
Rare Earths and Clean Energy: Analyzing China's Upper Hand

John Seaman

September 2010



**Gouvernance européenne
et géopolitique de l'énergie**

The Institut français des relations internationales (Ifri) is a research center and a forum for debate on major international political and economic issues.

Headed by Thierry de Montbrial since its founding in 1979, Ifri is a non-governmental and a non-profit organization.

As an independent think tank, Ifri sets its own research agenda, publishing its findings regularly for a global audience.

Using an interdisciplinary approach, Ifri brings together political and economic decision-makers, researchers and internationally renowned experts to animate its debate and research activities.

With offices in Paris and Brussels, Ifri stands out as one of the rare French think tanks to have positioned itself at the very heart of European debate.

*The opinions expressed in this text
are the responsibility of the author alone.*

ISBN: 978-2-86592-771-5
© All rights reserved, Ifri, 2010

IFRI
27, RUE DE LA PROCESSION
75740 PARIS CEDEX 15 – FRANCE
Tel : +33 (0)1 40 61 60 00
Fax : +33 (0)1 40 61 60 60
Email: ifri@ifri.org

IFRI-BRUXELLES
RUE MARIE-THERESE, 21
1000 – BRUXELLES – BELGIQUE
Tel : +32 (0)2 238 51 10
Fax : +32 (0)2 238 51 15
Email: info.bruxelles@ifri.org

WEBSITE: ifri.org

Contents

EXECUTIVE SUMMARY	2
INTRODUCTION	3
RARE EARTHS: AVOIDING A SHORTAGE	6
Central elements in a high-tech, clean energy future	6
Towards a global rare earth shortage.....	10
Increasing REO production: A long, difficult and potentially hazardous process	10
CHINA’S RARE EARTH STRATEGY, POLICY AND PRACTICE	14
China’s road to rare earth industry dominance.....	14
Problems facing China’s rare earth industry	16
<i>Growing domestic demand and dwindling reserves</i>	16
<i>Illegal mining and smuggling</i>	17
<i>Environmental devastation</i>	17
China’s assertive policy action	18
<i>Export quotas</i>	19
A broader industrial and economic strategy	21
Industrial relocation: The example of magnets	22
Rare earths, a new element in China’s “going out”?	23
RESPONDING TO CHINA’S RARE EARTH MONOPOLY	25
Japan: The case of a resource poor country	25
The US: The case of a resource rich country	27
The EU: The birth of a European strategy on rare earths?	29
A case against China’s rare earth policies in the WTO?	30
CONCLUSIONS AND POLICY RECOMMENDATIONS	31
REFERENCES	34

Executive Summary

An ominous but avoidable resource crunch in the so-called “rare earth elements” is now threatening the development of a number of key industries from energy to defense to consumer electronics. As key components in the latest generation of technologies, including specialized magnets for windmills and hybrid cars, lasers for range finders and “smart” munitions, and phosphors for LCD screens, demand for these rare metals is expected to grow rapidly in the years to come. But decades of underinvestment in the mining and separation of these elements across the globe has left the industry ill-prepared to meet this growing demand. Over the years, only China has recognized the strategic significance of these resources and has succeeded in gaining a near monopoly on production, currently churning out 97% of the world’s rare earth oxides. Faced with problems of its own, and eager to use its resource advantage to master higher levels of value-added production of rare earth-dependent products, China has increasingly limited the rest of the world’s access to these raw materials. This only complicates what was already projected to be a problematic resource shortage.

This issue demands a higher quality of public debate. Rare earth consuming countries outside of China have only recently become aware of their dependence and started to take stock of the risks. Time is of the essence. Bringing new supplies online to meet growing demand is a long, complicated and risky process but is nevertheless necessary to ensure the development of high tech industries, notably clean energy. Accessible reserves of rare earths do exist outside of China and mitigating the effects of the looming shortage requires opening up these reserves to production. Yet, as the Chinese experience attests, there are substantial risks to the environment associated with mining and separating rare earths. Care must be taken to ensure responsible mining practices across the globe. Longer-term solutions, such as recycling programs, increased efficiency in resource use and the development of alternatives to rare earths are important endeavors and should be pursued, but they should not be substitutes for developing rare earth supplies outside of China today.

John Seaman is a Junior Research Fellow in the Ifri Center for Asian Studies.

Introduction

The world is in the midst of a blossoming “clean energy” transformation. Since 2005, global investments in clean energy have grown by more than 230%, with worldwide investment in 2009 totaling more than \$162 billion. Projections for 2010 show that these investments could increase by 25%, reaching roughly \$200 billion by the year’s end.¹ The recent craze for “green growth” among many of the world’s most advanced economies is not only meant to respond to the threat of global climate change and reduce dependence on fossil fuels, but to revitalize local and national economies by creating new opportunities for growth and “green jobs”.

But international competition over who will reap the benefits of this new growth is mounting. For many, the home-grown development of the host of technologies necessary for the clean energy transformation is already challenging enough. High costs, public apathy and misguided political interference are complicating what is already an unprecedented technical challenge. But beyond the public eye there is the potential for another challenge to low carbon technologies in the form of an ominous resource crunch in the so-called “rare earth elements”. There are many commercial, strategic and geopolitical dimensions to this issue that need a higher quality public debate to ensure they are adequately reflected in our strategies for a sustainable energy future. As explained further in the first part of this paper, rare earths are an increasingly strategic grouping of raw metals that are included in a broad range of cutting edge technologies including but not limited to energy-related technologies such as for windmills, hybrid or electric vehicles, and energy-saving light bulbs. Demand for these technologies, and therefore the essential rare earth elements, has and will likely continue to increase dramatically. But ensuring economically attractive access to supplies of these elements is no simple task, and many experts agree that the world is rapidly heading for an acute shortage of processed rare earths largely because of underinvestment, but geopolitics may also come into play.

Since the mid-1980s China, which holds 37% of the world’s current proven, accessible rare earth reserves, has progressively gained a near monopoly on the mining and separation of these elements down to their oxide form. China now controls 97% of the

¹ “Who’s Winning the Clean Energy Race? Growth Competition and Opportunity in the World’s Largest Economies”, Pew Charitable Trusts, 2010, <http://www.pewtrusts.org/>.

global market for rare earth oxides (REO) largely because other resource holders have scaled down their activities or failed to make the investments necessary. As analyzed in the second part of this paper, China has recently initiated a series of reform measures that will have consequences for the global supply of REO. Of chief concern to the rest of the world is China's policy on limiting exports of these oxides. In early July 2010, China's Ministry of Commerce announced that REO export quotas in the second half of the year would be slashed by 72% in relation to the second half of 2009. This dramatic reduction came as a shock to many of the industry's top experts, who had expected at most only a quarter of the announced reduction. This action raises the question of global shortages for these key elements in the much more immediate future.

