



# Rare Earth Elements: The Global Supply Chain

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## Summary

The concentration of production of rare earth elements (REEs) outside the United States raises the important issue of supply vulnerability. REEs are used for new energy technologies and national security applications. Is the United States vulnerable to supply disruptions of REEs? Are these elements essential to U.S. national security and economic well-being?

There are 17 rare earth elements (REEs), 15 within the chemical group called lanthanides, plus yttrium and scandium. The lanthanides consist of the following: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Rare earths are moderately abundant in the earth's crust, some even more abundant than copper, lead, gold, and platinum. While more abundant than many other minerals, REE are not concentrated enough to make them easily exploitable economically. The United States was once self-reliant in domestically produced REEs, but over the past 15 years has become 100% reliant on imports, primarily from China, because of lower-cost operations.

There is no rare earth mine production in the United States. U.S.-based Molycorp operates a separation plant at Mountain Pass, CA, and sells the rare earth concentrates and refined products from previously mined above-ground stocks. Neodymium, praseodymium, and lanthanum oxides are produced for further processing but these materials are not turned into rare earth metal in the United States.

Some of the major end uses for rare earth elements include use in automotive catalytic converters, fluid cracking catalysts in petroleum refining, phosphors in color television and flat panel displays (cell phones, portable DVDs, and laptops), permanent magnets and rechargeable batteries for hybrid and electric vehicles, and generators for wind turbines, and numerous medical devices. There are important defense applications, such as jet fighter engines, missile guidance systems, antimissile defense, and space-based satellites and communication systems.

World demand for rare earth elements is estimated at 134,000 tons per year, with global production around 124,000 tons annually. The difference is covered by previously mined above-ground stocks. World demand is projected to rise to 180,000 tons annually by 2012, while it is unlikely that new mine output will close the gap in the short term. New mining projects could easily take 10 years to reach production. In the long run, however, the USGS expects that global reserves and undiscovered resources are large enough to meet demand.

Legislative proposals **H.R. 6160** (Dahlkemper) **H.R. 4866** (Coffman) and **S. 3521**(Murkowski) have been introduced to support domestic production of REEs, because of congressional concerns over access to rare earth raw materials and downstream products used in many national security applications and clean energy technologies. The House approved H.R. 6160 on September 29, 2010, by a vote of 325-98.

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## Introduction

The concentration of production of rare earth elements (REEs) raises the important issue of supply vulnerability. REEs are used for new energy technologies and national security applications. Is the U.S. vulnerable to supply disruptions? Are these elements essential to U.S. national security and economic well-being?

The examination of REEs for new energy technologies reveals a concentrated and complex global supply chain and numerous end-use applications. Placing the REE supply chain in the global context is unavoidable. U.S. mineral policy emphasizes developing domestic supplies of critical materials and the domestic private sector to produce and process those materials.<sup>1</sup> But some raw materials do not exist in economic quantities in the United States, while processing, manufacturing, and other downstream ventures in the United States may not be competitive with facilities in other regions of the world. However, there may be public policies enacted or executive branch measures taken to offset the U.S. disadvantage of its potentially higher cost operations. The current goal of U.S. mineral policy is to promote an adequate, stable, and reliable supply of materials for U.S. national security, economic well-being, and industrial production.

Aside from a small amount of recycling, the United States is 100% reliant on imports of REEs and highly dependent on many other minerals that support its economy. For example, the United States is more than 90% import-reliant for manganese (100%), bauxite (100%), platinum (94%), and uranium (90%). While import reliance may be a cause for concern, high import reliance is not necessarily the best measure, or even a good measure, of supply risk. The supply risk for bauxite, for example, may not be the same as that for REEs. However, in the case of REEs, the dominance of China as a single or dominant supplier of the raw material, downstream oxides, associated metals and alloys, is a cause for concern because of China's growing internal demand for its REEs.

This report provides a discussion on the major issues and concerns of the global supply chain for rare earth elements, their major end uses, and legislative and other policy proposals that Congress may consider to improve the U.S. rare earth position.

## What Are Rare Earth Elements?

There are 17 rare earth elements (REEs), 15 within the chemical group called lanthanides, plus yttrium and scandium. The lanthanides consist of the following: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Rare earths are moderately abundant in the earth's crust, some even more abundant than copper, lead, gold, and platinum.

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<sup>1</sup> U.S. mineral policies provide a framework for the development of domestic metal mineral resources and for securing supplies from foreign sources. Specifically, the Mining and Minerals Policy Act of 1970 (30 U.S.C. §21a) declared that it is in the national interest of the United States to foster the development of the domestic mining industry "... including the use of recycling and scrap." The National Materials and Minerals Policy, Research and Development Act of 1980 (30 U.S.C. 1601), among other things, declares that it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production, with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs.

While some are more abundant than many other minerals, most REEs are not concentrated enough to make them easily exploitable economically.<sup>2</sup> The United States was once self-reliant in domestically produced REEs, but over the past 15 years has become 100% reliant on imports, primarily from China, because of lower-cost operations.<sup>3</sup>

## Major End Uses and Applications

Currently, the dominant end use for rare earth elements in the U.S. are for auto catalysts and petroleum refining catalysts. Some other major end uses for rare earth elements include use in phosphors in color television and flat panel displays (cell phones, portable DVDs, and laptops), permanent magnets and rechargeable batteries for hybrid and electric vehicles, and numerous medical devices. There are important defense applications such as jet fighter engines, missile guidance systems, antimissile defense, and space-based satellites and communication systems. Permanent magnets containing neodymium, gadolinium, dysprosium, and terbium are used in numerous electrical and electronic components and generators for wind turbines. See **Table 1** below for selected end uses of rare earth elements.

