of rare earths — notably neodymium, dysprosium and terbium, which are heavily used in defense applications — "is largely controlled by Chinese suppliers."[28]

Indeed, rare earths are used throughout national defense, including laser detection, satellite communications, missile control systems and motors. Specifically:[29]

- Advanced jet aircraft engines depend upon yttrium thermal coatings to shield metal components from extreme heat.
- Rare earth permanent magnets that utilize neodymium move the fins of precision-guided munitions. Along with terbium and dysprosium, they are also used to silence rotor noise in stealth helicopter systems.
- Infantrymen use Ground Laser Target Designators to guide munitions to targets and

estimate ranges. These systems depend on garnets utilizing neodymium and yttrium.

- Military radar and detection systems — from sonar transducers to Multipurpose Integrated Chemical Agent Alarms (MICADs) — use neodymium, yttrium, lanthanum, lutetium and europium to amplify sounds and improve signal resolution.

In its *Strategic and Critical Materials 2013 Report on Stockpile Requirements*, the Department of Defense (DOD) reported a shortfall in the supply of 23 "strategic and critical" materials, including six rare earths: yttrium, dysprosium, erbium, terbium, thulium and scandium. The DOD recommended stockpiling these materials.[30]

The announcement was a change from 2012, when the DOD insisted there was an adequate supply of REs to match defense consumption. However, the 2012 DOD report was criticized for being less than thorough. For example, the 2012 report looked at mining but not manufacturing, did not analyze all heavy RE elements, and failed to mention China even once![31]

Energy. Some of the unique properties of rare earths allow the manufacture of lightweight, efficient components and final products. This is especially important for apllications where a reduction in energy use is desirable. But, as the *New York Times* notes, "for as long as the next 15 years, the supplies of at least five minerals that come almost exclusively from China will remain as vulnerable to disruption as they are absolutely vital to the manufacture of small yet powerful electric motors, energy-efficient compact fluorescent bulbs and other clean energy technologies."[32]

One of the biggest names in American energy is General Electric (GE), and GE is no stranger to critical minerals. The company currently uses 72 of the first 82 elements on the periodic table in its manufacturing — including all of the rare earths.[33] In July 2011, GE issued a report showing just how important the rare earths market is to the company's operations and illustrating how China's cuts to its RE export quotas affected prices:[34]

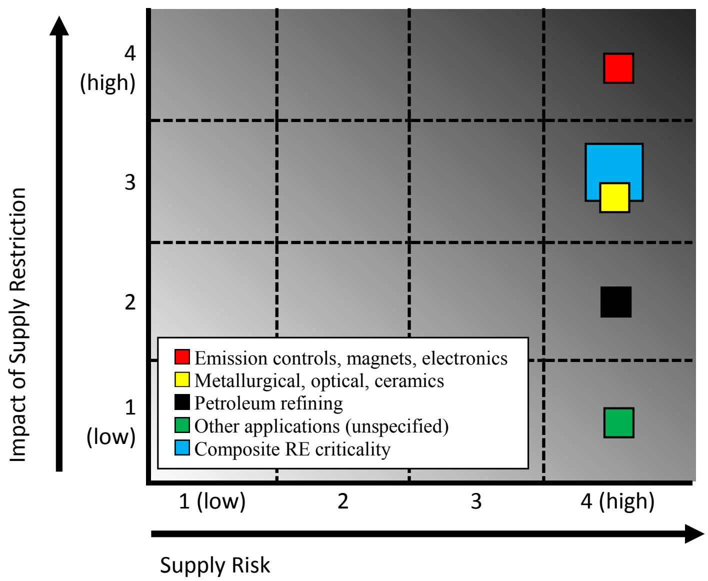
"Rare earths are undergoing extreme cost increases due to unprecedented market forces. In less than 12 months, costs of some rare earth oxide materials used in

