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Excerpt

Sourcing Rare Earths and Critical Minerals

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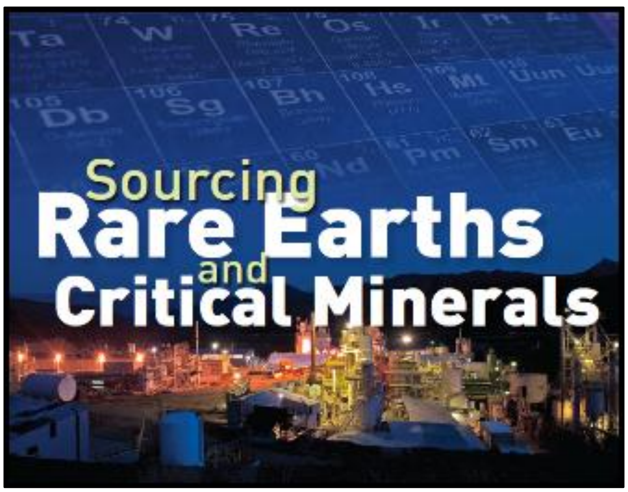


Who knew the U.S. economy was so deeply dependent on neodymium?

Until late last year, almost nobody did. Indeed, you would have been hard-pressed to find anyone who could name neodymium as an element, much less recognize it as one of the 17 rare earth elements that dangle like afterthoughts at the bottom of the periodic table.

Then in October, the Chinese announced plans to cut their production of rare earth metals and slash exports by roughly one-third. Since China currently accounts for about 95 percent of the world's rare earth output, the threat of global shortages suddenly loomed. Alarm bells rang in Washington and in the national business press, and globally, mining companies rushed to find new rare earth exploration projects and advance development projects as quickly as possible.

To understand how ubiquitous rare earth metals have become, look no further than the iPhone. It is powered by a permanent magnet made with the rare earth metal neodymium; the screen and display module are manufactured with europium, yttrium and terbium; and the lens in the camera has a coating of lanthanum.

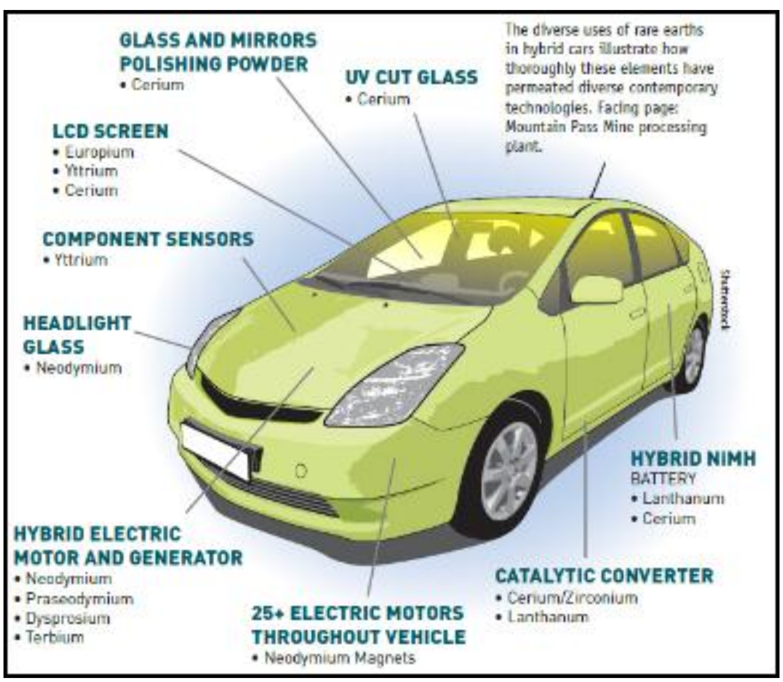
Consumption of rare earth metals isn't restricted to smart phones. They are in TV screens, computer hard drives and anti-lock brake systems. They are baked into aircraft engines and instrument systems, MRI and X-ray machines, and they are used in modern oil refining and water purification systems. Within a few years, rare earth metals such as europium, yttrium and terbium will be in almost every light bulb on sale at The Home Depot. And they are already incorporated into many defense systems, leading some analysts to attach national-security implications to China's announcement on rare earths.

The rise of rare earths

Rare earths, which are generally deposited together, are not actually all that rare. They occur widely, but in great diffusion, and there are only a few known deposits that are large and concentrated enough to support profitable mining operations. Another factor limiting supply is that they are difficult to separate from one another; rare earths tend to intermingle—with each other and with other minerals—and separating out a pure sample of any single element can be costly. A third limitation of supply is the infrastructure required to refine rare earths into usable forms, including the conversion of oxides to their metallic forms. This technology, which was largely developed in the United States but now primarily resides in Asia, is relatively undeveloped because these materials had little economic value until recently.

Within the last couple of decades, elements such as dysprosium, neodymium, europium and yttrium have become essential to the manufacture of products in health care, energy, computing, consumer electronics and the auto industry, hence the alarm over the news from China. Interruption in supply could have significant impacts on the U.S. economy.

