Rare Earth Metals & China

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CONTENTS

INTRODUCTION..... **2**

SECTION 1: BACKGROUND..... **2**

SECTION 2: CASE STUDY..... **7**

SECTION 3: IMPLICATIONS..... **11**

CONCLUSION..... **19**

INTRODUCTION

Rare earth metals (REMs) are vital to the world's economy. They are essential to developing technologies in the communications, electronics, and military weapons markets and world demand for rare earths is at an all time high. However, while countries are increasingly dependent upon REMs, the world supply of rare earths is becoming more and more dependent on China. The most recent statistics show that China produces an astounding 97.4 percent of the world rare earths and contains over 50 percent of the world's rare earth reserves.[1]

While China's monopoly over the supply of REMs is reason alone to raise concern, China has most recently used its monopoly power to influence international affairs. On September 21, 2010, the Chinese government unofficially restricted exports of REMs to Japan as leverage in a bilateral conflict with the Japanese government. While political tensions between Japan and China are not new, China's unofficial use of its rare earth production was both unexpected and aggressive. The reaction by the world, particularly the U.S., was strong and many condemned China's belligerent actions.

This paper examines the growing conflict between China's continued dominance of rare earth metal production and the world's growing dependency on them. We will try to answer the following questions: Why did China restrict exports to Japan and how does this impact the rest of the world? Do China's restrictive policies help or hinder its monopoly on rare earths? What can the rest of the world do to secure the REM supply chain?

The report is organized accordingly: Section 1 provides a brief background of rare earth metals, Section 2 discusses the September 2010 Japan-China incident, and Section 3 details the potential implications of China's rare earth monopoly.

SECTION 1: BACKGROUND

What are rare earth metals?

There are seventeen rare earth metals (REMs) or rare earth elements. Fifteen of the REMs are a group of elements called lanthanides found between the atomic numbers 51 and 71 on the periodic table. Beginning with atomic number 51, lanthanides include the following: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. The two non-lanthanide REMs are yttrium and scandium. These seventeen elements are grouped together because they exhibit similar chemical and physical properties.

While the group name suggests that these elements are scarce, they are actually relatively common. The name was given to them because the minerals in which they were originally discovered were extremely rare.[2] Some rare earths are as abundant as copper although

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1 Brown, T.J. , et al, "World Mineral Production: 2005-2009," British Geological Survey, Natural Environment Research Council, pp 88.

2 "Rare Earth Elements," British Geological Survey, Natural Environment Research Council. pp 1.

quantities of each individual element vary. Additionally, most REMs are rarely found in concentrated amounts in the earths crust, making mining for them costly.

Where are rare earth metals?

The United States Geological Survey (USGS) estimates that there are 110 million tons of rare earths in the world.[3] Rare earths are unevenly distributed in the earth's crust, with some countries containing much more of the resource than others. China has the most REMs and is projected to have 55 million tons of rare earth or 50 percent of the world's reserves. The Common Wealth of Independent States (CIS) is second to China, with 19 million tons or around 17 percent of the world's reserves.[4] And, the United States ranks third with 13 million tons or 11.8 percent of world reserves. The distribution of rare earths per country is in Table 1 below.

Countries	World Percent	Reserves (in tons)
China	50%	55,000,000
Commonwealth of Independent States	17%	19,000,000
United States	11.8%	13,000,000
India	2.8%	3,100,000
Australia	1.45%	1,600,000
Brazil	.44%	48,000
Malaysia	.27%	30,000
Other	20%	22,000,000
TOTAL	100%	110,000,000

Table 1. Estimated World REM Reserves as of January 2011 [5]

- *China*
  Not only does China have the most rare earth reserves, it also has the largest REM deposit in the world called the Bayan Obo deposit. The deposit is estimated to contain over 48 million tons of reserves.[6] Additionally, most of China's reserves have a sub-group of REMs called heavy rare earth metals (atomic number 64 through 71) that are not very common and are vital for green technology.
- *Commonwealth of Independent States*
  Of the twelve countries that make up CIS, Russia and Kyrgyzstan have the most rare earth reserves. The majority of Russia's REM deposits are in the Kola Peninsula, however, they are not currently being extracted. Kyrgyzstan has very large reserves estimated at around 51,500 tons.
- *United States*
  USGS studies have calculated that rare earth metals exist in California, Utah, Alaska, Idaho, Wyoming, Montana, and Missouri. The largest rare earth deposit in the U.S. is

[3] "Mineral Commodity Summaries" U.S. Geological Survey, January 2011, pp.2.
[4] The Common Wealth of Independent States (CIS) is a loose association of former Soviet Republics including Azerbaijan, Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan and Ukraine
[5] "Ibid.
[6] Rare Earth Elements," British Geological Survey, Natural Environment Research Council, pp 6.

located in Mountain Pass, California. It is estimated to have 4.3 million tons of REMs and was actively mined until 2002 but was stopped because of high environmental and compliance costs. [7] Currently, a U.S. company named Molycorp Minerals sells rare earth concentrates and refined products from Mountain Pass that were mined before 2002. The second largest mine in the U.S. is located in Bear Lodge, Wyoming and is estimated to have around 166,000 tons of REMs.[8]

- *Other Countries*
  Many of the countries in Table 1 that have not been mentioned either have large reserves that are of too low grade to be easily exploited or they have reserves that they are not mining. Current reports suggest that most of these countries are beginning to open up mines to extract their REMs or to issue preliminary papers on the costs and benefits of their extraction. For example, in January 2010 Canada began drilling for rare earths at Thor Lake of the Northwest Territories.[9] This is particularly significant because deposits at Thor Lake are estimated to have large amounts of heavy rare earth metals.