Table V
Distribution of Rare Earth Elements by Application

Application	Sc	Y	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Alloys & metallurgical uses	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■
Batteries			■	■	■	■	■				■						
Catalysts		■	■	■	■	■		■		■							■
Ceramics	■	■	■	■	■	■		■	■	■		■	■	■	■		■
Electronics		■	■	■	■	■					■	■		■			
Fertilizers			■	■		■											
Glass	■																■
Lamps	■	■	■	■	■	■		■	■		■	■	■	■	■		
Lasers	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Magnets				■	■	■		■	■	■	■	■	■				
Medical & pharmaceutical uses			■	■		■		■	■	■			■	■			■
Neutron absorption		■		■				■	■	■		■	■	■			
Phosphors	■	■	■	■			■	■	■	■	■	■	■	■	■	■	■

Source: Donald I. Bleiwas and Joseph Gambogi, "Preliminary Estimates of the Quantities of Rare-Earth Elements Contained in Selected Products and in Imports of Semimanufactured Products to the United States, 2010," U.S. Geological Survey, Report No. 2010-1072, 2013, page 5. Available at http://pubs.usgs.gov/of/2013/1072/OFR2013-1072.pdf.

Figure II
Criticality of Rare Earths by Application



Source: *Minerals, Critical Minerals, and the U.S. Economy*, National Research Council of the National Academies (National Academies Press, 2008), page 136. Available at http://www.nap.edu/openbook.php?record_id=12034&page=136.

lighting products have experienced increases ranging from 500% to more than 2,000%, and they continue to climb. For perspective, if the rate of inflation on the rare earth element europium oxide were applied to a $2.00 cup of coffee, the new cost would be $24.55."

Europium is used in energy-saving light bulbs and, due to new federal efficiency standards, demand for the element will continue to rise, at least in the short-to-medium term.[35]

Similarly, consider dysprosium, one of five REs assessed as critical and essential for clean energy technologies by the Department of Energy (DOE).[36] Dysprosium is used in wind turbines and electric cars, because its unique properties allow permanent magnets to function at high operating temperatures in wind turbines and electric motors. As demand for green technology has risen, there has been a corresponding spike in demand for dysprosium. However, production is unlikely to keep pace with demand. According to a report from the Massachusetts Institute of Technology:[37]

- Dysprosium production is estimated to grow at 6 percent per year, at most.
- But to meet the expected rise in dysprosium demand, production would need to grow more than twice as fast, or 14 percent annually.
- By 2040, the supply of dysprosium could be less than 10 percent of world demand.

The rise in global demand for dysprosium has already had a significant impact, with prices increasing 800 percent from 2006 to 2011. China produces 98 percent of the globe's dysprosium. Without an increase in supply or a drop in demand for rare earths, continued development of green technology could become difficult.[38] According to Michael Silver, chief executive of the chemical company American Elements, the "high cost of rare earths is having a significant chilling effect on wind turbine and electric motor production."[39]

The Department of Energy has identified four other critical rare earths — neodymium, yttrium, europium and terbium.[40] Figures III and IV depict the DOE's analysis of these elements' criticality. Again, because of their applications, demand for these elements will likely continue to rise:

- Neodymium is an important component of high-strength magnets used in electric vehicle motors, wind turbines, hybrid cars and energy-efficient appliances. Substitutes for these magnets are limited.[41]
- Yttrium, europium and terbium are used in CFLs (compact fluorescent) lamps, required to meet government efficiency standards, both in the United States and Europe.
- According to the DOE, no effective substitute for these three elements in fluorescent lighting has been identified, though the agency noted that increased use of LEDs (light-emitting diodes) in lighting fixtures could eventually cause a drop in demand.[42]

China is responsible for 96 percent to 99.8 percent of the world's supply of these critical elements. Additionally, dysprosium, yttrium and terbium are all heavy rare earths.[43]

The automotive industry is especially affected by rare earths supplies. With rising fuel efficiency standards and air quality concerns, many vehicle producers and consumers have turned to hybrid vehicles. These cars are loaded with small, but significant, rare earth components. Vehicles like the Toyota Prius hybrid contain 20 to 25 pounds of rare earths, while a standard automobile contains just half that amount.[44] For example, a hybrid car's batteries rely on lanthanum and cerium, and its motor uses four different rare earths — neodymium, praseodymium, dysprosium and terbium. In fact, more than 25 motors utilizing neodymium magnets are used in a Prius hybrid.[45] [Figure V shows the RE components in hybrid vehicles.]