A cursory analysis of the situation would interpret China's policies as a way to handicap foreign, mainly American, Japanese, or European industries. This analysis would explain the logic behind China's actions in the rare earths industry. But there are in fact justifications for China's latest actions that are not *necessarily* meant to subjugate or disadvantage foreign industries. The policies are designed to meet more immediate goals of adjusting to the projected growth in REO demand at home and reining in problems of illegal mining, smuggling and environmental devastation that have turned parts of China into barren wastelands. There is of course a broader economic strategy involved. These reforms hope to serve the larger, longer-term goals of aiding the development of higher value-added levels of production in China. This would generate better paying jobs for China's people and sow the seeds of a larger rebalancing of the country's export-driven economy through an increase in domestic consumption – a transformation that economists and policy makers in the West have been pushing China to do for years. While credence must be paid to this logic, one cannot fully discount some of the more strategic consequences of China's actions in the rare earths industry, particularly as competition over the green jobs of the future heats up. Indeed, the severity of China's most recent export quotas, if upheld, will have repercussions for companies around the world that depend on rare earths. Added to this are revelations about a number of attempts in recent years by Chinese state-backed companies to purchase rare earth mining facilities overseas that would have increased China's control of the world's resource base.

While China's growing market dominance in rare earths has spanned decades, capitals around the world have only just begun to realize the extent of their vulnerability. At this point, downstream industrial users of rare earths are more concerned with simply having access to these essential metals than about their price. The third part of this analysis will explore Japanese, American and European actions in the face of a possible rare earth resource crunch. Sooner rather than later new REO production chains will have to come online to meet global demand. The fact remains that, far from restricting global production, China's latest actions may have the ultimate effect

of encouraging the exploitation of proven reserves outside of China. The long term effects of a supply crisis in rare earths will depend largely on the ability of the rest of the world to boost production. Efforts have indeed been and are being made to develop these resources. But care must be taken not to sacrifice local ecosystems in the name of clean technology that is meant to preserve the environment. For the longer term, we will also need to identify strategies to promote the efficiency of resource use, to recycle, and to identify viable alternatives. The future competitiveness of industries in the West depends on it.

Rare Earths: Avoiding a Shortage

Central elements in a high-tech, clean energy future

Rare earth elements (rare earths) are a grouping of 16 chemical elements in the periodic table that include Yttrium (Y, atomic number 39) and the 15 lanthanides from Lanthanum (La, 57) to Lutetium (Lu, 71). A 17th element, Scandium (Sc, 21), is often included in the rare earths category as well. This class of metals is then often subdivided into groups of light and heavy rare earths based on their atomic number, with light rare earths generally being found in higher abundance than the heavies. These elements are often lumped into a broader category of “rare metals”. This paper will focus solely on the rare earth elements, a category that does not include metals such as Lithium (Li, 3, an alkali) or Rhenium (Re, 75, a transition metal), which are also essential raw metals but are subject to a slightly different analysis.

Despite the name, “rare earths” are not actually all that rare. In absolute terms they are rather abundant in the earth’s crust, all being at least as common as silver, and some being even more common than lead.² The problem comes in finding them in high enough concentrations where they can be extracted economically, as isolating the elements from the ores in which they are found is highly technical, extremely difficult and environmentally hazardous. For this reason, some in the industry have dubbed these elements “unobtainiums”.³

Rare earths have special magnetic, luminescent, and chemical properties that make them crucial for high technology. While the first of these elements was discovered in Sweden in the late 1700s, commercial applications have only emerged in the last 60 years. Today there are hundreds of applications from glass polishing to permanent magnets to superconductive alloys.⁴

² “Lanthanide Resources and Alternatives”, Oakdene Hollins Research & Consulting, May 2010, p. 3, <http://www.oakdenehollins.co.uk/industry-reports.html>.

³ R. Jones, “The Battle for Rare Earth”, *South China Morning Post*, 11 April 2010.

⁴ USGS, “Rare Earth Elements – Critical Resources for High Technology”, *USGS Factsheet 087-02*, 2002, <http://pubs.usgs.gov/fs/2002/fs087-02/>.

Table 1. The Rare Earth Elements

Symbol	Element Name	Atomic Number	Sub-classification
La	Lanthanum	57	Light
Ce	Cerium	58	Light
Pr	Praseodymium	59	Light
Nd	Neodymium	60	Light
Pm	Promethium	61	Light
Sm	Samarium	62	Light
Eu	Europium	63	Light
Gd	Gadolinium	64	Light
Tb	Terbium	65	Heavy
Dy	Dysprosium	66	Heavy
Ho	Holmium	67	Heavy
Er	Erbium	68	Heavy
Tm	Thulium	69	Heavy
Yb	Ytterbium	70	Heavy
Lu	Lutetium	71	Heavy
Y	Yttrium	39	Heavy*
Sc	Scandium	21	x

Note : * Yttrium, despite its low atomic weight, is often classified as “heavy” because minerals containing higher concentrations of the heavy rare earths (ex. Ionic clays) are also rich in Yttrium.

In the field of clean energy, rare earth metals are critical components in a number of increasingly important technologies that are driving the clean energy transformation. The automotive and the wind power industries are two areas where demand for these elements is significant and projected to increase. Neodymium, Praseodymium, Dysprosium and Terbium are used to make strong permanent magnets (NdFeB) that are more powerful and vastly smaller and lighter than traditional electric ferrite magnets. Electric motors in hybrid and electric vehicles use these magnets to reduce weight and increase efficiency, as they weigh only half of a traditional ferrite motor.⁵ A Toyota Prius hybrid motor, for example, uses 1kg of Neodymium, and a Mercedes S400 uses 0.5kg. The latest generation of larger wind turbines, particularly offshore, also uses NdFeB magnets as they increase efficiency and greatly reduce the need for and the cost of maintenance. Each permanent magnet-based gearless wind turbine, like the 3 megawatt direct drive turbine developed by Siemens, require 2,000kg (2 tons) worth of rare earth magnet, of which 600kg is Neodymium.⁶ Other major

⁵ M. James and Lynas Corporation Ltd., presentation, International Minor Metals Conference, 27 April 2010, London.