Why are REMs so important?
REMs have magnetic, thermal, and electrical properties that make them ideal for many developing technologies in the communications, electronics, and military weapons markets. There are substitutes for REMs but they are considered to be less effective.

- *Commercial*
  Current common commercial uses for earth metals include applications in auto catalysts, petroleum refining catalysts, phosphors in screen technology like smart phones and laptops, magnets, rechargeable batteries for hybrid and electric cars, wind turbines, and medical devices. As countries look to alternative, greener energies to fuel their cities, rare earth metals will become more and more important. The U.S. uses most of its rare earths as auto catalysts and petroleum refining catalysts.[10]
- *Military*
  REMs are vital to current military technologies because they are important ingredients in some of the world's strongest permanent magnets. Military weapons that require these magnets include jet fighter electrical systems, missile guidance systems, underwater mine detection systems, antimissile defense systems, and satellite power and communications systems.[11] Because REMs are essential to such an expansive number of military technologies, many countries, including the U.S., believe that continued access to and supply of REMs is a crucial element of national security.

Production Chain
While the specifics of earth metal production vary with ore type, the basic process remains the same. The four standard steps are illustrated below.[12]

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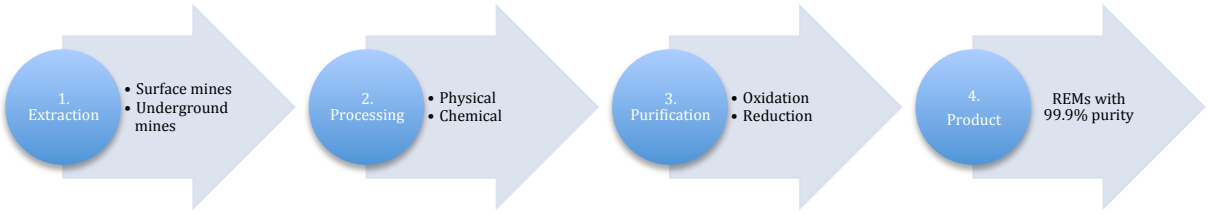
[7] Ibid.
[8] Ibid.
[9] Humphries, Mark. "Rare Earth Elements: The Global Supply Chain," September 30, 2010. Congressional Research Service, pp. 7.
[10] Auto catalysts transform the pollutants in vehicle exhaust into non-toxic waste.
[11] Humphries, pp 4.
[12] "Rare Earth Elements," British Geological Survey, Natural Environment Research Council, pp 14-15.



(1) *Extraction*
The initial step in the production chain is the extraction of the ores containing REMs from either surface or underground mines. Some ores with REMs are extremely radioactive and many countries have banned the mining of ores with high radiation. China has a major advantage in that most of its REM deposits are low in radiation.

(2) *Processing*
The second step in the production chain is the physical and chemical processing of ores to increase the REM concentration. Physical processing often includes grinding and using gravity filters to create a mineral concentrate. Chemical processing involves high temperatures and acids or bases to extract the REMs from the concentrate. This step is by far the most detrimental production step to the environment. The chemicals used in the processing of REMs have been accused in China of poisoning local residents, polluting drinking water, and ruining farmland.

(3) *Purification*
The third step purifies or separates the REMs from each other, a difficult task due to the similar characteristics of the earth metals. Purification can be achieved through various chemical methods. This step in the production chain is crucial as the value of a REM product is mostly dependent on its purity.

(4) *Product*
The end product is a solid-rare earth salt that can be as high as 99.99 percent pure. This product, however, comes at a significant cost. Estimates show that producing one ton of REMs creates on average 60,000 m^3 of gases mixed with sulfuric and hydrofluoric acid, 200m^3 of acid water, and 1.4 tons of radioactive waste.[13] Additionally, the production process is very energy intensive.

History of REM production
India and Brazil were the world's first major exporters of REMs until the 1940s when Australia and Malaysia started exporting rare earths. From the 1960s to the 1980s the United States was the dominant world producer, with the majority of the U.S.'s product being extracted from Mountain Pass, California. China's production of rare earths took off in the early 1980s and by 1988 it had moved past the U.S. into position as the world's leading REM producer.

[13] Ibid.

China's rise to top producer was a result of its cheap labor and soft environmental laws. As China has further solidified its top position, the world's REM prices have drastically decreased, potentially a result of cheap labor in China, while REM mine production has significantly increased.[14]

Current Situation

As of 2010, only China, Russia, India, Brazil, and Malaysia are known to be actively mining for earth metals. China remains the world's leading producer, and in 2009 the country extracted 97.4 percent of the world's REMs. Russia currently ranks in second with only 2,500 tons of REMs or 2 percent of the world's rare earth production. The last three countries combined only produced .56 percent of the world's production. The global production numbers are illustrated in Table 2 below.

	2005	2006	2007	2008	2009
Russia	2,027	2,935	2,711	2,470	2,500
Brazil	620	620	760	540	650
China	119,000	133,000	120,000	125,000	129,000
India	122	45	35	20	20
Malaysia	210	580	440	150	20
Total	121,979	137,180	123,964	128,180	123,190

Table 2. Production of Rare Earth Oxides, 2005-2009[15]

China's Dominance of the REM Market

In addition to its near-monopoly of raw rare earth production, China dominates the four steps of the supply chain and is the only exporter of commercial quantities of REMs (step 4 in the supply chain). China also manufactures many of the products that require rare earths. For instance, it currently creates 75 percent of the world's neodymium magnets, a crucial component in hybrid and electric cars.[16] Additionally, Chinese companies have started to invest abroad in REM production, particularly in Australia.

