U.S.-China Economic and Security Review Commission Staff Backgrounder

China's Rare Earths Industry and its Role in the International Market

Lee Levkowitz, Policy Analyst
Nathan Beauchamp-Mustafaga, Research Intern

November 3, 2010

Introduction

China produces 97 percent of the world's rare earth elements, a key component in a large assortment of advanced military and civilian technologies. Increasing global demand and Chinese reductions in export quotas over the past six years have led to international concerns about future supply shortages. Although the United States currently is seeking alternative sources for rare earths, the Government Accountability Office has stated that it may take up to 15 years before the United States is able to rebuild its U.S.-sourced rare earth supply chain.[1] In addition, China's monopoly over rare earths has led to fears of China using its dominance as leverage to influence other nations' foreign policies. The following backgrounder seeks to provide an overview of China's rare earth industry and how it affects the United States.

What Are Rare Earth Elements?

Rare earth elements are a collection of 17 elements that are critical to civilian and military high technology applications.[*] Rare earth elements are distributed globally, with 36 percent of known reserves located in China, and 13 percent located in the United States.[2] Although reserves are abundant, it is difficult to find them in sufficient concentrations where they can be profitably mined and processed.[3] After discovering a potential site to mine rare earth elements, it can take up to 10 years before a company is able to even begin rare earth mining.[†, 4] Further, the process of extracting and processing rare earth elements into alloys and permanent magnets to be used in high tech applications is laborious and capital intensive, costing more than $40 per kilogram of output.[‡,5]

Rare earths are used in a variety of applications because of their magnetic and conducive properties, to include:

---

[*] The rare earth elements include: scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.
[†] Operating a mine may require environmental permits, large sources of financing, building of infrastructure (including roads, railways, etc.), the acquisition of mining technology, and acquiring transportation for the materials available.
[‡] There are between 100-1000 steps to separate rare earth elements from ores extracted from the ground.

- **Commercial applications:** Rare earth elements are used in items ranging from cell phones and computer hard drives to MRI machines. In addition, they are necessary in the production of many green technologies, including electric and hybrid vehicle motors, wind turbines,[*] and energy efficient fluorescent light bulbs.[6]
- **Military applications:** Rare earths also play a critical role in sophisticated military applications including guidance and control systems; advanced optics technologies; radar and radiation detection equipment; and advanced communications systems. Some of the defense related weapons and equipment that contain rare earths are: Predator unmanned aerial vehicles, Tomahawk cruise missiles, Zumwalt-class destroyers, night vision goggles, smart bombs, and sonar transducers.[7] Nevertheless, a November 2010 Department of Defense report found that the U.S. military consumption of rare earth elements constitutes less than five percent of overall U.S. consumption.[8]

(For more information about the rare earth elements and their applications, see Appendix A.)

History of the Rare Earths Industry

While China dominates the rare earth production market today, the United States was once the world leader in rare earth production and innovation. From the 1950s until the 1980s, the United States was the number one producer and innovator for rare earth elements in the world, with most mining taking place at the facility in Mountain Pass, located near the Nevada border in the Mojave Desert of southeastern California. In 1984, the Mountain Pass mine accounted for 100 percent of U.S. domestic demand and one-third of global exports of rare earths.[9]

As the United States was leading the world's rare earth industry, leaders in Beijing began to realize China's potential to exploit its own abundant rare earth reserves; Deng Xiaoping allegedly stated in 1992, "There is oil in the Middle East; there are rare earths in China."[10] In the late 1970s, China's production capacity dramatically increased due to government support for developing enhanced mining techniques and research and development (R&D) for rare earth applications.[†,11] As a result, China averaged a 40 percent increase in rare earth production annually from 1978 to 1989, making it one of the world's largest producers. Most of China's rare earth mining has centered around China's Bayan Obo mine in Baotou, Inner Mongolia.

During China's build up of its domestic rare earth production capacity, many Chinese rare earth mining companies were not profitable, but were able to continue operations due to non-performing loans and other forms of financial support from Chinese government-controlled banks.[12] This support allowed Chinese rare earth companies to produce at low prices, thereby increasing exports of rare earths. China's increasing exports through the 1990s caused global prices to fall considerably, eventually driving non-Chinese producers out of business. The California-based Mountain Pass mine shut down in 2002 primarily as a result of lower-priced competition from Chinese suppliers, leaving the United States entirely dependent on imports for its domestic rare earths consumption.[13]

As mining of rare earth elements moved from the United States to China, production of rare earth oxides, alloys and permanent magnets used for many of the above-listed commercial and military applications moved to China as well. The relocation of production to China has resulted in the United States relinquishing its position as the leading country for research in rare earth technologies. Rare earths industry consultant Jack Lifton has stated that even if the United States was able to resume rare earth mining immediately, the erosion of technical expertise would leave U.S. producers unable to effectively refine rare earths into usable materials, and a lack of experienced researchers would significantly hinder U.S. commercial and military innovation in rare earths products.[14]