**Table 1. Rare Earth Elements (Lanthanides): Selected End Uses**

Light Rare Earths (more abundant)	Major End Use	Heavy Rare Earth (less abundant)	Major End Use
Lanthanum	hybrid engines, metal alloys	Terbium	phosphors, permanent magnets
Cerium	auto catalyst, petroleum refining, metal alloys	Dysprosium	permanent magnets, hybrid engines
Praseodymium	magnets	Erbium	phosphors
Neodymium	auto catalyst, petroleum refining, hard drives in laptops, headphones, hybrid engines	Yttrium	red color, fluorescent lamps, ceramics, metal alloy agent
Samarium	magnets	Holmium	glass coloring, lasers
Europium	red color for television and computer screens	Thulium	medical x-ray units
Gadolinium	magnets	Lutetium	catalysts in petroleum refining
		Ytterbium	lasers, steel alloys

**Source:** DOI, U.S. Geological Survey, Circular 930-N.

<sup>2</sup> U.S. Department of the Interior (DOI), Geological Survey (USGS), *Minerals Yearbook, Volume 1, 2007, Rare Earths* (Advance Release).

<sup>3</sup> DOI/USGS, *Rare Earth Elements—Critical Resources for High Technology*, Fact Sheet 087-02.

## **Demand for Rare Earth Elements**

World demand for rare earth elements is estimated at 134,000 tons per year, with global production around 124,000 tons annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tons annually by 2012, while it is unlikely that new mine output will close the gap in the short term.<sup>4</sup> By 2014, global demand for rare earth elements may exceed 200,000 tons per year. China's output may reach 160,000 tons per year (up from 130,000 tons in 2008) in 2014. An additional capacity shortfall of 40,000 tons per year may occur. This potential shortfall has raised concerns in the U.S. Congress. New mining projects could easily take 10 years for development. In the long run, however, the USGS expects that reserves and undiscovered resources are large enough to meet demand.

While world demand continues to climb, U.S. demand for rare earths is also projected to rise, according to the USGS Commodity Specialist Jim Hedrick.<sup>5</sup> For example, permanent magnet demand is expected to grow by 10%-16% per year through 2012. Demand for rare earths in auto catalysts and petroleum cracking catalysts is expected to increase between 6% and 8% each year over the same period. Demand increases are also expected for rare earths in flat panel displays, hybrid vehicle engines, and defense and medical applications.

## **The Application of Rare Earth Metals in National Defense<sup>6</sup>**

Current government policies pertaining to the acquisition of certain minerals for defense purposes are addressed, in part, in several different legislative initiatives, including the Defense Production Act (P.L. 81-774), National Defense Stockpile [Title 50 United States Code (U.S.C.) 98-h-2(a)],<sup>7</sup> Buy American Act (41 U.S.C. 10-10d), Berry Amendment (10 U.S.C. 2533a), and the Specialty Metal provision (10 U.S.C. 2533b). However, these policies do not present a unified opinion on whether every mineral is considered "critical," "strategic," or necessary for national security purposes, and there is a certain lack of cohesion to the application of these policies. As an example, rare earth elements (and rare earth metals) fall outside of the scope of the Berry Amendment and the Specialty Metal provision.<sup>8</sup>

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<sup>4</sup> Rare Earth Minerals: The Indispensable Resource for Clean Energy Technologies, presented at Minerals for a Green Society Conference, Washington, DC, by Mark A. Smith, CEO, Molycorp Minerals, February 4, 2010.

<sup>5</sup> DOI/USGS Minerals Yearbook, Volume 1, 2007.

<sup>6</sup> This section was prepared by Valerie Grasso, CRS Foreign Affairs, Defense, and Trade Division.

<sup>7</sup> The following information was accessed on March 10, 2010, from the Defense National Stockpile Center website, at <https://www.dnsc.dla.mil/inside.asp>, and GlobalSecurity.org, at <http://www.globalsecurity.org/military/agency/dod/dnsc.htm>. "The National Stockpile operates under authority of the Strategic and Critical Materials Stockpiling Act (50 U.S.C. 98-h-2(a)). This act provides that strategic and critical materials are stockpiled in the interest of national defense to preclude a dangerous and costly dependence upon foreign sources of supply in times of national emergency. The Defense National Stockpile Center administers the storage, management, and disposal of the Nation's inventory of strategic and critical materials essential to the military and industrial requirements of the United States in times of national emergency. The Congress of the United States has authorized the Defense National Stockpile Center to sell commodities that are excess to Department of Defense needs. Since 1993, DNSC sales have totaled approximately \$6.6 billion."

<sup>8</sup> For further discussion on the Berry Amendment and the Specialty Metals provision, see CRS Report RL31236, *The Berry Amendment: Requiring Defense Procurement to Come from Domestic Sources*, and CRS Report RL33751, *The Specialty Metal Provision and the Berry Amendment: Issues for Congress*, both by Valerie Bailey Grasso.