China's control over the rare earth market, coupled with the growing world demand and the importance of REMs has caused many countries to develop concerns about the security of the REM supply chain. These concerns are not without merit, as China has started to noticeably limit its production and export of REMs using quotas and export tariffs. The government is limiting its supply of REMs in an effort to conserve its rare earth resources and to limit harm to the environment. As illustrated in Figure 1 below, China's export quota has decreased steadily since 2007 from 40,000 tons of REMs to 22,512 REMs in 2010.[17]

[14]Papp, John F et al, "Factors that influence the price of Al, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elements, and Zn," USGS, Open-File Report, 2008, pp 45.
[15] Brown, T.J. , et al, "World Mineral Production: 2005-2009," British Geological Survey, Natural Environment Research Council, pp 88.
[16] Humphries, pp 8.
[17] Tse, Pui-Kwan, "China's Rare Earth Industry," United States Geological Surveys: Science for a Changing World, Open File report, 2011, pp 4.

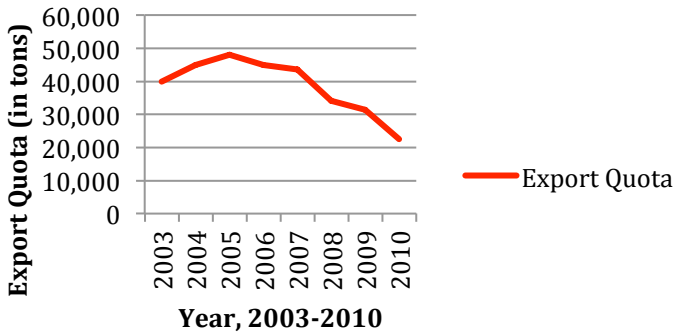


Figure 1. China's Export Quota, 2003-2010[18]

In addition to limiting exports, in 2007 China began placing a quota on total REM production. In the first year of the quota, the government restricted production to 119,500 tons.[19] In 2010, the production quota had decreased to 89,100 tons.[20] The government mandated quota on total production is particularly troubling because China's domestic consumption of rare earth metals is predicted to pass its current levels of domestic production by 2012.

China has historically used its control over the REM market for economic influence with other countries, but most recently, it has used it for political purposes. In September 2010, the Chinese government unofficially restricted exports of REMs to Japan as leverage in a bilateral conflict with the Japanese government.

Going Forward
Why did China restrict exports to Japan and how does this impact the rest of the world? How far can China push other countries around before it loses its control of the rare earth market? What can the rest of the world do to secure the REM supply chain? We try to answer these questions in the next two sections of this paper.

SECTION 2: CASE STUDY

THE CHINESE EXPORT QUOTA ON RARE EARTH METALS TO JAPAN

This case study begins with a brief history of China's recent spat with Japan, from the opening dispute over a fishing boat near the Senkaku Islands to the current situation. The case then examines how the embargo affected China and the rest world, and speculates on the rationale for China's actions. Finally, the case closes by looking at the possible policy responses for the rest of the world, with a specific focus on the United States and Japan.

[18] Ibid.
[19] Ibid.
[20] The discrepancy between actual tons of REM produced and the government quota numbers is explained by a growing black market for rare earths.

Timeline of China/Japan Dispute and Embargo

Japan claims that China restricted exports of rare earth minerals to Japan during a diplomatic dispute over fishing grounds although China disputes this claim. The spat was caused by a diplomatic tussle involving islands whose ownership is still under dispute.[21] Japan held a Chinese ship captain after his vessel collided with two Japanese coast guard vessels. The ship was fishing in waters controlled by Japan but historically claimed by China. After the Chinese fishing boat captain was detained for seventeen days near these contested waters, Japanese companies complained that Beijing blocked rare earth shipments to Japan, beginning on September 21, 2010. Regardless of the actual reason, it is clear that China was able to restrict access to rare earth minerals for three weeks, which has wide economic ramifications. For example, in July 2010, when China cut exports by 75%, the corresponding prices increased six times.[22] Under W.T.O. rules of fair trade, any official banning of exports is prohibited and would permit Japan to file a formal complaint with the W.T.O. However, China issued "an administrative halt" to shipments, which simply prevented the loading of exports to Japan and is much harder to prove under W.T.O rules.

It is important to note that this is not the first time that China has used its monopoly power to halt exports of their natural resources. In November of 2009, the U.S., European Union, and Mexico filed formal complaints with the W.T.O. against China for limiting access of yellow phosphorous and eight other minerals. The world is noticing that China is increasingly using its highly valued natural resources to influence non-economic issues. Japan is particularly concerned because they are a natural resource poor country and have long depended on imports to fuel their economy. Japan has been stockpiling rare earth magnetic materials for years and currently has two years of supplies but if these companies run out, Japan will have to buy directly from China.

Beijing's official response to accusations that they are restricting their exports is that they do not use rare earth metals as a bargaining tool but do not know when normal exporting of these minerals would be allowed to resume.[23] It is also important to understand the flow of operations for rare earth minerals. China mines large quantities of these rare earth metals, Japan manufactures most components containing these metals and the U.S. uses these components for a wide range of technologies including car motors, computers, and solar panels.

China's Rationale

China validates the export quotas with a variety of explanations, some of which seem more plausible than others.