⁶ C. Hocquard, Ifri Energy Breakfast Roundtable, Brussels, 20 May 2010.

wind turbine producers, such as Vestas and China's Goldwind have also been switching to direct drive systems using NdFeB magnets. Currently, only about 20% of wind turbines built today use these magnets, but projections show that the shift towards this technology may require an *additional* 3-5,000 tons of Neodymium by 2014.⁷

Other rare earths are also used for various clean energy applications. Hybrid vehicles have traditionally used long-life Nickel-metal hydride (NiMH) batteries that require 12 to 20kg of Lanthanum, if the Toyota Prius can be taken as a reference.⁸ In clean diesel technology, Cerium is used as a catalyst to control emissions by filtering exhaust. Other applications beyond the automotive industry are also prevalent, including phosphors for florescent lighting that require Europium, Terbium and Yttrium, which are set to drive up demand for these elements as well.

A number of exciting new clean technologies linked to rare earths are also being explored for future commercialization. Magnetic refrigeration using Gadolinium promises to revolutionize the market for refrigerators, freezers, and a range of air conditioners, doing away with the traditional gas compression refrigeration system. Rare earths can also be used in the transport and safe storage for hydrogen, an emerging candidate for a range future clean energy uses.⁹

But clean energy-related applications are not the only uses for these elements. Permanent magnets are used in computers, data storage and the latest portable music players and cell phones, while rare earth phosphors are used to light up plasma and LCD screens. Lanthanum has traditionally been used as a fluid cracking catalyst (FCC) in the oil refinery process, which greatly increases refinery yields. Rare earths have also found a number of key uses in the defense technologies industry.¹⁰ Table 2 shows the range and distribution of uses by category, as well as their projected demand for 2010 and 2014.

At the current stage of research and development, viable substitutes for rare earths have yet to be found without losing efficiency and effectiveness. No alternatives to rare earth-based permanent magnets exist that allow for miniaturization with equivalent energy yields. One case where substitution does exist is the development of Lithium-ion batteries for hybrid vehicles, which can be substituted for the Lanthanum-based NiMH battery,¹¹ but examples such as these remain few and far between.

⁷ J. Tuer, 2009 Roskill Rare Earth Conference Summary, Hudson Resources Inc., 25 November 2009, <http://www.hudsonresources.ca>.

⁸ J. Lifton, "What's the Play in Lanthanum II: Honda Is Joined by Toyota", *Resourceinvestor.com*, 24 July 2008.

⁹ USGS, "Rare Earth Elements – Critical Resources for High Techonology", *op. cit.*, and C. Hocquard, *op. cit.*

¹⁰ See: http://www.molycorp.com/defense_applications.asp

¹¹ Oakdene Hollins, *op. cit.*, p.25.

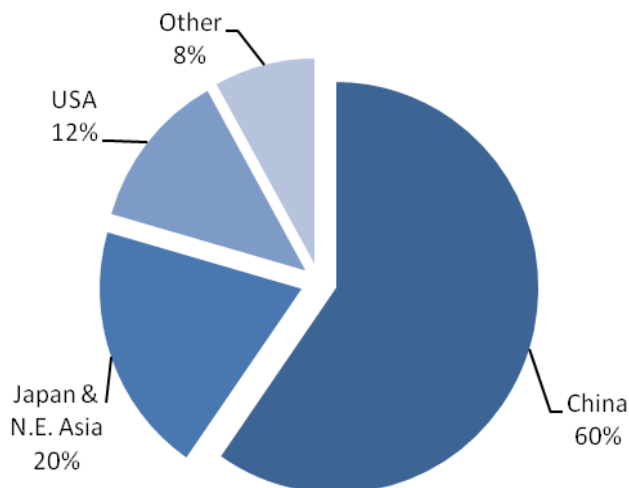
Table 2. Global Demand Forecast for REO by Application

(by percentage as a function of weight)

Application	2010 (%)	2014 (%)	Projected annual growth rate (%)
Magnets	24	28	12
Fluid Cracking Catalysts	16	14	4
Polishing Powder	15	15	8
Battery Alloy	12	16	15
Metallurgy excl. Battery	9	7	2
Glass Additive	8	5	-1
Auto Catalysts	7	7	8
Phosphors	6	6	8
Ceramics	1	1	4
Others	3	2	2
Total tonnage	135 000	182 000	8

Source: Lynas Corporation Ltd., presentation, International Minor Metals Conference, 27 April 2010, London.

Figure 1. Estimated Global Consumption of REO 2008



Source: IMCOA and Roskill presentation, "Rare Earths – A Golden Future or Overhyped?", April 2010.

Towards a global rare earth shortage

The growing number of applications for rare earths, coupled with the burgeoning demand for clean energy and the latest consumer technologies has raised the threat of an acute shortage in rare earths, as production has struggled to keep up. While demand for Rare earth oxides (REO) dipped in 2009 with the global economic recession, many of the world's experts foresee a supply deficit of REO by 2014, as demand over time is expected to exceed the industry's ability to produce and as commercial stocks are depleted (see table below). While new or re-opened mines outside of China are expected to increase global production, resulting in an overall surplus, shortfalls are nevertheless expected in certain elements, particularly in Neodymium and Europium, and the heavy rare earths Terbium, Dysprosium, and Yttrium.

Table 3. Forecast of Demand-Supply of Rare Earths in 2014 (+/- 15%)

Element	Demand REO (tons)	Supply REO (tons)	Balance	Balance as % of Demand
Lanthanum	51 050	54 750	3 700	7.25
Cerium	65 750	81 750	16 000	24.33
Praseodymium	7 900	10 000	2 100	26.58
Neodymium	34 900	33 000	-1 900	-5.44
Samarium	1 390	4 000	2 610	187.77
Europium	840	850	10	1.19
Gadolinium	2 300	3 000	700	30.43
Terbium	590	350	-240	-40.68
Dysprosium	2 040	1 750	-290	-14.22
Erbium	940	1 000	60	6.38
Yttrium	12 100	11 750	-350	-2.89
Ho-Tm-Yb-Lu	200	1 300	1 100	550.00
Total	180 000	203 500	23 500	13.06

Note: These projections tend to be at the lower end of the scale, but are considered more credible because they have been done by an independent consultancy, the Industrial Minerals Company of Australia (IMCOA). The Lynas Corporation, a prospective Australian rare earths producer, has projected that global supply will be limited to between 155,000 and 175,000 tons in 2014 depending on production from mines in southern China, which are particularly rich in heavy rare earths. Lynas projects additional, severe supply shortages in Lanthanum (19-27%) and Praseodymium (36-43%) and calculates more severe shortages in Neodymium (20-30%), Europium (9-30%), Terbium (33-56%), Dysprosium (12-48%), and Yttrium (from surplus to 30% deficit).