---

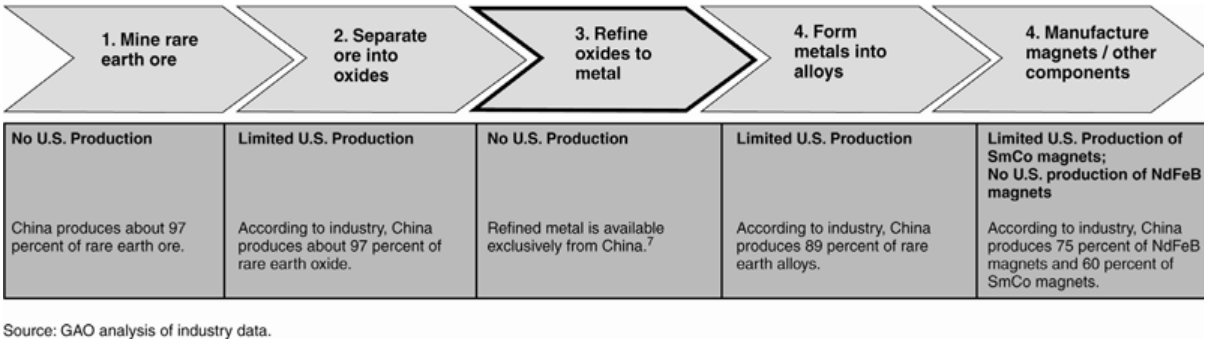
[*] A three-megawatt wind turbine uses around two tons of neodymium, a rare earth that is used in hyper-efficient motors and generators.

[†] Government-sponsored programs that support rare earth production and innovation include: Program 863; Program 973; the Nature Science Foundation of China; the Peking University-affiliated State Key Laboratory of Rare Earth Materials Chemistry and Applications; the Chinese Academy of Science-affiliated State Key Laboratory of Rare Earth Resource Utilization; the Baotou Research Institute of Rare Earths; and the General Research Institute for Nonferrous Metals.

Current State of China's Domestic Rare Earths Market

Today, China dominates almost all steps of the rare earth supply chain, from mining to the manufacturing of permanent magnets used in high tech applications.[*] Not only does China produce approximately 97 percent of the current world supply of rare earth elements, but it also produces 97 percent of rare earth oxides[†], and supplies 100 percent of rare earth refining capacity. (For more information on the rare earth supply chain, see Appendix C.)

Figure 1: Example of a Permanent Magnet Rare Earth Supply Chain



Source: Government Accountability Office, "Rare Earth Materials in the Defense Supply Chain," GAO Report: GAO-10-617R, April 1, 2010.

Problems Facing China's Rare Earths Industry

Although China produces most of the world's rare earths, its domestic industry faces a host of problems, including:

- **Smuggling** – China's rare earth industry is so large it is challenging to monitor illegal mining. Smuggling accounts for one-third of the total amount of rare earths leaving China. Illegal exports keep prices low and deplete strategic resources. As a result, Beijing has launched a nationwide crackdown on illegal mining activity in the second half of 2010.[‡,15]
- **Environmental damage** – The mining of rare earths produces millions of tons of wastewater, harmful chemical run-off, and radioactive byproducts which, if not properly disposed, can contaminate surrounding waters and farmlands. In China, lax mining regulations have led to severe environmental damage and toxic chemicals being poured into water sources. In order to cut production costs, many mine operators do not comply with environmental standards. Some analysts argue that China is able to operate its rare earth mines at one third the cost of U.S. mines in large part because of the country's lax environmental standards, and/or weak enforcement of those standards.[16]

Beijing's Attempts to Regulate the Industry

[*] A permanent magnet is magnetized and will always be magnetic, unlike electromagnets, which need electrical current to be magnetic. Neodymium iron boron (NeFeB) permanent magnets are the strongest magnets in the world and are used for a variety of applications, ranging from computer hard drives to guided missile destroyers. Samarium cobalt magnets (SmCo) are the second strongest magnets and have the highest resistance to demagnetization. They are used for precision guided munitions, helicopters, and advanced radar systems.

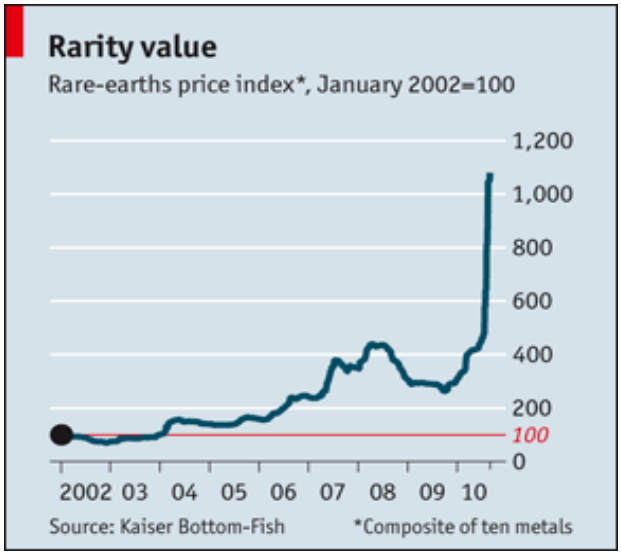
[†] Rare earth oxides are a component that is produced in the rare earth supply chain and used to make metals and alloys which are then turned into permanent magnets.