(1) *Maximize profits.* Many journalists and scholars have noted that China's control of rare earth minerals is similar to the Middle East's control of oil. Thus, China can use its monopoly status to restrict the supply of REMs to maximize profit.[24] Economic theory says that this profit maximization is constrained by the entry of new suppliers.

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[21] Editorial, "The Avoidable Rarity of Rare Earth Metals," *The Financial Times*, October 2010.
[22] Bradsher, Keith, "Amid Tensions, China Blocks Vital Exports to Japan," *The New York Times*, September 2010.
[23] "China Pledges Not To Use Rare Earth Minerals as Weapon," *BBC News*, October 2010
[24] FlorCruz, Jim, "Why China's Help to Japan Carries Weight," *CNN.com*, March 2011.

Thus far, China has been careful to not overly exploit this position because they do not want other countries to dilute China's monopolistic position. It is possible, however, that the action against Japan went too far. Today, both the US and Australia are investing in domestic production. A potential reaction to increased world production could be that China will try to stretch its monopoly even further (by further restricting exports) in an attempt to maximize its monopoly rents until other countries begin producing at competitive levels.

(2) *Minimize environmental harm***.** China has used environmental explanations as a reason for export quotas, which would otherwise be illegal under WTO rules. As discussed in section 1, there is certainly some credence to this explanation in the case of rare earth metals: the extraction of REMs has tremendous negative ecological impact as well as proving a health nightmare for workers and neighbors of the facility.

(3) *Save REMs for future generations***.** Although this explanation has merit for many natural resources, it is not particularly compelling in the case of REMs. As discussed, despite their name, rare earth metals are relatively abundant, especially in China. The primary difficulty with REMs is extracting them, which is technically complex and environmentally degrading, but not in finding deposits.

(4) *Exert political influence.* The Chinese-Japanese relationship is both long and tense, a result of many wars, occupations, land disputes and equally strong national pride.[25] The fishing ground dispute led to the lowest diplomatic relations since 2005, and highlighted by anti-Japanese protests throughout China. This dispute is important to all of Central Asia since these countries do not want Japan to come under China's sphere of influence. These countries do need China for economic trade but they want to balance this relationship with economic relations with the U.S., Russia and Latin America[26]. These sentiments are not meant to be anti-Chinese but are meant to maintain the balance of power so that their economic interests are preserved. This incident also led U.S.-Japan relations to become stronger as the U.S. spoke publically on Japan's behalf and reiterated how valuable their alliance has been over the past fifty years.

(5) *Promote domestic production up the value chain.* Restricting an important input would provide a double-boost to domestic suppliers. Not only does it mean that REMs will be more abundant in the domestic market (and therefore cheaper), but the metals will also be more expensive for foreign competitors. This will provide a powerful cost-saving for domestic producers of high tech and other goods. Furthermore, this strategy is also likely to result in high tech FDI, as foreign firms seek to gain from domestic sourcing of inputs.

The world's response

The outside world is responding to China's embargo through three different timeframes. In the short run, countries that rely on REMs for production inputs have pressured China through the media and attempted to negotiate an end to the embargo in both bilateral and multilateral talks. In the medium run, these countries are preparing legal action. Rumors abound that the United States and Japan may file a case through the WTO; once this happens, the usual dispute resolution process takes 18 months. In the long run, countries

[25] "China Tell Japan to Maintain Relations After Dispute Over Islands Erupts," *Bloomberg News*, October 2010
[26] Aston, Adam, "China's Rare Earth Monopoly," *Technology Review*, October 2010

outside of China will try to improve their own production capacity of REMs. Estimates for how long this will take range dramatically: from less than a year to more than five years. Thus far, attempts at negotiating with China over the export quota of REMs have been relatively unsuccessful. As mentioned above, the dispute between China and Japan was initiated when Japan detained a Chinese fishing captain. Although Japan has since returned the captain to his homeland, they have made little headway in lifting the embargo. This is partly due to China's confusing explanation for the embargo: initially, the country stated that the metals were not being shipped because Chinese firms were angry with Japan. This is in contrast to the common belief that the metals were held at Chinese ports due to a direct order from the government. In addition to Japan's failure at bilateral negotiations, multilateral talks have also failed. Despite substantial industry pressure, the G20 summit in Seoul, South Korea did not resolve the issue.

In the medium run, the United States and other REM-dependent countries are considering legal action through the WTO. There is an ongoing case regarding the legality of China's export quotas. The result of this ongoing case will likely determine whether a REM suit is filed by the United States. This case addresses China's export quotas of raw materials (particularly bauxite and magnesium) that are used in the production of steel and other metal alloys. China argues that the export quotas are legal because they are enacted to ensure that there is not excessive environmental degradation; however, the US, Mexico and the EU have brought the case based on a claim that the export quotas unfairly disadvantage foreign producers of these alloys. These quotas give Chinese producers an unfair advantage because their inputs are cheaper than their competitors, who face artificial shortages. If this case is resolved in favor of foreign producers, then it would set a precedent for a similar case in rare earths. If this were to occur, the US, Japan and other interested parties could respond in a few different ways:

- They could bring a new case to the WTO. Although the precedent set by the previous case bodes well, this process can be long, and there is still some uncertainty. Furthermore, a victory wouldn't necessarily end the export quota of rare earths, it may just enable them to enact counter-veiling duties.

- They could negotiate directly, using the previous case as leverage. This has the advantage of speed, but also has an uncertain outcome. This may also be strongly influenced by politics (especially for the Japanese), and may pull in seemingly unrelated issues as bargaining chips.