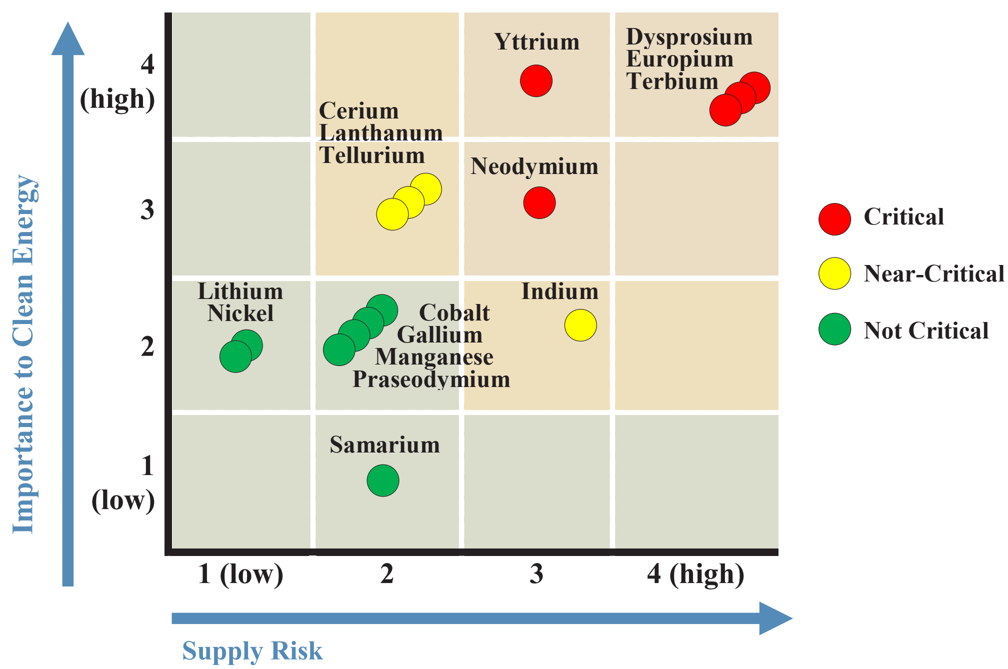
Without China, car dealerships would find many empty spots in their showrooms.[46] According to a 2011 PricewaterhouseCoopers report, 73 percent of automotive CEOs have problems with mineral and metal scarcity.[47]

Electronics. Consider cell phones, laptops, flat-screen televisions, speakers, portable music players, digital cameras, bar code scanners, DVD players, or even washers and dryers.[48] These consumer products are widespread, and all contain rare earth components.

For instance, an iPhone uses nine different rare earths — yttrium, lanthanum, cerium, praseodymium, neodymium, europium, gadolinium, terbium and dysprosium [see Table VI]. Dysprosium — deemed critical by the Department of Energy and at risk of shortage by the Department of Defense — is used throughout the iPhone, in its color screen, phone circuitry, speakers and vibration unit.[49] Yttrium, gadolinium, terbium and dysprosium are all heavy rare earths, which are especially scarce and expensive.