[‡] The crackdown consists of "[shutting] down unlicensed exploration and mining operations by demolishing construction, confiscating equipment and products, closing shafts and cutting off water, power and explosives supplies." Rujun Shen and Jacqueline Wong, "China plans crackdown on illegal rare earth mining," *Reuters*, May 20, 2010.

Recently, the Chinese government has taken measures to regulate the industry and to prevent the depletion of rare earth resources:

- **Reduced export quotas** – In the past five years, Beijing has reduced export quotas by 54 percent from 65,600 tonnes in 2005, in order to ensure enough resources to satisfy domestic demand and to regain control over operations.[17] An August 2009 draft report from China's Ministry of Industry and Information Technology, which controls the rare earths industry, also stated that in the next five years Beijing will ban the export of five rare earth minerals.[*,18] Since 2009, reductions have become more severe; in July 2010, China decreased the export quota for the second half of 2010 by 72 percent in a move which surprised non-Chinese rare earth industry officials.[19] Threats of further restrictions have driven up international prices for several rare earths and have sparked international concerns about supply shortages in coming years. The 2010 price of select rare earths has risen almost 500 percent over 2009 (see graph below).[20] In addition, numerous analysts have expressed concerns that quota reductions will increase U.S. dependence on China for finished goods.[21] (For more information on export quotas, see Appendix B.)

Figure 2: Select Rare Earths Price Index 2002-2010



Source: The Economist, "China restricts exports of some obscure but important commodities," September 2, 2010.

- **Technology-for-Resources Initiative** – Industry officials have discussed a potential new Chinese central government policy to attract foreign companies to establish rare earth processing plants in China, thereby creating more-profitable downstream processing sectors. The plan calls for reductions in export quotas to force companies to move their production facilities to China.[22]

- **Consolidation of the industry** – In recent years, Beijing has been closing smaller, illegal mining operations, while merging larger producers and limiting rare earth mining operations to state-owned enterprises. This process has allowed the government to assert more control over the industry. China plans to make the Baotou mine in Inner Mongolia the center of both

[*] The five rare earths are: dysprosium, terbium, thulium, lutetium and yttrium. China's State Council has not yet approved this draft.

production and innovation for the entire rare earth industry, by giving Baotou Steel, the state-owned operator of the Baotou mine, exclusive rights to mine rare earths in the region.[23] In addition, the central government plans to reduce rare earth mines from 123 to less than 10, and reduce processing firms from 73 to 20.[24] The Ministry of Industry and Information Technology has stopped issuing new licenses for domestic exploration until July 2011. In order to ensure these laws are implemented, over the next five years the ministry will conduct impromptu on-site visits and inspections.[25]

- **Unified Pricing Mechanism** – The Chinese central government has announced plans to implement a unified pricing mechanism to control rare earth prices. Two of China's biggest mining companies have agreed to publish a set price for select rare earths once a month.[26] Beijing has said this is part of efforts to cut down on illegal mining and stabilize the market, as well as to improve the profitability of mining companies.[27]
- **Stockpiling** – Chinese leaders have indicated that they will build a national rare earth resources strategic reserves base in northern China. It is unclear if China has started the construction of the base.[28]

Chinese Attempts to Acquire International Rare Earth Mines

Despite China possessing a majority of global rare earths reserves, several Chinese companies have also tried to acquire stakes in international mines:

- In 2005, China National Offshore Oil Corporation (CNOOC) submitted an $18.5 billion bid to purchase Unocal, the then-owner of the Mountain Pass rare earths mine.[*] CNOOC eventually dropped its bid after significant U.S. political opposition to the deal. If the deal were to have gone through, CNOOC would have gained control over the reserves in the Mountain Pass mine.
- In May 2009, China Non-Ferrous Metal Mining Company attempted to purchase a 51 percent stake in Lynas Corporation. Lynas Corporation owns Mount Weld mine in western Australia, the richest deposit of rare earth metals in the world. The Chinese company eventually backed out of the deal due to Australian government opposition.[29]
- Also in May 2009, Jiangsu Eastern China Non-Ferrous Metals Investment Holding Co. acquired a 25 percent stake in Arafura Resources, which owns the Nolans Bore mine in northern Australia.[30]