The primary defense application of rare earth materials is their use in four types of permanent magnet materials commercially available: Alnico, Ferrites, Samarium Cobalt, and Neodymium Iron Boron. With the exception of Neodymium Iron Boron, all of the materials are domestically produced. The United States has no production capabilities for Neodymium Iron Boron. Neo magnets, the product derived from Neodymium Iron Boron, and Samarium Cobalt, are considered important to many defense products. They are considered one of the world's strongest permanent magnets and an essential element to many military weapons systems, as described in the following examples.

- Jet fighter engines and other aircraft components, including samarium-cobalt magnets used in generators that produce electricity for aircraft electrical systems;
- Missile guidance systems, including precision guidance munitions, lasers, and smart bombs;<sup>9</sup>
- Electronic countermeasures systems;
- Underwater mine detection systems;
- Antimissile defense systems;
- Range finders, including lasers; and
- Satellite power and communication systems, including traveling wave tubes (TWT) rare earth speakers, defense system control panels, radar systems, electronic countermeasures, and optical equipment.<sup>10</sup>

Many scientific organizations have concluded that certain rare earth metals are critical to U.S. national security and becoming increasingly more important in defense applications.<sup>11</sup> Some industry analysts are concerned with an increasing dependence on foreign sources for rare earth metals; a dwindling source of domestic supply for certain rare earth metals; and the emergence of a manufacturing supply chain that has largely migrated outside of the United States. In July 2010, the China Ministry of Commerce announced that China would cut its export quota for rare earth minerals by 72%, raising concerns because of estimates that China controls approximately 97% of the global production of rare earth minerals.<sup>12</sup> It is also estimated that by 2012 China's domestic consumption will outpace China's domestic production of rare earth minerals.

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<sup>9</sup> For further discussion on precision-guided munitions, see CRS Report RL33539, *Intelligence Issues for Congress*, by Richard A. Best Jr., and CRS Report RL30727, *Airborne Intelligence, Surveillance, and Reconnaissance (ISR): The U-2 Aircraft and Global Hawk UAV Programs*, by Richard A. Best Jr. and Christopher Bolkcom.

<sup>10</sup> Haxel, Gordon B, Hendricks, James B., and Oris, Greta J. Rare Earth Elements: Critical Resources for High Technology. *U.S. Geological Survey*, Fact Sheet 087-82, accessed online on March 10, 2010, at <http://pubs.usgs.gov/fs/2002/fs087-02/>.

<sup>11</sup> Green Jeffrey A. Defense, Energy Markets Should Brace for Shortages of Key Materials. *National Defense Industrial Association*, October 2009; U.S. Lacks Data on Supply of Minerals Critical to Economy, National Security; Defense Stockpile is Ineffective. National Academy of Sciences, October 5, 2007, accessed online at <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=10052007>.

<sup>12</sup> Chang, Gordon G. Why Does China Want BP? *Forbes.com*, July 14, 2010. <http://www.forbes.com/2010/07/14/bp-china-oil-opinions-columnists-gordon-g-chang.html>

Some experts are concerned that DOD is not doing enough to mitigate the possible risk posed by a scarcity of domestic suppliers. As an example, the United States Magnet Materials Association (USMMA), a coalition of companies representing aerospace, medical, and electronic materials, has recently expanded its focus to include rare earth metals and the rare earth magnet supply chain. In February 2010, USMMA unveiled a six-point plan to address what they describe as the “impending rare earth crisis” which they assert poses a significant threat to the economy and national security of the United States.<sup>13</sup> However, it appears that DOD’s position assumes that there are a sufficient number of supplier countries worldwide to mitigate the potential for shortages.

## Rare Earth Resources and Production Potential

Rare earth elements often occur with other elements, such as copper, gold, uranium, phosphates, and iron, and have often been produced as a byproduct. The lighter elements such as lanthanum, cerium, praseodymium, and neodymium are more abundant and concentrated and usually make up about 80%-99% of a total deposit. The heavier elements—gadolinium through lutetium and yttrium—are scarcer but very “desirable,” according to USGS commodity analysts.<sup>14</sup>

Most rare earth elements throughout the world are located in deposits of the minerals bastnaesite<sup>15</sup> and monazite.<sup>16</sup> Bastnaesite deposits in the United States and China account for the largest concentrations of REEs, while monazite deposits in Australia, South Africa, China, Brazil, Malaysia, and India account for the second largest concentrations of REEs. Bastnaesite occurs as a primary mineral, while monazite is found in primary deposits of other ores and typically recovered as a byproduct. Over 90% of the world’s economically recoverable rare earth elements are found in primary mineral deposits (i.e., in bastnaesite ores).<sup>17</sup>

Concerns over radioactive hazards associated with monazites (because it contains thorium) has nearly eliminated it as a REE source in the United States. Bastnaesite, a low-thorium mineral (dominated by lanthanum, cerium, and neodymium) is shipped from stocks in Mountain Pass, CA. The more desirable heavy rare earth elements account for only 0.4% of the total stock. Monazites have been produced as a minor byproduct of uranium and niobium processing. Rare earth element reserves and resources are found in Colorado, Idaho, Montana, Missouri, Utah, and Wyoming. Heavy rare earth elements (HREEs) dominate in the Quebec-Labrador (Strange Lake) and Northwest Territories (Thor Lake) areas of Canada. There are high-grade deposits in Banyan Obo, Inner Mongolia, China (where much of the world’s REE production is taking place) and lower-grade deposits in South China provinces providing a major source of the heavy rare earth elements.<sup>18</sup> Areas considered to be attractive for REE development include Strange Lake and Thor Lake in Canada; Karonga, Burundi; and Wigu Hill in Southern Tanzania.