Thus, the way that the US, Japan, and other countries respond in the medium run is heavily dependent upon this legal outcome. It is useful to note that a preliminary report by the WTO suggests that there are substantial flaws in China's defense in the bauxite and magnesium case. If this report proves prophetic, it is likely that a case concerning rare earth metals will be filed sooner rather than later.

In the long run, it is likely that countries apart from China will begin to boost their own REM production capacity. Although knowledge of China's monopoly has existed for some

time,[27] the exercise of their economic clout has prompted many countries to ensure their own REM security. Although China does maintain cost advantages in REM production, it is certainly not the only country with these natural resources. For example, an American company, Molycorp, owns one of the richest known reserves of rare earth metals on the planet. The Obama administration has fast-tracked the operation of this facility and it appears that it could be producing as much as 10% of the world's REM supply by 2014.[28]

The other long run solution lies in competing technology. Some researchers are attempting to develop new materials that could either replace rare earth minerals or decrease the need for them.[29] For example, a number of research firms in the US are evaluating the possibility of using nanocomposites to dramatically reduce the reliance on REMs. These nanocomposites would theoretically enable the use of REMs to become much more efficient, and thus require far fewer quantities per product. Although this wouldn't eliminate the need or demand for REMs, it would substantially reduce it. Nevertheless, a viable economic competitor is still a long way off; there is progress in this area.[30]

SECTION 3: IMPLICATIONS OF CHINA'S MONOPOLY ON RARE EARTHS

It is expected that there will be some significant economic, environmental, and social consequences if China continues its restrictive export policy.[31] Because of these effects, anticipated or present, we will consider the impact of Chinese rare earth export restrictions and what outcomes and strategies may grow out of these policies. In short, how do these restrictive policies help or hinder China's monopoly on rare earths?

Economic Effects

- *Chinese Perspective:*

Export quotas will decrease the supply of rare earths in the world markets. It is expected that the supply shortage will raise intensively among rare earths in 2014, especially the supply of neodymium, europium, terbium, dysprosium and yttrium will be affected.[32] This will cause world prices of metals to rise in the short term and become more volatile with respect to China's alternating export policy in the long term.

In contrast to the global market, the export restrictions will promote Chinese producers to use rare earths in order to increase domestic supply in the manufacturing industries. Thereby, this policy would contribute more to the growth of the Chinese economy by

[27] For example, the GAO report: Rare Earth Materials in the Defense Supply Chain. This was published in April 2010, months before the flare-up between China and Japan.
http://www.gao.gov/new.items/d10617r.pdf
[28] http://cleantechnica.com/2010/12/28/california-to-mine-rare-earth-materials-again/
[29] Garamone, Jim, "U.S.-Japan Pact Has Demonstrated Worth," *Defense.gov*, January 2011.
[30] http://www.technologyreview.com/energy/26538/page2/
[31] Walker, S. Breaking the Rare-Earth Monopoly, Engineering and Mining Journal; December 2010, 10; ABI/INFORM Global pg. 46.
[32] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.

accelerating the value-added production in the domestic economy instead of exporting these metals to the world. Apart from this, as rare earths are finite and China technically holds only a share of rare earths globally, the Chinese government might want to use these resources only for developing its domestic manufacturing industries to gain more competitiveness in the markets. In other words, it will want to invest in its future in lieu of present circumstances.

The government is also working to block smuggling operations, which combine the rare earth oxides with steel composites to abstain from deductions. When they arrive at the import destination they are then reverse-processed to extract the key elements. According to current data, Japan is a primary principle in this process by purchasing nearly 20% of Chinese rare earth oxides via smuggling.[33] In creating and implementing this restrictive export policy with production and transport regulations, the Chinese government is pursuing plans to close small-scale companies and to promote the merging of larger producers as a general tactic to increase its control over the industry and to prevent illegal transactions.[34]

Regarding China's trade policy, one of the goals of the Chinese government is to draw the attention of the foreign investors from abroad. China is planning to incentivize them to move their production facilities and their technical capabilities to China if they want access to the rare earths market. Thereby, the Chinese firms could further improve their production advantages by benefiting from the high-tech knowledge and skilled human capital of foreign companies. The goal of this policy is made explicit as seen in the statement of the Vice-Chairmen of Inner Mongolia that "we are not taking the short term view of trying to prop up prices. Imposing controls and reducing exports aim to attract more factories using rare earths metals from home and abroad to Inner Mongolia."[35] In this way, the Chinese government is gambling to firmly seal its influence and control on the rare earths market by internalizing the production and market for these minerals - though the real benefit of this strategy seems unclear since the export restrictions have only encouraged trading countries to begin redeveloping or building up their own mines and knowledge resources.

- *Global Perspective:*

There are numerous countries that possess quantities of raw rare earths or once produced and processed rare earths: the United States, Canada, Australia, Brazil, Vietnam, Chile, etc. However, as China has been granted a rare earths monopoly by former competitors, few of these countries are currently capable of processing extracted materials or have lost necessary research and development or technical knowledge to swiftly resume operations. China's move to restrict the supply of rare earths has called into question the international cost-incentives that granted China a monopoly in a major sector of global trade and technological innovation by failing to diversify global rare earth supplies. It is obvious that Japan, the

[33] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.
[34] Hurst, C. China's Rare Earth Elements Industry: What Can the West Learn?, Institute for the Analysis of Global Security, March 2010.
[35] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.