The Geopolitical Implications of China's Dominance of the Rare Earth Market

In September 2010, a Chinese fishing trawler allegedly struck two Japanese coast guard vessels in disputed waters near the Senkaku Islands (called the Diaoyu Islands in China). The resulting arrest by the Japanese government of the Chinese fishing boat's crew and detention of the captain brought Chinese-Japanese relations to their lowest point in years. In addition to Beijing's calls for the immediate release of the captain and the suspension of high level exchanges, Japanese industry officials reported that China had cut off exports of all rare earth oxides, salts and metals to Japan, the world's biggest importer of Chinese rare earths.[31] The day after reports of the export ban, Japan released the captain of the Chinese fishing vessel. Nevertheless, Chinese customs officials reportedly did not release shipments of rare earths to Japan until almost two months later.[32]

The Chinese Commerce Ministry has denied halting exports of rare earths as a result of the incident, while China's Minister of Commerce, Chen Deming, has suggested that exporters of rare earths may

[*] In October 2008, Molycorp Minerals, LLC acquired the Mountain Pass mine from Chevron.

have halted exports because of their own personal feelings toward Japan.[*,33] In addition, Premier Wen Jiabao denied the allegations, stating that "China is not using rare earths as a bargaining chip."[34] While Japanese government officials have not officially accused the Chinese government of enacting a rare earths embargo over the diplomatic row, they have conceded that a *de facto* ban of minerals was in effect.[35] There were also unconfirmed reports that the *de facto* rare earth export ban extended to numerous U.S. and European companies.[36]

The allegations of a politically-motivated Chinese embargo on rare earths exports have far-reaching implications. Many analysts saw the move as an unexpected escalation to a territorial dispute, and companies worldwide viewed this as evidence of the need to diversify supply sources of rare earths.[37] The increased wariness over China's seeming monopoly on rare earths has reinvigorated financial support for new rare earth mines outside of China, to include efforts by entrepreneurs in the United States to obtain financing to re-open the Mountain Pass mine, and by efforts in Japan to fund new mining ventures in Australia, Kazakhstan, Mongolia and Vietnam.[38]

Predicted Future Supply and Demand for Rare Earth Elements

Chinese domestic demand for rare earths has steadily increased alongside the growth of China's economy and its increased production of newer technologies that require rare earth elements.[†] In the past, China's massive production of rare earths has been able to satisfy both domestic and international needs. However, analysts predict that China's domestic demand for rare earths will soon match, if not eclipse, its domestic supply. The rest of the world, too, will continue to demand rare earth elements at higher rates as countries recover from the global financial crisis and continue to develop and consume high tech goods. Indeed, Dudley Kingsnorth, a prominent consultant in the industry, has forecast a global shortage of 15,000 tons in 2010 due to reduced Chinese export quotas.[39] If global demand continues to increase at the current rate, by 2015, there will be a significant global gap between supply and demand equaling about 40,000 tons.[‡,40] In addition, if China continues to reduce export quotas and bans the export of a number of rare earths, this production gap could be even larger.[41]

U.S. Responses

The U.S. government and private industry are responding to potential production gaps in a number of ways. These include:

- **Opening new mines** – In 2008, Molycorp Minerals, LLC, a company based in Colorado, purchased the Mountain Pass mine in California. The company expects the Mountain Pass mine to achieve full-scale production of mining and separation of cerium, lanthanum, praseodymium, and neodymium by 2012. Molycorp had an initial public offering in July 2010, but the results were below expectations and the company is still waiting for Department of Energy approval for a loan-guarantee.[42] The Department of Defense is also considering providing financial assistance to U.S. producers such as Molycorp.[43] Nevertheless, Mountain Pass will not have the capability needed to refine the oxides into rare earth metals in the immediate future.[§, 44]

---

[*] During the purported export ban, all 32 licensed exporters halted exports on the same day, including 10 foreign companies.

[†] China's campaign to become the leader in global clean energy technologies will dramatically increase its demand for rare earths. The new wind turbines that several Chinese companies plan on building require approximately two tons of rare earth elements per windmill.

[‡] In 2010, global demand for rare earth elements was expected to be 136,100 tons, up 48 percent from 2000. Mr. Kingsnorth estimates that in 2015 global demand for rare earths will reach 210,000 tons. However, these specific numbers vary among industry officials.

[§] Nearly six dozen other companies in the United States, Canada, Australia, South Africa, and elsewhere are also attempting to begin production of rare earths in the coming years. With the exception of the Mountain Pass mine and Lynas Corporation's Mount Weld mine in Australia, most of the companies lack environmental permits and mineral processing equipment to begin production within the next five years. Other U.S. sites being explored include Bear Lodge in Wyoming, Diamond Creek and Lemhi Pass in Idaho, and Elk Creek in Nebraska.