Source: Oakdene Hollins, Lanthanide Resources and Alternatives, May 2010, p.39, (Data from IMCOA)

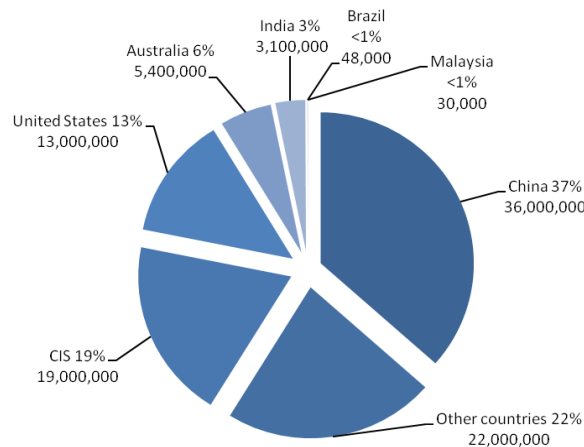
Depending on the severity and duration of the shortage, tradeoffs will have to be made and certain industries, such as wind power and electric vehicles, could suffer. Moreover, the increasing diversity of

uses for REO from energy to defense to everyday consumer products makes the emerging supply issue all the more complicated and far reaching.

Increasing REO production: A long, difficult and potentially hazardous process

Recoverable rare earth deposits are found at various locations around the world, principally in China, the former Soviet Union, and the United States. But the production – the mining, separation and refining of these elements down to their oxide form – is almost entirely done in China, which now controls 97% of the global market for REO.

Figure 2. Proven, Recoverable Reserves of Rare Earth Elements 2009 (tons of REO)



Source: USGS, Rare Earths Mineral Commodity Summary, 2010

Table 4. Rare Earth Mine Production 2009

China	120 000
India	2 700
Brazil	650
Malaysia	380
CIS	NA
Others	NA
Total (rounded)	124 000

Source: USGS, Rare Earths Mineral Commodity Summary, 2010

Mitigating the effects of the shortage in rare earths depends in large part on the ability of mines around the world to increase REO production. But bringing new mines online and developing chains of production is extraordinarily complex. Rare earths are chemically similar elements that are found together in varying compositions,

making them very difficult to extract from the minerals they are found in, and then from each other. As no two deposits are the same, extraction methods specific to each mine must be developed, requiring extensive time and considerable expertise.¹²

The rare earth refining process is also very risky for the environment. Radioactive thorium and uranium often accompany rare earths. Moreover, the overall separation process involves a series of acid baths that involve toxic chemicals such as ammonium bicarbonate and oxalic acid. Simply treating the byproducts of REO production can be a technical, costly process. Ensuring environmental safeguards are in place and obtaining the necessary approvals to begin operating in many countries like the US, Canada or Australia is complicated and involves long lag times. Strict environmental regulations in the US State of California are one reason why the mine at Mountain Pass, traditionally the heart of REO production in the US, could not compete with Chinese producers and eventually had to stop mining operations in 2002. Respecting these regulations, however, is necessary to ensuring that the deployment of green technologies does not have other environmental implications.

Adding to the environmental issue are the financial risks associated with investing in an industry that is dominated by China and heavily influenced by the Chinese government. Although China may be restricting exports, causing prices to rise today, investors fear that it could reverse course tomorrow in order to maintain its global control over the industry.¹³ China succeeded in driving others out of business once, and many fear that it could do it again. With long lag times from the moment an investment decision is made to the moment a mine begins making profits, any number of things can happen to influence global demand and prices. This makes securing the financial capital necessary for bringing a mine online difficult.

Assuming that exploration, financing, and obtaining the proper permits are successful, some estimate that it would take a start-up project between 6-10 years before it can begin production.¹⁴ Two of the world's major mines, Mount Weld in Australia, and California's Mountain Pass, have the necessary approvals and infrastructure to begin producing rare earths, but are still working to secure financing. They and a number of other, smaller mines in South Africa, Vietnam, Kazakhstan and Australia could come online in the next 2-3 years.¹⁵ Other projects are at least 5 years away from production. But simply

¹² For an explanation of the technical aspects involved in rare earth production, see: St.B. Castor and J.B. Hendrick, "Rare Earth Elements" in J.E. Kogel, N.C. Trivedi, and J.M. Barker (eds.), *Industrial Minerals and Rocks*, Society of Mining, Metallurgy and Exploration, 2006, pp. 780-784.

¹³ C. Hocquard, presentation, Ifri Energy Breakfast Roundtable, Brussels, 20 May 2010.

¹⁴ Oakdene Hollins, 2010, *op. cit.*, p.16

¹⁵ G. Hatch, "China's Rare Earths Game Plan: Part 2 – The Issue of Pricing", Technology Metals Research, 19 July 2010, and IMCOA and Roskill presentation, "Rare Earths – A Golden Future or Overhyped?", April 2010.

increasing production is not enough. In order for the production to be sustainable, downstream industries such as magnet and battery manufacturing must also be available to purchase refined REO. In a study focusing on the defense industry, the US Government Accountability Office (GAO) estimates that it could take up to 15 years to get a sustainable industry back up and running in the US.¹⁶ This means that China is a crucial player in determining how the rare earth shortage will play out in the years to come.

¹⁶ United States Government Accountability Office, "Rare Earth Materials in the Defense Supply Chain", presentation before US Congress, 14 April 2010, <http://www.gao.gov/new.items/d10617r.pdf>.

China's Rare Earth Strategy, Policy and Practice

For now, China is the rare earth wildcard. With a near monopoly in REO production, the magnitude of the projected shortage and its effects on industrial end-users across the globe will be heavily influenced in the short and medium term by China's production and export policies. But China has recently taken actions that threaten the supply lines of companies abroad, namely setting strict quotas on REO exports, establishing quotas for its own mine production, and building internal stockpiles. Understanding the challenges facing China's rare earth industry is crucial to understanding these policy choices. Chinese demand for rare earths is rapidly approaching the country's ability to produce and the current organization of its mining sector is unsustainable. But by the same token, there are broader economic and geopolitical issues at play, and China's managing of its dominant position in rare earths reflects a broader economic agenda that could threaten the competitiveness of a broad range of foreign companies, particularly in areas crucial to clean energy and defense.