United States, and the European Union are the countries most severely affected by the quota policy since, as previously mentioned, their significant high-tech export industries depend heavily on rare earth imports. They are the biggest buyers but their response to China's export restrictions may differ due to variances in the amount of natural rare earth resources available in their own countries.

United States

The U.S. closed its last rare earths min in 2002,[36] in reaction to the cheaper prices of rare earths exported from China along with environmental concerns over U.S. mining practices. Jeffrey Green of J.A. Green and Company reports that, as Chinese policy has moved to supply domestic producers and to lure manufacturers from abroad, price spikes three- to eightfold have resulted from China's move to restrict the global supply of rare earths.[37] Because of this, the only factors that protect China's global monopoly on rare earths from the U.S. reinvesting and restarting their own mines are issues of environmental regulation and time demands to put mines back into operation - with a fully operational U.S. mine estimated to be ready within a year producing an annual output of 20,000 metric tons of rare earths, utilizing improved water recycling processes and a natural gas power plant for electrical power generation.[38]

Since it has significant reserves, the United States has a different plan in comparison to Japan and the European Union. It is anticipated that it will re-open its existing rare earth mines or open new ones for production. According to the strategic plan of the US Department of Energy (DOE),[4] the United States:

- will use its resources more efficiently and in compatibility with environmental legislation to develop new methods for recycling rare earths,
- will reduce its dependency on crucial materials including rare earths by establishing either diversified global supply chains or a domestic supply chain,
- will accelerate investments in research and development in order to find magnetic materials that can act as substitutes for rare earths,
- will improve technical expertise on rare earths,
- will increase public awareness about rare earths and their importance.

[36] Service, R. F. (2010). "Chinese Threat on Rare Earth Minerals Could Revitalize U.S. Mines," Science Insider. Retrieved from http://news.sciencemag.org/scienceinsider/2010/09/chinese-threat-on-rare-earth-minerals.html
[37] Service, R. F. (2010).
[38] Knowledge@Wharton (2011). "China's Rare Earth Dominance: Another Global Resource Scramble in the Making?" Retrieved from http://knowledge.wharton.upenn.edu/arabic/article.cfm?articleid=2646&language_id=1

Along with this strategic plan, the United States Trade Representative (USTR) will prepare a brief report about the foreign trade of the rare earths industrial sector and apply for actions to be taken in the platform of the World Trade Organization (WTO) if necessary.[39] Further details on complaints to the WTO will be brought up again when looking at the social effects of China's rare earths restrictions.

Japan

Unlike the United States, Japan and the EU do not have substantial resources. Thus, they are forced to find alternative resources by increasing cooperation with other exporting countries. The Japan Oil, Gas and Metals National Corporation (JOGMEC), responsible for the security of rare earths for the Japanese manufacturing sector, continues to search for new mines throughout Asia, Africa, and the Americas. In addition to this, the government has been trying to find new methods to increase the efficiency in usage and specialization, especially in extracting rare earths from recycled goods.[40] A current example can be seen in Japan's trade agreements with Vietnam in response to China's export quotas. Last year, Japanese Prime Minister Naoto Kan met with Vietnamese Prime Minister Nguyen Tan Dung and the two countries released a joint statement profiling Vietnam's decision to make Japan a major partner in the exploration, mining, development and production of its own rare earths sector along with a commitment from Japan to build up Vietnam's nuclear energy sector.[41] Along with government policies, major private firms in the country have made joint venture agreements to provide for production sustainability. For example, a joint venture between Innovation Metals (IMC) and Advanced Material Japan (AMJ) will work to process light rare earths from feedstock inventory and recycled materials in Vietnam.[42]

At the height of the Sino-Japanese tensions over last year's territorial row, the embargo on rare earth exports to Japan was considered to be more a political gesture in response to Japan's handling of the incident than anything else. This perception was supported by the fact that Japanese companies had already been stockpiling rare earth resources to buffer the effects of a potential supply shortage - assuring confidence in the short-term.[43] However, the greater concern at present is the long-term effects of Chinese export policy on Japan's recovery efforts after the earthquake and tsunami of March 11, 2011. In the aftermath of the disaster, Japan's industrial capacity and economy have been adversely affected and it remains to be seen what industries in the economy will resume exporting Japanese goods and which industries will actually slow down production due to the on-going recovery and need to shift logistical capacities for humanitarian and strategic reasons.[44]

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[39] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.
[40] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.
[41] BBC News (2010). "Rare earths supply deal between Japan and Vietnam." Retrieved from http://www.bbc.co.uk/news/world-asia-pacific-11661330
[42] MetalBulletin.com (2011). "IMC-AMJ Vietnam rare earths does not depend on new supply: Wong." Retrieved from http://www.metalbulletin.com/Article/2794115/IMC-AMJ-Vietnam-rare-earths-venture-does-not-depend-on-new-supply-Wong.html
[43] Service, R. F. (2010).
[44] Lifton, J. (2011). "The Impact Of The Japanese Earthquake and Tsunami On Short-Term Rare-Earth Demand," Technology Metals Research. Retrieved from http://www.techmetalsresearch.com/2011/03/the-impact-of-the-japanese-earthquake-and-tsunami-on-short-term-rare-earth-demand/