- **R&D for alternatives and recycling** – Many high tech companies have begun conducting R&D for cost effective ways to recycle rare earth elements from old equipment, such as computers and electronic motors. In addition, some companies have been researching alternative elements to replace rare earths.[*] However, the U.S. Geological Survey has noted that substitutes are currently available for many applications, but generally are less effective than the use of rare earths.[45]

- **Department of Energy (DOE) "Strategic Plan for Technology Minerals"** – In March 2010, DOE announced a strategic plan for rare earths and other materials in clean energy technologies. The plan will focus on globalizing the supply chain for rare earths, technology innovation for recycling rare earths, and developing substitutes for rare earths. The DOE's official report is not yet complete.[46]

- **Stockpiling** – The Department of Defense has added several rare earth elements to a list of minerals that it would like added to the Defense National Stockpile Center. However, the military cannot add any material to the stockpile without Congressional approval in a process that could take up to two years.[47]

- **Legislation** – There have recently been a number of legislative bills introduced regarding rare earths:

    - In March 2010, Rep. Mike Coffman (R-CO) introduced the Rare Earths Supply-Chain Technology and Resources Transformation (RESTART) Act of 2010 (H.R. 4866), a bill calling for the stockpiling of rare earths and the establishment of rare earth production facilities in the United States.[48] Sen. Lisa Murkowski (R-AK) has introduced similar legislation in the Senate, named the Rare Earths Supply Technology and Resources Transformation Act of 2010 (S. 3521).[49]

    - In May 2010, Rep. Coffman also introduced an amendment to the National Defense Authorization Act for Fiscal Year 2011 (H.R. 5136) requiring the Department of Defense to define which rare earths, if any, are critical to national security and to provide an assessment of the rare earth supply chain. If any of the rare earths are found to be critical, the Defense Secretary will be required to come up with a plan to ensure long-term availability of the materials by 2015.[50]

    - In September 2010, Rep. Kathleen Dahlkemper (D-PA) introduced, and the House of Representatives subsequently passed, the Rare Earths and Critical Materials Revitalization Act of 2010 (H.R. 6160). The bill directs the DOE to support new rare earth technology through public and private sector collaboration, and coordination with the European Union. The bill also calls for loan guarantee commitments for rare earth-related investments such as the Mountain Pass mine.[51]

- **W.T.O. Filings** – In October 2010, the U.S. Trade Representative initiated a Section 301 investigation into China's clean energy sector, in response to a petition filed by the United Steelworkers Union.[52] Among other things, the petition alleges that China's rare earth export quotas violate the World Trade Organization General Agreement on Tariffs and Trade.[53]

[*] Japan is a world leader of both rare earth recycling and adaption. For example, during the September 2010 purported Chinese rare earth export ban, Toyota, with government-funded research, was able to unveil a new magnet system that eliminated the need for neodymium. The Toyota Prius previously needed two to four pounds of neodymium.

Appendix A: Rare Earth Element Uses and Sources [54]

Minerals	Atomic No.	Commercial Use	Mine Production Sources	U.S. Import Sources	Other Known Resources
Scandium (Sc)	21	Stadium lights, lasers, aluminum alloys (sporting equipment)	China, Kazakhstan, Russia, Ukraine	China, Russia, Ukraine*	Australia, Madagascar, Norway, United States
Yttrium (Y)	39	Lasers, fuel efficiency, microwave communication for defense and satellite industries, color televisions, computer monitors, temperature sensors	Brazil, China, India, Malaysia	China-90%, Austria-8%, Japan-1%, United Kingdom-1%	Canada, Australia, United States
Lanthanum (La)	57	Electric car batteries, high-tech digital cameras, video cameras, laptop batteries, x-ray films, lasers	Brazil, China, India, Malaysia	China-91%, France-3%, Japan-3%, Russia-1%	Australia, Brazil, South Africa, Sri Lanka, Thailand, United States
Cerium (Ce)	58	Lens polishes (glass, television faceplates, mirrors, optical glass, silicon microprocessors, disk drives)			
Praseodymium (Pr)	59	Searchlights, airport signal lenses, photographic filters			
Neodymium (Nd)	60	High-strength magnets (cell phones, computers), anti-lock brakes, air bags, lasers			
Promethium (Pm)	61	Portable X-ray units			
Samarium (Sm)	62	Glass, miniature speakers, capacitors			
Europium (Eu)	63	Compact fluorescent bulbs, color televisions, computer screens			
Gadolinium (Gd)	64	Neutron radiography, magneto-optic recording technology			
Terbium (Tb)	65	High-strength magnets, energy-efficient fluorescent lamps			
Dysprosium (Dy)	66	High-strength magnets			
Holmium (Ho)	67	Glass tint, few uses			
Erbium (Er)	68	Metal alloys, lasers			
Thulium (Tm)	69	Lasers			
Ytterbium (Yb)	70	Stainless steel			
Lutetium (Lu)	71	Petroleum refining catalysts			

* No definitive data exists listing import sources, but most imported material is thought to be from these countries.