“We’re using a much larger portion of the periodic table than we were even 20 years ago,” says Eggert. “Many of these new uses are for elements that up until now have been used in very small quantities. So a new use or two can dramatically change the demand and temporarily overwhelm the ability of supply to keep up.”



The diverse uses of rare earths in hybrid cars illustrate how thoroughly these elements have permeated diverse contemporary technologies. Facing page: Mountain Pass Mine processing plant.

To date, the most important uses for rare earth elements have been in the manufacture of various kinds of permanent magnets, lighting and a range of optical and imaging applications. Rare earth magnets, which can include neodymium, dysprosium and samarium-cobalt, are up to three times more powerful than their conventional counterparts. This is particularly valuable in turbines and electric motors, which can be smaller and lighter, but pack the same punch**. Fluorescent light bulbs and video screens depend on fluorescence qualities in certain rare earths.** In fact, the first commercial use of a rare earth metal was in color televisions in the 1950s. Europium, which glows red when hit with an electron beam, is still used today in LED and plasma TVs, along with another rare earth, terbium, which glows green. Other critical applications for rare earths exist in laser and X-ray imaging technologies, which make use of their interactions with high-energy waves.

Vital to growth industries

Not surprisingly, these special electrical properties of rare earth elements are helping to drive technological innovation in some critical sectors of the economy. Electrical motors made with rare earths are used in almost all hybrid cars, where space, performance and weight is at a premium. Most modern wind turbines, another global growth industry, also incorporate rare earth magnets. “A modern 3-megawatt wind turbine uses about a thousand pounds of neodymium,” says Vince Matthews, director of Colorado Geological Survey, adding that the U.S. produces almost no neodymium at present.

Energy-saving compact fluorescent light bulbs gain much of their brightness from rare earth phosphors, most commonly yttrium, terbium and europium. With the industrialized world rapidly moving from incandescent to fluorescent bulbs (the U.S. conversion is scheduled to be complete by 2014), this industry represents a built-in demand spike for rare earths. Some additional energy-related products that use rare earths include photovoltaic cells, nickel-metal hydride rechargeable batteries and energy efficient windows.

Health care is another key industry that relies on rare earths. Imaging techniques such as CAT scans, MRIs, digital X-rays and lasers take advantage of the elements’ optical properties. Computer and smartphone manufacturers employ rare earths in permanent magnets, hard drives and LED screens. The petroleum industry uses the metals as well—chiefly cerium, which serves as a fluid catalytic cracking catalyst.

A matter of national security

Important as rare earths are to so many diverse and vital sectors of the economy, much of the alarm over future supplies concern just one industry: defense. Military jets, guided missile systems, satellite communications and myriad other defense applications all now incorporate rare earths. As in the energy sector, rare earth permanent magnets have numerous uses. They drive the electrical systems found in planes, ground vehicles, satellites and communications equipment. These magnetic properties also play an essential role in the functioning of traveling wave tubes, which amplify signals from military satellites and other communications systems. Additionally, lasers, range finders, detection systems, night-vision equipment and a host of other military applications rely on rare earths’ optical qualities.

The U.S. Department of Defense conducted a study of the global supply chain in 2009 and was concerned enough to propose a new oversight program, the Strategic Materials Security Management System, to monitor supplies of rare earths and other critical minerals. The Department of Commerce, Department of Energy and White House Office of Science and Technology Policy have also undertaken studies or developed strategic plans to address the danger of rare earths supply shortages.

Governmental concern about Chinese control of the rare earths market dates back to at least 2005. It was then that the China National Offshore Oil Corporation tried to purchase UNOCAL, then the parent company of California's Mountain Pass Mine, which holds the largest known reserve of rare earths in the United States. After the Bush administration was asked by the House of Representatives to review the bid on grounds of national security, the sale was scuttled. Another Chinese state-owned company attempted to purchase the mine in 2007 from Chevron, but Mountain Pass ended up being sold to Denver-based Molycorp Minerals. Located south of Las Vegas in the California desert, Mountain Pass was the world's largest producer of rare earth metals from the 1950s until the early 1990s. But rising costs and increased competition from China's state-subsidized mines caused Mountain Pass to reduce, and ultimately cease, production. By the mid-2000s, U.S. rare earth mining had virtually disappeared.

"We went from a situation where we had one dominant miner, which happened to be in the United States, to one where we have a dominant mining country," Eggert says. "And that country has now signaled it will reduce its supply to the rest of the world."