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<sup>13</sup> Magnet Materials Supply Chain Players Propose Six-Point Plan to Address Impending Rare Earths Crisis, *USMMA*, February 4, 2010, accessed online at <http://www.usmagnetmaterials.com/?p=74>.

<sup>14</sup> *Ibid.*

<sup>15</sup> Bastnaesite is mineral with the formula  $(\text{Ce, La})\text{CO}_3(\text{F,OH})$  that may contain other rare earth elements.

<sup>16</sup> Monazite is a mineral with the formula  $(\text{Ce, La, Nd, Th})\text{PO}_4$  that may contain other rare earth elements.

<sup>17</sup> DOI/USGS Circular 930 N, *International Strategic Minerals Inventory Summary Report—Rare Earth Oxides*, by Wayne Jackson and Grey Christiansen, 1993.

<sup>18</sup> Dr. Anthony N. Mariano, *The Nature of Economic REE and Y Minerals on a World Level*, presented at the MIT Energy Initiative Workshop, April 29, 2010.



Careful consideration should be given to the feasibility of mining and processing of REEs as a byproduct of phosphorus deposits and from titanium and niobium mines in Brazil.<sup>19</sup> Canadian, Chinese, and U.S. firms have recently assessed various REE deposits associated with development of primary minerals such as gold, iron ore, and mineral sand projects in the United States. **Table 2** below illustrates China's near-monopoly position in world rare earth production. However, REE reserves and the reserve base are more dispersed throughout the world. China holds 36% of the world's reserves (36 million metric tons out of 99 million metric tons) and the United States holds about 13%. South Africa and Canada (included in the "Other" category) have significant REE potential, according to the USGS. REE reserves are also found in Australia, Brazil, India, Russia, South Africa, Malaysia, and Malawi.

**Table 2. Rare Earth Elements: World Production and Reserves—2009**

Country	Mine Production (metric tons)	% of total	Reserves (million metric tons)	% of total	Reserve Base <sup>a</sup> (million metric tons)	% of total
United States	none		13.0	13	14.0	9.3
China	120,000	97	36.0	36	89.0	59.3
Russia			19.0	19	21.0	14
(and other former Soviet Union countries)						
Australia			5.4	5	5.8	3.9
India	2,700	2	3.1	3	1.3	1
Brazil	650		small			
Malaysia	380		small			
Other	270		22.0	22	23	12.5
Total	124,000		99.0		154	

**Source:** U.S. Department of the Interior, Mineral Commodity Summaries, USGS, 2010.

- a. Reserve Base is defined by the USGS to include reserves (both economic and marginally economic) plus some subeconomic resources (i.e., those that may have potential for becoming economic reserves).

There is no rare earth mine production in the United States. U.S.-based Molycorp operates a separation plant at Mountain Pass, CA, and sells the rare earth concentrates and refined products from previously mined above-ground stocks. Neodymium, praseodymium, and lanthanum oxides are produced for further processing, but these materials are not turned into rare earth metal in the United States. While the United States exports much of its REE stocks to Japan, that material is not counted in the trade equation for import reliance because the material is not produced from a primary source.

<sup>19</sup> Ibid.

Molycorp, which has an exploration program underway to further delineate its rare earth mineral deposits, has plans for full mine production in the second half of 2012 and has plans to modernize its refinery facilities. Molycorp's Mountain Pass deposit contained an estimated 30 million tons of REE reserves and once produced as much as 20,000 tons per day.<sup>20</sup> Mountain Pass cut-off grade (below which the deposit may be uneconomic) is, in some parts, 7.6%, while the average grade is 9.6%. U.S. Rare Earth (another U.S. based company), in the pre-feasibility stage of mine development, has long-term potential because of its large deposits in Idaho, Colorado, and Montana.<sup>21</sup>

Canadian deposits contain the heavy rare earth elements dysprosium, terbium, and europium, which are needed for magnets to operate at high temperatures. Great Western Minerals Group (GWMG) of Canada and Avalon Rare Metals have deposits with an estimated high content (1%-2%) of heavy rare earth elements.<sup>22</sup> Avalon is developing a rare earth deposit at Thor Lake in the Northwest Territories of Canada. Drilling commenced in January 2010. Thor Lake is considered by some in the industry to contain one of the largest REE deposits in the world with the potential for production of heavy REEs.<sup>23</sup> GWMG owns a magnet alloy producer in the U.K. When GWMG begins production in Canada and elsewhere, they plan to have a refinery near the mine site allowing greater integration and control over the supply chain. Great Western's biggest advantage could be its potential for a vertically integrated operation.

The Lynas Corp., based in Australia, has immediate potential for light rare earths development, according to investor analyst Jack Lifton. Development of Lynas's Mt. Weld deposit in Australia is underway and there is potential to reopen the rare earth mine Steenkampskraal in South Africa. An agreement between GWMG and Rare Earth Extraction Co. Ltd. of Stellenbosch to develop the mine is in progress. The Japan Oil, Gas, and Metals National Corporation (JOGMEC) signed an agreement with Midland Exploration Inc. for development of the Ytterby project in Quebec, Canada. JOGMEC is under the authority of the Japanese Ministry of Economy, Trade, and Industry with a mandate to invest in projects worldwide to receive access to stable supplies of natural resources for Japan.