Appendix B: The History of China Export Quotas for Rare Earth Elements

Chinese Export Quota History 2004- 2010 (Metric Tons of Rare Earth Ore)					
	Rare Earth Quota				
Year	Domestic Companies	Foreign Companies Operating in China	Annual Total	Annual Percent Change	Rest of World Demand
2005	28,040t	17,659t	65,609t	0%	46,000t
2006	45,752t	16,069t	61,821t	- 6%	50,000t
2007	43,574t	16,069t	59,643t	-4%	50,000t
2008	40,987t	15,834t	56,939t	-5.50%	50,000t
2009	33,300t	16,845	50,145t	-12%	25,000t
2010	22,513t	7,746t	30,259t	-40%	55,000t

Sources: Dudley Kingsnorth, "The Challenges of Meeting Rare Earths Demand in 2015," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010); Lynas Corporation, "Chinese Rare Earth Export Quota Significantly Reduced for Second Half 2010," July 9, 2010.

Appendix C: Non-Chinese Producers of Rare Earth Products

Oxides	
Company	**Country**
Japan Oil, Gas and Metals National Corp	Japan
Lynas (expected production 2011)	Australia
Molycorp (expected production 2012)	United States
Metals, Alloys & Powders	
Company	**Country**
Santoku Corporation	Japan, US
Shin Etsu	Japan
Great Western Minerals Group/ Less Common Metals	Canada, UK
Phosphors	
Company	**Country**
Rhodia	US, France
Magnets: Distributors/Fabricators*	
Company	**Country**
Adams (NdFeB, SmCo)	US
Allstar (NdFeB)	US
Bunting (NdFeB, SmCo)	US
Dura Magnetic (NdFeB, SmCo)	US
Integrated Magnetics (NdFeB, SmCo)	US
KJ Magnetics (SmCo)	US
Magnet Sales (NdFeB, SmCo)	US
Magnetic Component Engineering, Inc. (NdFeB, SmCo)	US
Quadrant (NdFeB, SmCo)	US
Stanford Magnetics (NdFeB, SmCo)	US
Dexter Magnetic Technologies (NdFeB, SmCo)	US, UK, China
Magnets: Manufacturers†	
Company	**Country**
Electron Energy Corporation (SmCo)	US
Thomas and Skinner (Plans for NdFeB)	US
Arnold Magnetic Technologies (SmCo and plans for NdFeB)	US, Switzerland
Vacuumschmelze GmbH/ Neorem (NdFeB, SmCo)	Germany, Finland
Hitachi Metals (NdFeB, SmCo)	Japan
Shin Etsu (NdFeb, SmCo)	Japan

NOTE: NdFeB = Neodymium Iron Boron, SmCo = Samarium Cobalt

Source: Jeff Green, "Government Action (Inaction?) in the Strategic Materials Market," (Critical and Rare Metals Summit III: Rare Earths Outlook, Washington, DC, October 27, 2010).

* Distributor/Fabricators typically import overseas material and resell it to domestic customers. Many merely pass product through from manufacturers to end-users. Others do some minimal grinding. The more sophisticated of the lot will fabricate higher value components using imported magnets.

† Manufacturers typically create their own proprietary alloys, and either cast or sinter magnets from those alloys. Control over the quality of the alloys is an important distinction of this group, as they are not typically dependent on overseas material suppliers. In addition to cast and sintering capabilities, the magnet manufacturers also typically utilize heat treating processes, in order to further enhance the properties of the magnets. The magnet manufacturers generally maintain a full range of manufacturing capabilities, to enable them to manufacture all forms of custom designs and applications. Magnet manufacturers can also fabricate high value components utilizing the magnets they have made.

Appendix D: Current and Future Rare Earth Production by Country

Country	% of Global RE Reserves	Total RE Production 2009 (tonnes)	Active/Planned Mine	Rare Earths Mined
China	36%	125,000 (20,000 additional tonnes from "unofficial sources")	Baotou Mine (Bayan Obo, Inner Mongolia)	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium
			Xunwu Mine (Jiangxi Province)	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium, Yttrium
			Longnan Mine (Jiangxi Province)	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium, Yttrium
Russia	19%	2,470	Loparite mine (Lovozerskaya, Russia)	Lanthanum, Cerium, Praseodymium, Neodymium
United States	13%	0 (processing of stockpiled rare earths led to 2,150)	Molycorp mine (Mount Pass, California) - **PLANNED TO RE-OPEN 2012**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Gadolinium
Australia	5%	0	Lynas mine (Mount Weld) - **PLANNED TO OPEN 2011**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium
			Arafura Resources mine (Noalans Bore) - **PLANNED TO OPEN 2013**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium, Dysprosium
India	3%	50	Various mines	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium
Malaysia	0.03%	380	Lahat mine (Perak)	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium, Yttrium
Brazil	0.04%	650	N/A	N/A
Canada		0	Nechalacho mine (Thor Lake) - **PLANNED TO OPEN 2015**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium, Dysprosium
			Hoidas Lake - **PLANNED TO OPEN 2014**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium, Dysprosium