Threatened supplies, soaring demand

Demand for rare earths is steadily rising. The U.S. Congressional Research Service estimated worldwide consumption at 124,000 tons in 2010 and forecasts a rise to as many as 180,000 tons by 2012. However, China's exports are projected to drop below 30,000 tons this year. As a consequence, prices have skyrocketed. Neodymium oxide, used in the manufacture of rare earth permanent magnets, has gone from **$20,000 per ton in January 2010, to $160,000 in January 2011.**

While these are alarming numbers, they are not as dire as they may seem at first blush. Molycorp is producing again: "We're currently refining approximately 3,000 tons of rare earths per year from stockpiled ore," says Ross Bhappu PhD '88, chairman of Molycorp's board. Once they are fully operational, this number will increase. "We'll initially be producing about 19,000 tons a year when we restart, but we'll be quickly expanding our capacity to 40,000 tons by late 2013." Mount Weld Mine in Western Australia has now completed a concentration plant that will prepare concentrate for export to Kuantan, Malaysia, where a new processing plant is slated for completion by late 2011. Total production from the Kuantan facility will be about 20,000 tons per year.

Other projects are under development, but will take longer to come online. The Bokan Mountain deposit in Alaska has generated keen interest, and exploration has begun at sites in Wyoming and Idaho. Colorado Rare Earths plans to develop claims in Gunnison and Custer counties. Congress has gotten involved as well. Colorado Congressman Mike Coffman has introduced legislation that would create a national rare earth strategic stockpile, and Colorado Senator Mark Udall is sponsoring a bill aimed at jumpstarting research and development. Equally critical: research and education Udall's bill is particularly important, according to Eggert, because it's aimed at more than just identifying and developing reserves. "Without good information about the material life cycle," he says, "it becomes difficult for both private and public entities to make good decisions. I'm thinking about activities such as scientific and technical research that typically have been the domain of universities and federal laboratories, as well as private companies."

Plenty of problems remain to be solved. "The biggest challenge in recovering these metals is in refining," says Pat Taylor, director of Mines' Kroll Institute. "Rare earths tend to occur in conjunction with one another and are all very similar chemically, so separating one from the other is a big challenge. They're very difficult to reduce in a pure phase."

The Kroll Institute has research projects under way that relate to rare earths extraction and refining. It is also participating in a pilot recycling program to recover rare earths from fluorescent bulbs. The National Science Foundation-funded program was launched last year in conjunction with General Electric and the waste-management company Veolia (the nation's largest recycler of fluorescent bulbs)

Taylor has also taken the lead in one of the most important aspects of the drive to reactivate U.S. rare earths production: education. Because the industry has been essentially dormant for two decades, there is a gap in expertise. Metallurgists, chemical engineers and mining professionals who have specialized in rare earths are few and far between, and demand for trained personnel in the U.S. is rising.

That's why Taylor and colleague Corby Anderson developed the class Extraction and Refining of Rare Metals, which debuted in the spring 2011 semester. The first of its kind anywhere in the U.S., the course has been in the planning stages for more than two years. In addition to students, the course is also open on a noncredit basis to professionals in the mining industry who want to add to their expertise.

Such initiatives can't roll out soon enough for Molycorp. "We have a limited supply of chemical engineers and metallurgical engineers to draw from," says Bhappu**. "As a nation, we haven't been turning out enough metallurgical engineers who are knowledgeable about rare earths.** It's essential to reactivate those programs**. China is educating thousands of specialists in this area.** We need to have a fair number of grad students who are writing master's theses or PhD dissertations focused specifically on critical metals."

Karl Gschneidner of Iowa State University's Ames Laboratory estimates that in the short term, "about 170 trained persons having PhD, master's and bachelor's degrees are required per year to quickly fill in the present void of technically trained personnel."

Beyond rare earths

Although they are central to the curriculum, Taylor's course is not only focused on rare earth metals. It also covers other scarce but critical minerals, such as lithium and tellurium.

"The present situation is not just about rare earths," says the Colorado Geological Survey's Matthews. "It's important to understand that. There are many critical minerals which the U.S. must import." The real question, he notes, is whether these critical minerals will remain available at a reasonable price.

"It's broader than rare earths," agrees Eggert, who points to platinum, palladium, rhodium, manganese and indium as other minerals facing supply risks. "Rare earths have shone a light on a broader set of issues."

Addressing those issues will require a multipronged approach, Eggert believes. "There are basically two ways to overcome supply risk. One is to develop alternative sources. The other is to substitute away from the at-risk elements in the design of materials. Mines has research activities in both areas. Another role for Mines is in better understanding the markets and life cycles of rare earths and other critical minerals. These are small, highly fragmented markets with limited information; they're poorly understood. Developing a more complete inventory of current production capacities, reserves, end-use markets and waste repositories will help us get our production back up to speed more quickly."

Outlook

Looking ahead, the most hopeful estimates say the U.S. can become self-sufficient in rare earths production by 2015. More cautious analysts forecast that it will take more than a decade.

But for industry, self-sufficiency isn't the issue. The problem will be fixed once there is a well-diversified global supply. Thanks to the work of governments, NGOs, universities and private corporations around the world, progress has been made; but there's plenty yet to be done, so expect to hear more on this topic from Mines, where expertise on rare earths and scarce critical minerals is in such abundance.