In response to this, the processing on rare earths is likely to be reduced this year until Japan's economy makes a full recovery - this, in turn, means that despite minimal purchases and stockpiling that a short-term increase in supply will lead to a short-term decrease in prices as Japan processes less in its efforts to rebuild devastated areas and restore economic stability.[45] As rare earths production customers are mostly in China and Japan, the Japanese earthquake's effect on rare earths prices is apparent. Between Chinese export policies and Japan's recovery, there is a general attitude that investors will find ways to meet global demand by focusing on rare earths ventures outside of China - particularly those with "ample deposits of the lighter rare-earths in development," notably critical elements such as dysprosium, terbium, and europium.[46]

European Union

The European Union, like Japan, has a low natural endowment of rare earths. One of the main priorities of the EU is to protect the environment through supporting clean energies, such as wind and solar power, and to control the level of carbon emissions. Thus, the EU is dependent on rare earths in advancing these technological and environmental goals. In 2008, the European Commission's Raw Material Supply Group prepared a national plan to point out its dependency on these rare earth metals and suggested considerable policy actions:[6]

- Increasing market accessibility to rare earths through bilateral and multilateral trade agreements,
- Benefiting from the dispute settlement tools of the WTO, as per the US example, and conducting actions if necessary,
- Increasing the number of investments in R&D and human capital for the rare earths sector,
- Supporting recycling programs for rare earths.

It should be noted that there is a significant difference between Japan and the European Union. The EU is at the stage of evaluating the current situation and planning whereas the Japanese government is at the stage of executing its national plan. Along with different policy priorities, it is anticipated that all three countries will increase their stockpiles in the domestic market for securing their dependent industries in the short term.

Environmental Effects

[45] Lifton, J. (2011).
[46] Lifton, J. (2011).

The environmental detriment caused by the production of rare earths is a notable side effect of mining and processing. Within the production process, radioactive thorium, uranium and, later in separation, acid baths consisting toxic chemicals are used.[47] Due to the severe risk of using such hazardous materials and strict environmental legislation giving rise to high production costs, developed countries, such as the United States and Canada, have in recent years preferred to import rare earths from China instead of mining their own reserves. However, producing rare earths threatens China's ecosystem and is responsible for significant water pollution. For example,[7] the Baotou region, as China's major rare earths producer, generates 10 million tons of waste water per year that is discharged into the water system, flowing into the Yellow River, which is the primary source of water for 150 million people.

The environment is one of the major problems China faces at present. It has been facing numerous protests from farmers and the local population, along with pressure from developed countries about protective legislation and the impact of China's growth on the global environment. Therefore, the government has decided to minimize the detrimental effects of producing rare earths and to provide environmental sustainability in applying this restrictive trade policy. If the developed countries were to re-open their existing mines or search for new ones in order to increase the production of rare earths according to their respective national plans, they would assuredly set strict environmental and health standards in order to control against the possibility of environmental devastation.

Within the context of energy policy, the Chinese government has been encouraging "green energy technology" alongside the European Union. This support has led to an increase in the usage of solar and wind power as well as the production of wind-powered electrical generation, hybrid electric vehicles, and permanent magnet generators. Since rare earths are the main inputs for production of these green technologies, it is expected that the domestic consumption of rare earths will ascend drastically in the future. Additionally, the government has been implementing regulations to promote more control of the rare earth industry since 2008. According to these regulations, the Ministry of Land and Resources suspended any applications for survey or mining licenses for rare earth ores in China for two years, lasting until June 30th, 2010. The purpose of this particular regulation was to thwart over-exploitation and to protect and support scientific and efficient usage of these important resources.[48]

In general, if the trajectory of future environmental policies across the world fail to be strict enough they will likely lead to greater concern for the environment and the long-term exploitation of a critical resource. However, if these policies are too restrictive or over-regulating with regards to environmental and public health issues it is unlikely that any country could meet global demand for rare earths. In this manner, it is somewhat ironic that a major resource which green technological solutions and alternative energy campaigns depend on is not only environmentally hazardous to produce but also capable of stalling these very programs and innovations from continued growth or viability in the global market of tomorrow.

[47] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.
[48] Seaman, J. Rare Earths and Clean Energy : Analyzing China's Upper Hand, IFRI, September 2010.

Social Effects

One of the impacts of the export quota policy is the increase of domestic production in China and its iterative effects upon supporting producers with higher economies of scale and the potential attraction of more foreign direct investments. Unavoidably, if foreign firms do move their operations into China, this situation will create more job opportunities for the Chinese people. At the same time, by importing high technology and specialized labor and services, Chinese labor could advance themselves in terms of technical and educational qualifications in order to secure higher paid jobs. Therefore, they could attain a better standard of living and increase their household incomes - though, with the rare earths market contained solely in China it will have mixed effects upon living conditions both in terms of environmental quality and a reversal of urban migration into outlying regions in China. This would mean that rural regions where mining operations are dominant sectors of the local economy would develop and balance the development of major cities such as Beijing and Shanghai, but could easily raise further concerns for local sustainability and growth as most mining operations are controlled by state-run corporations. This means that competition among firms would also be greatly reduced.

As alluded to in our assessment of the economic effects of China's export restrictions, the impact of stockpiling the Chinese supply of rare earths is of great importance. Stockpiling proposals and efforts in China, Japan, South Korea, and the United States have all occurred and raise several questions and concerns about China's motives and future as a supplier of rare earths.[49] Under the direction of the Ministry of Land and Resources, a pilot project in Baotou, Inner Mongolia, had begun last year with 10 storage facilities built by the state-controlled Baotou Steel Rare-Earth Group.[50] China's move to stockpile a strategic reserve is in response to new reports that the Chinese rare earths supply is shrinking as world demand increases. China has consistently justified export restrictions based on environmental concerns and increased internal demand.