Vietnam	0.03%	0	Dong Pao mine (being developed by Japan) - **PLANNED TO OPEN 2012**	Lanthanum, Cerium, Praseodymium, Neodymium, Samarium
Other	22%	0		
Total	**100%**	**128,550**		

Sources: U.S. Department of Energy, "Critical Materials Strategy," December 2010.; Dudley Kingsnorth, "Rare Earths: Facing New Challenges in the Next Decade," Industrial Minerals Company of Australia, Pty Ltd., March 2010. *http://www.terramagnetica.com/downloads/IMCOA-2010-03-SME-Presentation-Final-R2.pdf*

NOTE: The Department of Energy (DOE) estimates that in the short term (0-5 years), the following rare earths will be deemed "critical" in terms of weighing the tightness of supply vs. increasing demand: **dysprosium**, **europium**, **indium**, **terbium**, **neodymium**, and **yttrium**. Despite several new mines coming online in the next five years, DOE maintains that the following rare earth elements will still be critical in the medium term (5-15 years): **dysprosium**, **europium**, **terbium**, **neodymium**, and **yttrium**.[55]

[1] Government Accountability Office, "Rare Earth Materials in the Defense Supply Chain," *GAO Report: GAO-10-617R*, April 1, 2010.
[2] Government Accountability Office, "Rare Earth Materials in the Defense Supply Chain," *GAO Report: GAO-10-617R*, April 1, 2010.
[3] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[4] Government Accountability Office, "Rare Earth Materials in the Defense Supply Chain," *GAO Report: GAO-10-617R*, April 1, 2010.
See also: Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[5] Dudley Kingsnorth, "The Challenges of Meeting Rare Earths Demand in 2015," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010).
[6] Stephen Marcus, "A cleantech resource crisis: Will rare earth and lithium availability thwart cleantech growth?" *Cleantech Group LLC*, January 2010.
See also: Institute for Energy Research, "Rare Earth Elements are Vulnerable to Supply Disruptions When China Controls 97% of the World's Production," January 17, 2010.
[7] Keith A. Delaney, "Rare Earth Supply and National Security & Clean Energy," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010).
[8] Gopal Ratnam, "U.S. Defense Department Sees No Rare-Earths Crisis; May Aid U.S. Producers," *Bloomberg*, October 31, 2010.
[9] Jack Lifton, "The Battle Over Rare Earth Metals," *The Journal of Energy Security*, January 12, 2010.
[10] *Xinhua*, "Mouqiu Guoji Huayuquan: Zhongdong You Shiyou Zhongguo You Xitu" (In Search of International Discourse Rights: The Middle East has Oil, China has Rare Earths), September 13, 2010.
[11] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[12] "China and the Future of Rare Earth Elements," *Stratfor*, October 12, 2010.
[13] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
See also: Keith A. Delaney, "Rare Earth Supply and National Security & Clean Energy," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010).
[14] Lara Crigger, "Jack Lifton: US Has Been 'Foolish' On Rare Earth Metals," *Hard Assets Investor*, September 3, 2010.
See also: Hurst, Cindy. "China's Ace in the Hole: Rare Earth Elements." *Joint Force Quarterly* 59 (2010): 121-26.
[15] *China Daily*, "Unified Pricing to Buoy Rare Earths Prices." July 8, 2010.
See also: Rujun Shen and Jacqueline Wong, "China plans crackdown on illegal rare earth mining," *Reuters*, May 20, 2010.
[16] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[17] Dudley Kingsnorth, "The Challenges of Meeting Rare Earths Demand in 2015," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010).