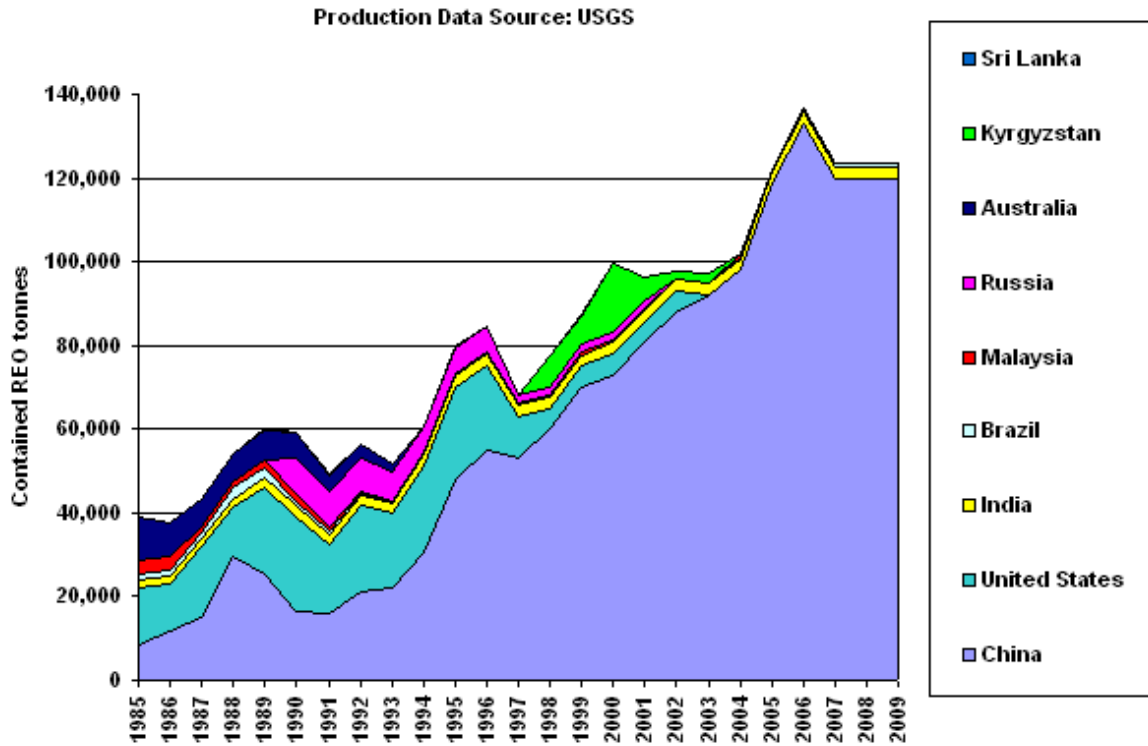
China's road to rare earth industry dominance

Surprisingly, from 1950 until the late 1980s, the United States was the world's dominant supplier of REO, with the Mountain Pass mine in California as the nation's workhorse. As such, the US established itself as the global leader in rare earth research and innovation, developing a broad range of applications. But this was not to last. From the 1960s China began to view rare earths as an increasingly strategic resource and would gradually increase investment in exploration and improving methods for REO production. Throughout the 1980s its mining operations increased dramatically and production grew at an annual rate of 40% from 1978 to 1989.¹⁷ A combination of government support, cheap labor, and low environmental standards meant that China could produce REO at lower cost than the rest of the world. It would progressively overtake the US as the world's primary producer. As global prices buckled under the weight of growing, cheap supplies from

¹⁷ C. Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?", Institute for the Analysis of Global Security (IAGS), March 2010, p. 11, <http://www.iags.org>.

China, mine operators abroad began to lose money and either had to cut back on production or close their doors indefinitely. Even Mountain Pass would finally cease mining in 2002.

Figure 3. Annual REO Production 1985-2009



Source: Kaiser Bottom-Fish Online, <http://www.kaiserbottomfish.com/>

China's rare earth production today is often divided into two regions: north and south. In the north, the Baotou region of Inner Mongolia is the heart of rare earth mining and possesses the majority of the country's proven reserves and production capacity, at anywhere from 55-80,000 tons of REO per year. These reserves favor higher concentrations of the light rare earths found in the mineral bastnäesite. Mines in Sichuan and Gansu provinces, with an estimated capacity of 10,000 tons of REO per year, are included in the northern region and also possess higher concentrations of the light rare earths. In the south, the provinces of Jiangxi, Fujian, Guangdong and Hunan and the Guangxi autonomous region make up what is often called the "ionic clays region", named after the grouping of minerals that the region's rare earths are found in. This region has an estimated capacity of somewhere between 45-60,000 tons of REO per year depending on the source. Its deposits boast a higher concentration of the more valuable heavy rare earths.¹⁸

¹⁸ Chen Zhanheng, "Outline on the Development and Policies of China Rare Earth Industry", The Chinese Society of Rare Earths (CSRE), 7 April 2010,

Problems facing China's rare earth industry

Despite China's position as the world's dominant REO producer, decades of rapid growth in the industry, coupled with a lack of oversight and the burden of supplying the world with REO have spawned a range of inter-related problems.

Growing domestic demand and dwindling reserves

Just as worldwide demand for REO is growing, so too is China's own demand. Figures from the Chinese Society of Rare Earths (CSRE) show that the country's consumption has grown rapidly since 2004 and reached over 70,000 tons in 2007. The most rapid growth has been in demand from "new materials" that include magnets, phosphors, catalysts and batteries, which now account for over 60% of the country's demand.¹⁹ This demand has no doubt been and will continue to be fueled by heavy investments in clean energy. In 2009, China was the world's top investor in clean energy technology at over \$34 billion.²⁰ The country has doubled its installed wind power capacity every year since 2006 and is now the world's largest producer of wind turbines. By 2020, China is expected to boost its wind power capacity to 100 gigawatts (GW) or more, up from 12 GW in 2008.²¹ It also hopes to develop its automobile industry and become a world leader in electric vehicles.²² In 2008, China accounted for 60% of global rare earth demand, or 74,000 tons of REO, and the CSRE projects that Chinese demand could reach 138,000 tons by 2015 and 190,000 by 2020.²³

Despite its relative wealth in rare earth deposits, China's industry experts are increasingly worried about the sustainability of their current production trends. Some analysts have expressed fears that China's production won't even be able to keep up with its own future demand. In 2007, Dudley Kingsnorth, widely regarded as one of the world's top experts on rare earths, predicted that by 2012 Chinese demand would catch up to domestic production, and many still believe this to be the case.²⁴ Others have forewarned in the media that China's rare earth reserves will be fully depleted within the

<http://www.cs-re.org.cn/en/> and Lynas Corporation, Ltd., "Will There Be Sufficient Rare Earths to Meet Demand from Clean Energy Technology?", presentation, International Minor Metals Conference, London, 27 April 2010, <http://www.lynascorp.com>.