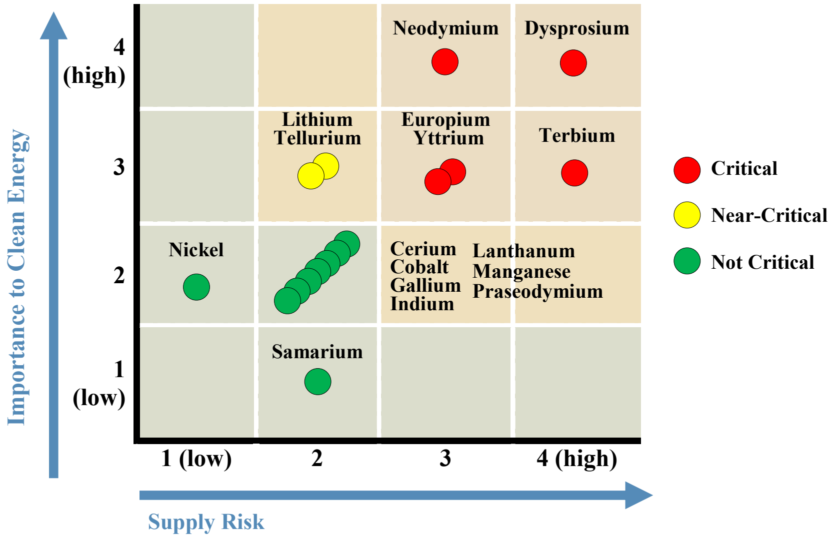
A look at neodymium — used not only in electric vehicles but in headphones and computer disks — reveals how a change in supply affects the electronics market. Notably, neodymium is a light rare earth — much more abundant than the HREEs — yet it is hardly immune to price hikes and market manipulations. In 2011, when China reduced its export quota, raised taxes on REs and announced that it would not approve new rare earth mining projects, prices for neodymium soared.[50] What cost $19 a pound in May 2010 was selling for $129 per pound a year later on the spot market.[51] The price of the element rose 1,400 percent from the end of 2008 to mid-2011.[52]

Figure III
Energy-Critical Minerals in the Short Term (2011-2015)



Source: "Critical Materials Strategy," U.S. Department of Energy, December 2011, page 4. Available at http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

Figure IV
Energy-Critical Minerals in the Medium Term (2015-2025)



Source: "Critical Materials Strategy," U.S. Department of Energy, December 2011, page 4. Available at http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

Particularly affected by the price spike were speaker manufacturers, as neodymium is light and allows for miniaturization. For example:[53]

- Using neodymium can cut the weight of an automotive speaker in half, says Ken Kantor, president of ZT Amplifiers. In a car, weight is critical to gas mileage.
- To make speakers small, "neo" magnets are frequently used; replacing neo magnets in a pair of headphones could increase the speaker's weight significantly, from 0.5 ounces to 2 ounces.

Audio companies struggled with skyrocketing neodymium prices because replacing the element required significant redesigns.[54] "We have seen no other raw material increases like this, nor have we experienced anything comparable in our history," said Audio-Technica product manager Kurt Van Scoy, who called neodymium the "heart of the drivers and capsules" for the company's headphones and microphones.[55]

The bottom lines of other companies have been affected by rising RE prices. The income of Seagate Technologies and Western Digital Corporation, two producers of hard disk drives, fell as rare earth costs rose from July 2011 to September 2011. According to Bloomberg Government, Seagate's net income dropped 37 percent due to rising rare earth prices, while Western Digital's fell 21 percent.[56]

Legislative Efforts to Address the Rare Earths Supply

Somewhat ironically, these highly energy-efficient minerals are also hard to reach because of environmental regulations that make procuring a mining permit in the United States an exceedingly difficult and lengthy process.[57] It takes an average of seven to 10 years to obtain a mining permit in the United States, far longer than the two-year average in Canada and Australia.

As a result, lawmakers have drafted legislation to improve the regulatory process relating to mining in order to jumpstart investment and encourage the development of an American rare earths supply chain. In the House, H.R. 761, the National Strategic and Critical Minerals Production Act of 2013, sponsored by Representative Mark Amodei (R-Nev.), would set a schedule for each part of the permitting process and impose a strict 30-month limit for the total review process. A coordinator would be designated to organize the approval process between all relevant agencies.