If, contrary to these reasons, China is actually suffering shortages of rare earths rather than seeking to restrict supplies to unfairly advantage domestic growth, then complaints filed to the World Trade Organization, such as the United Steelworkers Union 301 Petition among others, could be invalidated.[51] The nature of China's plans to build up a strategic reserve of rare earths throw into doubt the intent of these export quota measures and forces us to consider the possibility of China joining with the United States, Japan, and the European Union as a buyer rather than a major supplier. Nonetheless, even if China does become a buyer of rare earths, the move could easily grant China further powers to influence global prices.[52] In such an event, it is likely that the increased prices of rare earths would be transferred onto consumers in order for companies to pay for increased manufacturing costs. Therefore, increased control over global prices and supply by China would adversely raise the cost of electronics, from mobile phones to computers; render green technological innovation outside of China more cost-prohibitive; and complicate national defense budgets

[49] Areddy, J. T. (2011). "China Moves to Strengthen Grip Over Supply of Rare-Earth Metals," Wall Street Journal. Retrieved from http://online.wsj.com/article/SB10001424052748704124504576117511251161274.html

[50] Areddy, J.T. (2011).

[51] Reisman, L. (2011). "China to Go From Seller to Buyer of Rare Earth Metals?" Metal Miner. Retrieved from http://agmetalminer.com/2011/01/11/china-to-go-from-seller-to-buyer-of-rare-earth-metals/

[52] Areddy, J.T. (2011).

as rare earths are used by the U.S. for precision-guided weapons, stealth technologies, and night-vision goggles.[53]

While figures and estimates about national stockpiles are not readily available or currently under legislation, we can consider instead the case of the world's first and currently only private company to hold a corporate stockpile of rare earths elements - the Canadian-based Dacha Strategic Metals Inc. According to their most recent physical inventory portfolio, as seen in the table below, Dacha has 82,000 kilograms of several key minerals valued at $44.9 million USD in their storage facility in Pusan, South Korea. Additionally, Dacha keeps 120,000 kilograms of Yttrium Oxide valued at $3.5 million USD stored in Shanghai, China.[54]

To give these figures a bit more context, a brief review of rare earths consumption will be helpful. Global demand for rare earths is estimated to double from 125,000 metric tons in 2010 to 250,000 metric tons in 2020 - of this 125,000 tons, China supplied 120,000 metric tons with Russia providing 2,500 metric tons, the US 2,400 metric tons, and India 25 metric tons.[55] Globally, there are 200 rare earths projects in operation or being developed.[56] Given that one metric ton equals 1,000 Kgs, Dacha has substantial amounts in storage but not enough to completely render Chinese export quotas harmless. Without increased production from major deposits in other countries, the social and technical infrastructure of the developed world is likely to fall into a slump as a key resources for Information and Communication Technologies become scarer. Thus, the question moving forward is how the global market will work to meet demand - whether through magnetic substitutes for rare earths, recycling programs, or by re-opening and developing larger mines in the U.S., Canada, Australia, and beyond.

Metals	Grades	Quantity (kgs)[57]	Spot Price/kg (US$)	Market Value (US$millions)	Market Value (C$millions)[58]
Busan, South Korea					
Dysprosium Oxide	*4N*	*15,000*	*$699*	*$10.5*	*$10.0*
Dysprosium Fe	*Santoku*	*12,000*	*$653*	*$7.8*	*$7.5*
Gadolinium Oxide	*4N5+*	*10,000*	*$185*	*$1.9*	*$1.8*
Lutetium Oxide	*4N+*	*3,000*	*$800*	*$2.4*	*$2.3*
Neodymium Oxide	*4N+*	*18,000*	*$221*	*$4.0*	*$3.8*
Terbium Oxide	*4N+*	*14,000*	*$1,195*	*$16.7*	*$16.0*

[53] Knowledge@Wharton (2011).
[54] Dacha Strategic Metals, Inc. (2011). Retrieved from http://www.dachacapital.com/Inventory/default.aspx
[55] Knowledge@Wharton (2011).
[56] Knowledge@Wharton (2011).
[57] 4N=99.99%, *4N+ = 99.99+%, 5N = 99.999%, 4N5+ = 99.99%/99.999+%*
[58] *US$1.00=C$0.9601*

Yttrium Oxide	*5N*	*10,000*	*$160*	*$1.6*	*$1.5*
Shanghai, China					
Yttrium Oxide	*4N5+*	*120,000*	*$29*	*$3.5*	*$3.3*
Total:		***202,000***		***$48.4***	***$46.2***

Table 3. Metals Inventory as of April 22, 2011

CONCLUSION

Like China, if developed countries chose to produce rare earths in their economies, they would need to hire more qualified labor, such as technicians, scientists, and engineers. In addition to this, they would have to give priority to education and training programs; in other words, human capital investment, both in technical capacity and expertise, is a must to balance the gap between China and competing countries looking to enter or re-enter the rare earths sector. If current stockpiles and policy measures work to bolster the rising demand for rare earths for the next decade, it would be possible for China to lose monopoly power as competing countries undercut China's supply. Given the rising prices resulting from China's export quotas, China no longer holds the price advantage for its production capacity and is weakened in its trading future in the rare earths market because of these massive price spikes. As an element of vital importance to our technological innovation and social infrastructure at home and in the office, there is no justification for apathetic or patient responses. China's bid to flex its monopoly muscles have caused quite a stir in the global market but it not certain that this appearance of economic strength will translate into further consolidation of resources, talent, and technology.