¹⁹ Chen Zhanheng, *op. cit.*

²⁰ Pew Charitable Trusts, *op. cit.*, p.26.

²¹ J. Seaman, "Le boom des énergies propres en Chine", *Lettre du Centre Asie* 48, Ifri, décembre 2009, <http://www.ifri.org/>.

²² K. Bradsher, "China Outlines Plans for Making Electric Cars", *The New York Times*, 10 April 2009, <http://www.nytimes.com/>, and D. Barboza, "China to Invest Billions in Electric and Hybrid Cars", *The New York Times*, 19 August 2010, <http://www.nytimes.com/>.

²³ Chen Zhanheng, *op. cit.*, and IMCOA and Roskill presentation, *op. cit.*

²⁴ C. Hurst, *op. cit.* p.27.

next 30 years if the current pace of production is maintained.²⁵ If not properly managed, Chinese authorities are now concerned that the country's rare earth boom could go to bust.

Illegal mining and smuggling

Historically, management of China's rare earth mining industry has been notoriously lax, particularly in its southern, heavy rare earth-producing regions. This has only exacerbated the supply crunch. While there are over 100 producers of varying sizes and capacities in the country as a whole,²⁶ there are many more that operate off the books. Industry executives have claimed that half of the mines extracting heavy rare earth-filled ore in the south now operate without licenses. In Guangdong Province, some analysts even estimate that REO production is 10 times the established production quota.²⁷ According to some reports, many of these mines have been able to operate with impunity because they are tied into criminal networks with connections to local Communist Party officials.²⁸ Operating on the books increases costs and lowers profitability, but by reducing their costs, illegal mines contribute to lowering the overall price of REO and threaten the solvability of more legitimate operations. Low prices have indeed been a major concern for many of the country's producers.

As a corollary, smuggling has also become a serious problem and contributes significantly to China's projected supply problem. In order to dodge export taxes and quotas, many smuggling operations will mix rare earth oxides with steel composites as a means of avoiding detection. Once they have reached their destination the process is reversed. Though certainly not the only destination, Japan is one country that benefits from smuggling, as estimates suggest that nearly 20% of rare earth oxides imported by Japan are purchased on the black market.²⁹ In 2008, it was estimated that 20,000 tons or nearly one third of China's total exports left the country illegally.³⁰

Environmental devastation

Nonexistent or lax environmental regulation and the pressure to reduce production costs have also played havoc on local ecosystems in China, polluting waterways, destroying farmland and threatening the health of

²⁵ Xin Zhiming, "What's the Rare Earth War All About?", *China Daily*, 28 April 2010, and Miho Nagano, "China's Rare-Earth Policies Spark Apprehension for Automakers", *Investor's Business Daily*, 20 April 2010.

²⁶ Chen Zhanheng, *op. cit.*

²⁷ Zhou Yan, "No Quick Fix for Illegal Rare Earth Hunt", *China Daily*, 22 June 2010.

²⁸ K. Bradsher, "Earth-Friendly Elements, Mined Destructively", *The New York Times*, 26 December 2009; and L. Hilsom, "Chinese Pay Toxic Price for a Green World", *The Sunday Times*, 6 December 2009.

²⁹ The Japan Investor, "The Coming Rare Earth Metals Crunch", *TJI Market Letter*, 21 September 2009, www.japaninvestor.com.

³⁰ C. Hurst, *op. cit.*, p. 15.

those working in REO production and living downstream from production facilities. Environmental standards in China have failed to keep up with the growth of the rare earth industry. According to statistics published by the CSRE, in the Baotou region of Inner Mongolia, where the majority of the country's REO is produced, the industry as a whole produces roughly 10 million tons of wastewater per year, most of which is discharged into the local water system without being properly treated. From there it finds its way into the Yellow River, on which some 150 million people depend for their primary water supply.³¹ Similar stories exist in China's southern regions, where legitimate and illegitimate mines alike cut corners in order to reduce costs.³²

Protests by farmers and local villagers have been lodged against mines on the local level and, as public discontent over more general environmental issues increase throughout China, the central authorities have begun to grow more concerned about the potentially destabilizing effects of polluting industries such as rare earth mines.

China's assertive policy action

These issues have given impetus to a series of policy actions that have been taken in recent years. Many of these policies have been adopted in an attempt to bring the industry under control, prevent overexploitation, and support prices to better serve mines that operate legitimately and responsibly. By putting a stop to illegal mining and supporting prices it is thought that rare earth producers will then be better able to invest in the necessary safeguards and treatment procedures that will improve the industry's environmental record. Many of these policies were supported by China's Ministry of Industry and Information Technology (MIIT), the government body that oversees the rare earth industry, in 2009 through a draft plan entitled the "Rare Earths Industry Development Plan 2009-2015". Although the plan was not adopted in its entirety, portions of it have been implemented piece by piece.

To bring production under control, the MIIT has set nationwide REO production quotas for the last five years and Ministry of Land and Resources announced in 2009 that the issuing of new production licenses would be halted until at least July 2011. Plans have also been announced to establish a strategic stockpile of rare earths in Inner Mongolia that could store 200,000 tons of REO.³³ Beginning in 2006, the Ministry of Commerce (MOC) has established various export taxes for oxides and concentrates leaving the country, currently levied at 15-25% of their value depending on the element concerned. Beginning in 2007, rebates on the 16% value-added tax

³¹ C. Hurst, *op. cit.*, p. 17.

³² K. Bradsher, *op. cit.*, 26 December 2009; and L. Hilsum, *op. cit.* 6 December 2009.