Additionally, the bill would reduce the regulatory hurdles associated with mineral exploration under the National Environmental Policy Act of 1969 if the lead federal agency determines the permitting process provides sufficient environmental protection.[58]

In the Senate, the Critical Minerals Policy Act of 2013 (S. 1600), sponsored by Senator Lisa Murkowski (R-Alaska), calls for federal agencies to act "with maximum efficiency and effectiveness" by setting timelines and avoiding duplicative reviews by collaborating and consulting with state governments.[59]

These are positive steps, though the Senate bill lacks the concrete deadlines and more formal coordination process outlined in the House bill. Neither bill has yet to pass,

Table VI
Rare Earth Elements in the Apple iPhone

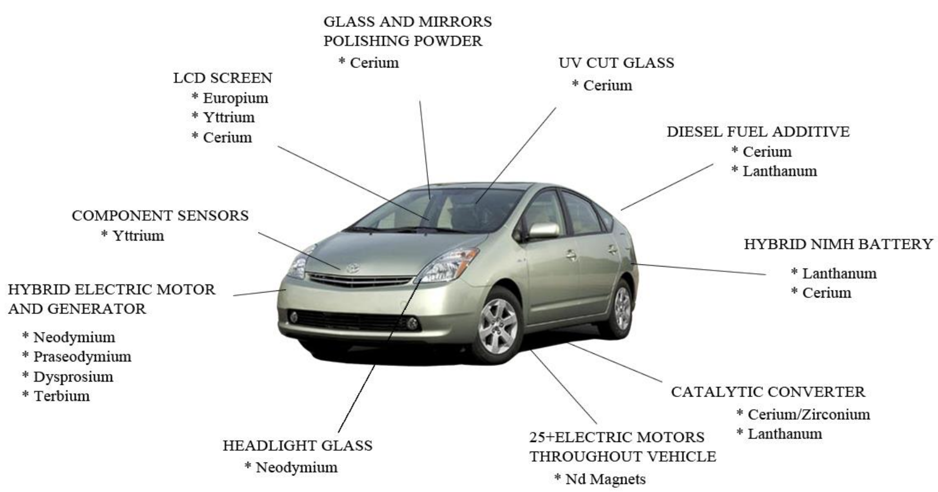
Component	Y	La	Ce	Pr	Nd	Eu	Gd	Tb	Dy
Color Screen	■	■		■		■	■	■	■
Glass Polishing		■	■	■					
Phone Circuitry		■		■	■		■		■
Speakers				■	■		■	■	■
Vibration Unit						■		■	■

Source: Nabeel Mancheri, Lalitha Sundaresan and S. Chandrashekar, "Dominating the World: China and the Rare Earth Industry," National Institute of Advanced Studies, April 2013, page 5. Available at http://threeconsulting.com/pdfs/China-rare-earth-strategyin-wHighlights-.pdf.

though S.1600 has bipartisan support.

More recently, on February 6, 2014, Senator Roy Blunt introduced the National Rare Earth Cooperative Act (S. 2006), and on June 17, 2014, Representative Steve Stockman (R-Texas) introduced an identical bill in the House.[60] This legislation would establish "the Thorium-Bearing Rare Earth Refinery Cooperative to provide for the domestic processing of thorium-bearing rare earth concentrates as residual unprocessed and unrefined ores." Heavy REs, which are generally more valuable and scarce than light REs, are often found in ores containing radioactive thorium.

Figure V
Rare Earths in Hybrid Vehicles



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Conclusion

To counter the threat of critical minerals shortages, the United States needs to develop a domestic rare earths supply chain. The unique capabilities of rare earths allow for efficiencies — including miniaturization and low energy use — that are only growing in significance as modern technology develops. Depending upon China for these critical components puts the American economy in peril. Few people recognize the significance of rare earths, but that could change — dramatically — if the United States finds itself on the receiving end of a supply disruption.

Ann Norman is a senior research fellow, Xinyuan Zou is a research associate and Joe Barnett is senior director of policy research at the National Center for Policy Analysis.

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