Access to a reliable supply to meet current and projected demand is an issue of concern. In 2009, China produced 97% of the world's rare earth elements (measured in rare earth oxide content) and continues to restrict exports of the material through quotas and export tariffs. China has plans to reduce mine output, eliminate illegal operations, and restrict REE exports even further. There are some immediate supply concerns with lower rare earth export quotas in China. China has cut its exports of rare earth elements from about 50,000 metric tons in 2009 to 30,000 metric tons in 2010. According to a Bloomberg news report, a July 2010 announcement by China's Ministry of Commerce would cut exports of REEs by 72%, to about 8,000 metric tons, for the second half of 2010.<sup>24</sup>

While limited production and processing capacity for rare earths currently exists elsewhere in the world, additional capacity is expected to be developed in the United States, Australia, and Canada

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<sup>20</sup> The Jack Lifton Report, *The Rare Earth Crisis—Part I*, by Jack Lifton, October 2009.

<sup>21</sup> *Rare Earth Strategic Supplies More Important Than Price*, Industrial Metals/Minerals Interview of Jack Lifton by The Gold Report, December 14, 2009.

<sup>22</sup> Ibid.

<sup>23</sup> Ibid.

<sup>24</sup> "China Cuts Rare Earth Export Quota," Bloomberg News Report, July 9, 2010.

within two to five years, according to some experts.<sup>25</sup> Chinese producers are also seeking to expand their production capacity in areas around the world, particularly in Australia. There are only a few exploration companies that develop the resource, and because of long lead times needed from discovery to refined elements, supply constraints are likely in the short term.

## Supply Chain Issues

The supply chain for rare earth elements generally consist of mining, separation, refining, alloying, and manufacturing (devices and component parts). A major issue for REE development in the United States is the lack of refining, alloying, and fabricating capacity that could process any future rare earth production. There is one U.S. company, Electron Energy Corporation (EEC) in Landisville, PA, producing samarium-cobalt (Sm-Co) permanent magnets, while there are no U.S. producers of the more desirable neodymium-iron-boron (NdFeB) magnets needed for numerous consumer electronics, energy, and defense applications. EEC, in its production of its Sm-Co permanent magnet, uses small amounts of gadolinium—an REE of which there is no U.S. production. Even the REEs needed for these magnets that operate at the highest temperatures include small amounts of dysprosium and terbium, both available only from China at the moment. EEC imports magnet alloys used for its magnet production from China. Santoku America, Inc., produces at its Tolleson, AZ, facility, both NdFeB and Sm-Co alloys used in the production of permanent magnets. They are the only U.S. producer of the NdFeB alloy.

A Government Accountability Office (GAO) report illustrates the lack of U.S. presence in the REE global supply chain at each of the five stages of mining, separation, refining oxides into metal, fabrication of alloys and the manufacturing of magnets and other components.<sup>26</sup> China produces 97% of the REE raw materials, about 97% of rare earth oxides, and is the only exporter of commercial quantities of rare earth metals (Japan produces some metal for its own use for alloys and magnet production). About 90% of the metal alloys are produced in China (small production in the United States) and China manufactures 75% of the neodymium magnets and 60% of the samarium magnets. A small amount of samarium magnets are produced in the United States. Thus, even if rare earth production ramps up, much of the processing/alloying and metal fabrication would occur in China. According to investor analyst Jack Lifton, the rare earth metals are imported from China, then manufactured into military components in the United States or by an allied country.

Lifton states that many investors believe that for financing purposes, it is not enough to develop REE mining operations alone without building the value-added refining, metal production, and alloying capacity that would be needed to manufacture component parts for end-use products. According to Lifton, vertically integrated companies may be more desirable. It may be the only way to secure investor financing for REE production projects.<sup>27</sup> Joint ventures and consortiums could be formed to support production at various stages of the supply chain at optimal locations around the world. Each investor or producer could have equity and offtake commitments. Where U.S. firms and its allies invest is important in meeting the goal of providing a secure and stable

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<sup>25</sup> Jack Lifton, “Is The Rare Earth Supply Crisis Due to Peak Production Capability or Capacity,” [michaelperelman.worldpress.com](http://michaelperelman.worldpress.com), September 6, 2009.

<sup>26</sup> U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain*, GAO-10-617R, April 1, 2010.

<sup>27</sup> Op. Cit., Lifton Interview by The Gold Report, December 14, 2009.

supply of REEs, intermediate products, and component parts needed for the assembly of end-use products.

## **Role of China**

State-run (“State-Key”) labs in China have consistently been involved in research and development of REEs for over fifty years. There are two State-Key labs: (1) Rare Earth Materials Chemistry and Applications, which has focused on rare earth separation techniques and is affiliated with Peking University, and (2) Rare Earth Resource Utilization, which is associated with the Changchun Institute of Applied Chemistry. Additional labs concentrating on rare earth elements include the Baotou Research Institute of Rare Earths, the largest rare earth research institution in the world, established in 1963, and the General Research Institute for Nonferrous Metals established in 1952.<sup>28</sup> This long term outlook and investment has yielded significant results for China’s rare earth industry.