³³ Zhou Yan and Yang Yijun, "Rare Earth Reserve Approved", *China Daily*, 11 February 2010.

have also been withdrawn on exports of rare earth raw materials. Combining these two taxes, the OECD calculates that non-Chinese rare earth processors now pay at least 31% more for their raw materials than Chinese processors.³⁴

In June 2010, the government also began a five-month, intensified crackdown on illegal mining and smuggling. The first major arrests of this crackdown were made in mid-July involving seven individuals smuggling a reported 4,196 tons of rare earth metals and compounds worth over \$16 million.³⁵ The crackdown is set to be followed by a long-term supervisory system for the industry.³⁶ To compliment this crackdown, authorities have announced that they will support REO prices in the south of the country by establishing a unitary pricing system in Jiangxi, Fujian, Guangdong and Hunan provinces and the Guangxi autonomous region, where illegal mining has been particularly prevalent. It is hoped that by avoiding cut-throat competition over pricing then legitimate producers will better be able to follow the rules and respect the environment. Unitary pricing established in the northern producing regions, particularly Inner Mongolia, is cited as a major contributor to reducing the instances of illegal mining there. In the long run, the goal is to consolidate the industry nationwide by establishing three distinct zones of production – north, west and south – and vastly reducing the number of players in order to make it easier to manage. In the south, for example, the goal is to favor the emergence of three to five major players.³⁷

Export quotas

Among these actions, the policy that has caused by far the most tension internationally is the implementation of export quotas that have limited the access of companies abroad to Chinese-produced REO. Beginning in 2005, China's MOC has imposed ever-stricter quotas on REO exports. In September 2009, it announced what was the sharpest decrease to date, dropping the quota by 12% from levels a year earlier. At the same time the MIIT floated a proposal to ban unprocessed heavy REO exports by 2015. After almost immediate international outcry, the proposal for a ban was withdrawn, but the quotas remained. In early July 2010, the MOC then announced that quotas in the second half of the year would be slashed by an

³⁴ J. Korinek and Jeonghoi Kim, "Export Restrictions on Strategic Raw Materials and Their Impact on Trade", *OECD Trade Policy Working Papers*, No. 95, OECD Publishing, 2010,

<http://www.oecd.org/dataoecd/6/26/44905633.pdf>.

³⁵ "Rare Earth Smugglers Arrested in China", *The People's Daily Online*, 14 July 2010, <http://english.peopledaily.com.cn>.

³⁶ Wang Qian, "Government Cracks Whip on Rare Earth Mining", *China Daily*, 21 May 2010.

³⁷ Zhou Yan, "Unified Pricing to Buoy Rare Earth Prices", *China Daily*, 8 July 2010, for an early analysis of the unitary pricing system see: Gareth Hatch, "China's Rare Earths Game Plan: Part 2 – The Issue of Pricing", *Technology Metals Research*, 19 July 2010, www.techmetalsresearch.com.

astounding 72% in relation to the same period in 2009, and 40% year-on-year. This dramatic reduction came as a shock to many of the industry's top foreign experts, who had expected at most only a quarter of the announced reduction. According to Dudley Kingsnorth, "Chinese rare earth export quotas for 2010 are now significantly less than rest of the world (ROW) consumption. The quotas for 2010 total 30,250 t REO compared with ROW forecast demand of 50-55,000 t. Total ROW production capacity is currently 10-12,000 at best, which indicates a shortfall this year [of] 10-15,000 t at least."³⁸

Table 5. Evolution of China's Rare Earth Export Quotas

Year	Export Quota (tons of REO)	Percentage Change Year-on-Year	Estimated non-Chinese Demand (tons of REO)
2005	65 609	0	46 000
2006	61 821	-6	53 000
2007	59 643	-4	55 000
2008	56 939	-5.5	54 200
2009	50 142	-12	35 000
2010	30 250	-40	50-55 000

Note: Quotas for 2009 and 2010 are recorded in yearly total combining both semesters

Source: OECD, Metal Pages, Technology Metals Research

Justifications for these quotas vary, but in general they have two main goals. First, explained above, is the goal of ensuring that demand in China is met and that the country does not squander its resource advantage. As Liu Aisheng, director of the CSRE explained to the China Daily, "The rare earths industry officials have realized that, after many years of continued growth in exports, the industry didn't receive due profit returns. They adjusted the policy to ensure that the resources are optimally utilized."³⁹ But Chinese officials are also relatively open about the fact that they hope to draw REO end user foreign companies to China using export quota reductions. Zhao Shuanglian, Vice-Chairman of the Inner Mongolia autonomous region, explained to the China Daily 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 earth metals from home and abroad to Inner Mongolia."⁴⁰ Foreign companies will have access to China's rare earths, but they will have to move their production and their technological know-how to China in order to do so. As Wang Caifung, head of rare earth policy making at the MIIT, pointed out at an annual Minor Metals and Rare Earth Conference in

³⁸ G. Hatch, "China's Rare Earth Game Plan: Part 1 – The Effects of Reduced Export Quotas", *Technology Metals Research*, 14 July 2010.

³⁹ "China reduces rare earth export quota by 72%", *Chinadaily.com.cn*, 9 July 2010.

⁴⁰ Xin Dingding, "Rare earth, common problem", *China Daily*, 3 September 2009.

Beijing in September 2009, exports of semi-finished goods will be limited, but China will encourage the sales of finished rare earth products.⁴¹

A broader industrial and economic strategy

China's policy actions not only aim to clean up the industry and ensure domestic supplies to meet growing Chinese demand, but play into a larger goal of generating economic growth, creating jobs at home and boosting China's industrial competitiveness. The rare earth industry is now a cornerstone in a wider restructuring of the Chinese economy bent on increasing domestic wealth and consumption. After all, China's emergence as the world's dominant rare earth producer did not happen by accident. Its leaders recognized early on that its wealth of mineable deposits constituted a strategic advantage. As production ramped up, Deng Xiaoping, China's leader and Communist Party Chairman famously made the revealing correlation in 1992 that "there is oil in the Middle East; there is rare earth in China." But Chinese leaders also recognized that the resource advantage could be translated into a boon for economic development and the competitiveness of Chinese industries. In 1999, Jiang Zemin, China's President and Deng's successor, would explain the logic: "improve the development and application of rare earth and change the resource advantage into economic superiority."⁴²

Today, global REO production is worth an estimated \$1.3 billion, but the industries that rely on these elements are reportedly worth over \$4.8 trillion.⁴³ Downstream industries hold the majority of the jobs and wealth. China is hoping to use its resource advantage and the growth in projected demand of rare earth applications not simply to sell more raw materials, but to develop the country's production capacity of the high tech applications themselves. Profits from this higher-earning production would then benefit Chinese companies and create more, higher earning jobs at home. At a time when upward pressure is being put on wages in China and masses of young, unemployed graduates are scouring the job market in search of skilled work, growth spurred on by a well-planned management of rare earth resources could help to ease social tension. As Dudley Kingsnorth explained for the South China Morning Post, "China

⁴¹ "Chinese Official Qualifies Rare Earth Curb", *China Economic Review*, 7 September 2009, <http://www.chinaeconomicreview.com>; and C. Hurst, *op. cit.*, p.21.