[18] Ambrose Evans-Pritchard, "World faces hi-tech crunch as China eyes ban on rare earth metal exports," *Telegraph*, August 24, 2009.
[19] *China Daily*, "China Reduces Rare Earth Export Quota by 72%," July 9, 2010.
[20] The Economist, "China restricts exports of some obscure but important commodities," September 2, 2010.
[21] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[22] Yajun Zhang, "China Dangles Rare-Earth Resources to Investors," *Wall Street Journal*, August 16, 2010.
See also: *People's Daily*, "China's Inner Mongolia Regulates Rare Earth Export to Attract Investment: Official," September 2, 2009.
[23] *Reuters,* "China Consolidates Rare Earth Mining in Baotou," Sept 15, 2010.
[24] *China Daily*, "Bigger Say Set on Rare Earths Market," August 10, 2010.
[25] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[26] Brian Spegele, "China Takes Step to Set Rare-Earth Prices," *Wall Street Journal*, August 11, 2010.
[27] *China Daily*, "Unified Pricing to Buoy Rare Earths Prices," July 8, 2010.
[28] House Science and Technology Committee Subcommittee on Investigations and Oversight, *Hearing on Rare Earths Minerals and 21st Century Industry,* testimony Mark A. Smith, March 16, 2010.
See also: *People's Daily*, "MIIT: China to Establish Rare Metal Reserve System in 2010," December 23, 2009.
[29] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" *Institute for the Analysis of Global Security*, March 2010.
[30] Elizabeth Behrmann, "China's interest in Arafura Resources gains approval," *The Australian*, May 29, 2009.
[31] Keith Bradsher, "China Is Blocking Minerals, Executives Say," *New York Times*, September 23, 2010.
[32] Keith Bradsher, "China Is Said to Resume Shipping Rare Earth Minerals," *New York Times*, October 28, 2010.
[33] Keith Bradsher and Edward Wong, "China's Ban on Selling Rare Earth Minerals to Japan Continues," *New York Times*, October 10, 2010.
See also: Keith Bradsher, "Trade Officials Ponder China's Rare Earth Stance," *New York Times*, October 13, 2010.
[34] Su Qiang, "Rare Earth Will Not Be Used as Bargaining Chip," *China Daily*, October 8, 2010.
See also: Keith Bradsher and Edward Wong, "Chinese Leader Denies Using Mineral Exports for Political Ends," *New York Times*, October 8, 2010.
[35] Hiroko Tabuchi, "Block on Minerals Called Threat to Japan's Economy," *New York Times*, September 28, 2010.
[36] Keith Bradsher, "China Said to Widen Its Embargo of Minerals," *New York Times*, October 19, 2010.
[37] James T. Areddy, et al, "China Denies Halting Rare-Earth Exports to Japan," *The Wall Street Journal*, September 23, 2010.
[38] Patrick Chovanec, "The Politics of Rare Earth," *Forbes*, October 4, 2010.
[39] Gareth Hatch, **"**China's Rare Earths Game Plan: Part 1 - The Effects Of Reduced Export Quotas," *Technology Metals Research*, July 14, 2010.
[40] Elisabeth Behrmann and Gopal Ratnam, "Lynas Says Rare Earths Demand to Grow at 9% a Year," *Bloomberg*, October 25, 2010.
See also: Dudley Kingsnorth, "The Challenges of Meeting Rare Earths Demand in 2015," (Technology and Rare Earth Metals Policy Conference, Washington, DC, March 17, 2010).
[41] House Science and Technology Committee Subcommittee on Investigations and Oversight, *Hearing on Rare Earths Minerals and 21st Century Industry,* testimony Mark A. Smith, March 16, 2010.
[42] Josie Garthwaite, "Molycorp IPO Raises $394M for Greentech Metals," *GigaOM*, July 29, 2010.
[43] Gopal Ratnam, "U.S. Defense Department Sees No Rare-Earths Crisis; May Aid U.S. Producers," *Bloomberg*, October 31, 2010.
[44] "Rare Earth Materials in the Defense Supply Chain," *GAO Report: GAO-10-617R*, April 1, 2010.
See also: Keith Bradsher, "Challenging China in Rare Earth Mining," *The New York Times*, April 21, 2010.
[45] U.S. Geological Survey, "Rare Earths," *Mineral Commodity Summaries,* January 2010.
See also: "China and the Future of Rare Earth Elements," *Stratfor*, October 12, 2010.
[46] U.S. Department of Energy, "DOE Announces RFI on Rare Earth Metals," May 6, 2010.
[47] Liam Pleven, "Pentagon in Race for Raw Materials," *The Wall Street Journal*, May 3, 2010.
[48] Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010 (RESTART Act), H.R. 4866, 111th Cong. (2010).
[49] Rare Earths Supply Technology and Resources Transformation Act of 2010, S. 3521, 111th Cong. (2010).
[50] H.R. 5136, 111th Cong. (2010) (enacted).
[51] Rare Earths and Critical Materials Revitalization Act of 2010, H.R. 6160, 111th Cong. (2010)
[52] "United States Launches Section 301 Investigation into China's Policies Affecting Trade and Investment in Green Technologies," Office of the United States Trade Representative, October 15, 2010.
[53] "China's Policies Affecting Trade and Investment in Green Technology" The United Steel, Paper and Forestry, Rubber, Manufacturing, Energy, Allied Industrial and Service Workers International Union, September 9, 2010.
[54] James B. Hedrick, "Rare Earths," *U.S. Geological Survey*, January 2010.
James B. Hedrick., "Scandium," *U.S. Geological Survey*, January 2010.
James B. Hedrick., "Yttrium," *U.S. Geological Survey*, January 2010.
Dudley Kingsnorth, "Rare Earth Mineral Production," *The New York Times*, August 31, 2009.
Molycorp Minerals, "The Green Elements."
[55] U.S. Department of Energy, "Critical Materials Strategy," December 2010.