Major iron deposits in the Bayan Obo in Inner Mongolia contain significant rare earth elements recovered as a byproduct or co-product of iron ore mining. China has pursued policies that would use Bayan Obo as the center of rare earth production and R&D. REEs are produced in the following provinces of China: Baotou (Inner Mongolia) Shandong, Jiangxi, Guangdong, Hunan, Guangxi, Fujian, and Sichuan. Between 1978 and 1989, China’s annual production of rare earth elements increased by 40%. Exports rose in the 1990s, driving down prices. In 2007, China had 130 neo-magnet producers with a total capacity of 80,000 tons. Output grew from 2,600 tons in 1996 to 39,000 tons in 2006.

Spurred by economic growth and increased consumer demand, China is ramping up for increased production of wind turbines, consumer electronics, and other sectors, which would require more of its domestic rare earth elements. Safety and environmental issues may eventually increase the costs of operations in China’s rare earth industry as domestic consumption is becoming a priority for China. REE manufacturing is set to power China’s surging demand for consumer electronics—cell phones, laptops and green energy technologies. According to the report by Hurst, China is anticipating going from 12 gigawatts (GW) of wind energy in 2009 to 100 GW in 2020. Neodymium magnets are needed for this growth.<sup>29</sup>

China’s policy initiatives restrict the exports of rare earth raw materials, especially dysprosium, terbium, thulium, lutetium, yttrium, and the heavy rare earths. The export restrictions would not likely affect the downstream metal or magnets. According to Hurst, China wants an expanded and fully integrated REE industry where exports of value-added materials are preferred. It is common for a country to want to develop more value-added production and exports if it is possible. Hurst also suggests China wants to build strategic stockpiles of raw materials as South Korea and Japan have done, and thus have better control over global supply and prices.

The recent (September 2010) maritime conflict between China and Japan in which Japanese officials claimed that China held up rare earth shipments to Japan (denied by Chinese officials) has heightened the urgency among many buyers to seek diversity in its sources of rare earth materials.

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<sup>28</sup> China’s Rare Earth Elements Industry: What Can the West Learn? by Cindy Hurst, Institute for the Analysis of Global Security, March 2010.

<sup>29</sup> Ibid.

## Rare Earth Legislation in the 111<sup>th</sup> Congress

Congress is concerned about the potential problems with access to rare earth raw materials and downstream products used in many national security applications and clean energy technologies. The Senate Energy and Natural Resources Committee Subcommittee on Energy held a hearing to address the role of strategic minerals and rare earth elements in renewable energy technologies on September 30, 2010. DOE Assistant Secretary for Policy and International Affairs, David Sandalow, discussed Department of Energy efforts to develop a strategic plan for rare earth elements. Legislative proposals have been introduced in the 111<sup>th</sup> Congress to address these issues.

### **H.R. 6160, Rare Earths and Critical Materials Revitalization Act of 2010**

House bill **H.R. 6160** was introduced on September 22, 2010, and reported (H.Rept. 111-644) by the House Committee on Science and Technology on September 28, 2010. The House approved the bill on September 29, 2010, by a vote of 325-98.

The bill would establish an R&D program within the DOE to assure long-term supply of rare earth materials. The R&D program would, among other things, seek to identify and test potential substitutes, improve extraction, processing, recovery, and recycling technology of rare earth materials. The Secretary of Energy would establish an R&D Information Center and collaborate with members of the European Commission to coordinate activities of mutual interest. The proposed R&D Information Center would be a repository for scientific and technical data, assist scientists and engineers in using the Center, provide advice to the Secretary on the R&D program and promote information sharing among the interested parties. The Secretary of Energy would present a plan to Congress that describes R&D activities and their anticipated contribution to providing rare earth materials to the U.S. economy, explain the requirements of the DOE loan guarantee program and the status of the programs receiving loan guarantee support. After four years the program would be assessed by the National Academy of Sciences (NAS). The program would be authorized for \$70 million over a five-year period (2011-2015).

H.R. 6160 would establish a Rare Earth Materials Loan Guarantee program for commercial application of new and improved technologies for the separation, and recovery of rare earths, the preparation of rare earths (i.e., oxides, metal, and alloys) and the application of rare earths in the production of magnets, batteries, optical systems, and electronics, among other things. The Secretary would be required to cooperate with the private sector to assure complete rare earth materials production capacity five years after H.R. 6160 would be enacted into law. The authority to enter into loan guarantees would expire in 2018. The bill would also amend sections 3, 4, and 5 of the National Materials and Minerals Policy Research and Development Act of 1980.

### **H.R. 4866, the Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010**

The House bill, **H.R. 4866** (Coffman) was introduced on March 29, 2010, has 16 co-sponsors, and was referred to the House Committee on Ways and Means, Subcommittee on Trade. The purpose of the bill is

To reestablish a competitive domestic rare earths minerals production industry; a domestic rare earth processing, refining, purification, and metals production industry; a domestic rare earth metals alloying industry; and a domestic rare earth based magnet production industry and supply chain in the United States.

The bill would establish executive agents (at the Assistant Secretary level) from the Departments of Commerce, Defense, Energy, Interior, and State to serve on an interagency working group. The U.S. Trade Representative (USTR) and White House Office of Science and Technology Policy would also appoint representatives to the working group. The secretaries and the representatives appointed from above agencies would assess rare earth supply chain to determine which REEs are critical to national and economic security. Based on a critical designation, rare earth elements would be stockpiled in the national stockpile administered by the Defense Logistics Agency as part of the National Defense Stockpile. The DLA would, if necessary, make a commitment to purchase rare earth raw materials to process and refine raw materials including purchases made from China if necessary. Stockpiling would be terminated when working group agencies determine REEs are no longer critical to U.S. national security or economic well-being.

The USTR would review international trade practices of REE producers to examine possible market manipulation. Action before the WTO would be possible. Loan guarantees would be provided for supply chain development and the House bill would require a report that would describe “mechanisms” for obtaining loan guarantees for new supply chain development in the U.S. The Department of Defense (DOD) would issue guidance for obtaining loans for new defense supply chains and the Department of Energy (DOE) would issue guidance for development of a domestic supply chain for civilian and commercial purposes.

There is a Sense of Congress statement that would use the Defense Production Act (DPA) of 1950 to develop domestic rare earth supply chain and to provide workforce development and training to reestablish the United States as the preeminent center for rare earths production. R&D funding would also be authorized and if no projects are taking place under DPA, the Congress would want to be notified.

## **S. 3521, Rare Earths Supply Technology and Resources Transformation Act of 2010**

A Senate proposal, **S. 3521**(Murkowski), similar to H.R. 4866, would expedite permitting to increase domestic exploration and development of REEs. A Rare Earth Policy Task Force would be established and would be composed of the Secretaries of Interior, Energy, Defense, Commerce, State, and Agriculture. A representative from OMB, CEQ, and others as deemed necessary by the Secretary of the Interior would also serve on the task force. The Rare Earth Policy Task Force would monitor the acceleration of REE projects, review policies that discourage REE development, and report to Congress on results annually. The Secretaries of Interior, Energy, and others would assess supply chain vulnerability and determine elements “critical” to clean energy technologies. They would prepare a stockpile report to determine if rare earth materials critical for clean energy technology, national and economic security should be stockpiled and determine if legal authorities exist to procure stockpile.

If a stockpile were established for clean energy, national defense, and economic security of the United States, it would contain rare earth oxides, and other storable forms of rare earths and alloys. DOE would issue guidance on obtaining loan guarantees to support a domestic supply

chain for clean energy and defense technologies. The DPA would be used to reestablish a domestic supply chain of REEs. A sense of the Congress provision would fund workforce development and training and R&D.

## **H.R. 5136, the Fiscal Year 2011 National Defense Authorization Act**

The House-passed bill (H.R. 5136) would require the Secretary of Defense to assess the rare earth material supply chain to determine if any of the materials were strategic or critical to national security. If the material is determined to be strategic, the Secretary would be required to develop a plan to ensure long-term availability by December 31, 2015. The Secretary shall submit a report to Congress on the assessment and the plan not later than 180 days after enactment of this legislation.

Also, based on congressional findings, among other things, there is an urgent need to eliminate U.S. vulnerability related to the supply of neodymium iron boron magnets and to restore the domestic capacity to manufacture sintered neodymium iron boron magnets used in defense applications. Within 90 days of enactment of this bill the Secretary of Defense would be required to submit a plan, to the appropriate congressional committees, to establish a domestic source of sintered neodymium iron boron magnets used in defense applications.

## **P.L. 111-84, the Fiscal Year 2010 National Defense Authorization Act**

In the proposed House and Senate (H.R. 2647/S. 1390) versions of the defense authorization bill for 2010, Representative Mike Coffman and Senator Evan Bayh introduced legislation to direct the Comptroller General to determine the extent to which specific military weapons systems are currently dependent upon rare-earth materials and the degree to which the United States is dependent upon sources that could be interrupted or disrupted. The measure also directed DOD to describe the risks (both current and projected) involved in the United States' dependence on foreign sources of these materials, and any steps DOD has taken or plans to take to address any potential risks to national security.<sup>30</sup> The measure was passed in the Fiscal Year 2010 National Defense Authorization Act.<sup>31</sup>

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<sup>30</sup> McCormack, Richard. China's Complete Control of Global High-Tech Magnet Industry Raises U.S. National Security Alarms. *Manufacturing & Technology News*, Vol. 16, No. 16, September 30, 2009, viewed online at <http://www.manufacturingnews.com/news/09/0930/magnets.html>.

<sup>31</sup> P.L. 111-84 was signed into law on October 28, 2009. The text, as it appears in the bill, reads as follows.

Sec. 843. Report on Rare Earth Materials in the Defense Supply Chain.

(a) Report Required.—Not later than April 1, 2010, the Comptroller General shall submit to the Committees on Armed Services of the Senate and House of Representatives a report on rare earth materials in the supply chain of the Department of Defense.

(b) Matters Addressed.—The report required by subsection (a) shall address, at a minimum, the following: (1) An analysis of the current and projected domestic and worldwide availability of rare earths for use in defense systems, including an analysis of projected availability of these materials in the export market. (2) An analysis of actions or events outside the control of the Government of the United States that could restrict the access of the Department of Defense to rare earth materials, such as past procurements and attempted procurements of rare earth mines and mineral rights. (3) A determination as to which defense systems are currently dependent on, or projected to become dependent on, rare earth materials, particularly neodymium iron boron magnets, whose supply

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## Possible Policy Options

### Authorize and Appropriate Funding for a USGS Assessment

In addition to the two current legislative proposals, Congress could authorize and appropriate funding for a USGS comprehensive assessment to identify economically exploitable REE deposits (as a main product or co-product), and where REE could be exploited as a byproduct. Authorizations and additional appropriations could be supported for basic science research on substitutes and efforts at secondary recovery for REEs. Additionally, R&D may be necessary on how to proceed in the exploitation of high-thorium monazite deposits where REE could be produced as a byproduct.

### Support and Encourage Greater Exploration for REE

Supporting/encouraging greater exploration for REE efforts in the United States, Australia, Africa, and Canada could be part of a broad international strategy. There are only a few companies in the world that can provide the exploration and development skills and technology for REE development. These few companies are located primarily in Canada, Australia, China, South Africa, and the United States, and may form joint ventures or other types of alliances for R&D, and for exploration and development of REE deposits worldwide, including those in the United States. Whether there should be restrictions on these efforts in the United States is a question that Congress may ultimately choose to address.

### Challenge China on Its Export Policy

Challenging China on its export restrictions through the WTO would involve filing a dispute based on WTO rules that generally prohibit members from imposing restrictions (i.e., quotas) or other restraints (e.g., minimum prices or licensing) on exports. In June 2009, the United States filed a dispute over raw material exports from China, which included: bauxite, coke, fluor spar, magnesium, manganese, silicon carbide, silicon metal, yellow phosphorus and zinc.<sup>32</sup> Some REE analysts assert that China sets export restrictions to meet growing Chinese demand for raw materials and to force the manufacturing of end-use products in China.<sup>33</sup>

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could be restricted—(A) by actions or events identified pursuant to paragraph (2); or (B) by other actions or events outside the control of the Government of the United States. (4) The risk to national security, if any, of the dependencies (current or projected) identified pursuant to paragraph (3). (5) Any steps that the Department of Defense has taken or is planning to take to address any such risk to national security. (6) Such recommendations for further action to address the matters covered by the report as the Comptroller General considers appropriate. (c) Definitions.—In this section: (1) The term “rare earth” means the chemical elements, all metals, beginning with lanthanum, atomic number 57, and including all of the natural chemical elements in the periodic table following lanthanum up to and including lutetium, element number 71. The term also includes the elements yttrium and scandium. (2) The term “rare earth material” includes rare earth ores, semi-finished rare earth products, and components containing rare earth materials.

<sup>32</sup> Office of the U.S. Trade Representative, Press Release, “WTO Case Challenging China’s Export Restraints on Raw Material Inputs,” June 23, 2009.

<sup>33</sup> Irma Venter, “Investors take closer look at rare earth elements as technology, green revolution pick up pace,” Mining (continued...)



## Establish a Stockpile

Establishing a government-run economic stockpile and/or private-sector stockpiles that would contain supplies of specific REE broadly needed for “green initiatives” and defense applications is a policy advocated by some in industry and government. This may be a prudent investment. Generally, stockpiles and stockpile releases could have an impact on prices and supply but would also ensure supplies of REE materials (oxides, metals, etc.) during times of normal supply bottlenecks. An economic stockpile could be costly and risky, as prices and technology may change the composition of REEs that are needed in the economy.

According to USGS,<sup>34</sup> DOD along with USGS is examining which of the REEs might be necessary in the National Defense Stockpile (NDS). In the recent past, NDS materials were stored for wartime use based on a three-year war scenario. Some of the rare earth elements contained in the National Defense Stockpile were sold off by 1998. However, rare earth elements were never classified as strategic minerals.<sup>35</sup> DOD had stockpiled some yttrium but has since sold it off, and none of the REEs have been classified as strategic materials. A critical question for stockpile development would be: What materials along the supply chain should be stockpiled? For example, should the stockpile contain rare earth oxides or alloyed magnets which contain the REEs, or some combination of products?

The National Research Council (NRC) has produced an in-depth report on minerals critical to the U.S. economy and offers its analysis as described here: “... most critical minerals are both essential in use (difficult to substitute for) and prone to supply restrictions.”<sup>36</sup> While the NRC report is based on several availability criteria used to rank minerals for criticality (geological, technical, environmental and social, political, and economic), REEs were determined to be critical materials assessed at a high supply risk and the possibility of severe impacts if supplies were restricted. Some of the REE applications are viewed as more important than others and some are at greater risk than others, namely the Heavy Rare Earth Elements (HREEs), as substitutes are unavailable or not as effective.<sup>37</sup>

The federal government and private sectors are beginning to address how to secure reliable rare earth materials (raw materials through metals and alloys) from China and non-Chinese sources in the short term, and how to rebuild the U.S. supply chain for the long term.

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Weekly Online, <http://www.miningweekly.com>, September 18, 2009.

<sup>34</sup> Phone interview with Jim Hedrick, Rare Earth Specialist, USGS, October 1, 2009.

<sup>35</sup> For a discussion of the strategic materials for defense uses, see CRS Report RL33751, *The Specialty Metal Provision and the Berry Amendment: Issues for Congress*, by Valerie Bailey Grasso.

<sup>36</sup> National Research Council, *Minerals, Critical Minerals, and the U.S. Economy*, National Academies Press, 2008.

<sup>37</sup> DOI/USGS, *Minerals Yearbook*, Volume 1, 2007.

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