⁴² "Rare Earth: An Introduction", Baotou National Rare-Earth Hi-Tech Industry Development Zone, accessed on 6 August 2010 at <http://www.rev.cn/en/int.htm>.

⁴³ R. Jones, "The Battle for Rare Earth", *South China Morning Post*, 11 April 2010; and K. Bradsher, "Earth Friendly Elements, Mined Destructively", *The New York Times*, 26 December 2009.

dominates the rare earth supply and only employs, for argument's sake, hundreds of workers to get it out of the ground. To refine it further, they employ thousands more workers. But to get the real value added and produce the end products – the phones, cars and hard disks – then China can employ millions. And China will need to supply 300 million [extra] jobs by 2020.”⁴⁴

This also plays into a broader economic strategy designed to rebalance China's economy. For decades China has been dependent on export-driven growth. Western leaders have long decried trade imbalances and Chinese policies that favor exports at the expense of its internal consumption. In the aftermath of the global economic crisis, the need to rectify global imbalances is all the more evident, and China is now determined to spur consumption at home.⁴⁵ A key to generating this consumption is to increase domestic wealth, and one important element in creating this wealth is capturing value-added steps in the production ladder. This affects rare earths in two ways. First, curbing the export of REO promotes the development of higher value-added levels of rare earth-related production in China. Rather than simply being content with selling oxides and refined rare earth metals, restricting exports of these products supports the development of local manufacturers of rare earth applications and industries further downstream. After all, why be content with selling REO when you can eventually sell the electric cars and wind turbines that depend on them? Secondly, mastering value-added production of rare earth-related technologies in China also requires foreign expertise and technology. As mentioned above, restricting REO export quotas is meant in part to encourage foreign manufacturers of rare earth-dependant technologies to move to China, bringing with them highly specialized knowledge and innovation that could give Chinese companies an advantage over the purely foreign competition.

Industrial relocation: The example of magnets

Even without more coercive incentives to relocate to China, the magnet industry is one example of how China's resource advantage has helped the country acquire downstream industries from overseas. As mining operations in the United States closed down, much of the industry-related research, innovation and immediate downstream production disappeared along with it. In 1990, the US was at the cutting edge of the sinistered rare earth magnet industry and counted 12 producers in an

⁴⁴ R. Jones, *op. cit.*

⁴⁵ “China to step up economic restructuring”, Chinese Government's Official Web Portal, Gov.cn, accessed 1 August 2010, http://www.gov.cn/english/2010-02/27/content_1543777.htm, and R. Garnaut, “The Turning Period in Chinese Development”, The East Asia Forum, 1 August 2010, <http://www.eastasiaforum.org>.

industry worth \$600 million. Today, China is increasingly the dominant rare earth magnet producer, accounting for 75% of global production. Japan now accounts for nearly all of the remaining production outside of China. The industry is now worth some \$7 billion and is expected to double in the next 10 years.⁴⁶

But all this relocating did not simply follow the resources every time. China has been known on occasion to seek out and acquire the industries it needs. In 1986, the automaker General Motors developed a division called Magnequench to manufacture NdFeB magnets for its vehicles. Nine years later, in 1995, Beijing San Huan New Materials High-Tech Inc. and the China National Non-Ferrous Import & Export Corporation teamed up with an American firm, the Sextant Group, to purchase Magnequench. The US government approved the transaction on the grounds that Magnequench would remain in the US for five years. When five years was up, Magnequench was relocated to China and took a number of cutting edge technologies with it.⁴⁷

Rare earths, a new element in China's "going out"?

China's rare earth ambitions do not seem to stop at its borders. In recent years, Chinese companies have made a number of attempts to acquire rare earth mining operations overseas. In 2005, the state-owned China National Offshore Oil Corporation (CNOOC) made a much-publicized bid for the American company Unocal. What is less known about this bid is that Unocal owned the mine at Mountain Pass, having previously acquired the mine's operator, Molycorp. The US Congress effectively blocked CNOOC's acquisition and Unocal was purchased by the Chevron Corporation. Later, Chinese companies made two attempts to acquire Mountain Pass from Chevron, but were unsuccessful. In 2008, Molycorp was eventually sold to a group of private equity firms in the US, including Goldman Sachs.⁴⁸

Chinese companies have also recently sought to acquire stakes in mining operations in Australia. In 2009, the China Non-Ferrous Metal Mining Co. made a bid for a 51% stake in Australia's Lynas Corporation, which owns Australia's most developed rare earth mine at Mount Weld. Mount Weld is also thought to have one of the richest concentrations of rare earths in the world. The Chinese

⁴⁶ J. Kennedy, "Critical and Strategic Failure of Rare Earth Resources", presentation at the SME Annual Meeting 2010, Phoenix, AZ, <http://www.smenet.org/rareEarthsProject/>; and Molycorp Minerals, "Global Outlook", accessed 6 August 2010, <http://www.molycorp.com/globaloutlook.asp>.

⁴⁷ C. Hurst, *op. cit.* p.13.

⁴⁸ Goldman Sachs then sold its stake to the partner firms in March 2010. K. Bradsher, "Challenging China in Rare Earth Mining", *The New York Times*, 22 April 2010, <http://www.nytimes.com>.

company backed out of the bid in September 2009 after the Australian Foreign Investment Review Board (FIRB) said that China Non-Ferrous would have to lower its bid to less than a majority stake and limit its representation on the board to less than half. The FIRB did, however, accept another bid by Jiangsu Eastern China Non-Ferrous Mining Investment Holding Co. for a 25% stake in Australia's Arafura Resources Ltd., which currently owns and operates another rare earth project at Nolan's Bore.⁴⁹

Chinese efforts to invest in rare earth mining operations overseas should be expected to continue. As Chinese demand grows, developing mines overseas becomes an ever more profitable business for Chinese companies. These companies also have a distinct advantage over much of the world in that they can offer unrivaled expertise in the rare earth industry and the downstream capacities to refine rare earth metals and manufacture rare earth products. For smaller economies such as South Africa, Canada or even Australia, joint ventures with Chinese companies to develop mines represent less risk than a host of other options because of China's ability to guarantee a market for REO. According to Jack Lifton, an industry consultant and longtime expert, "the enormous cost of financing the development of a rare earth mine today makes it almost impossible for such an operation to be profitable at the ore concentration stage – the most common stage at which a mining operation stops. Chinese investors can consolidate rare earth mines with existing Chinese ore processing and refining operations, and even with rare earth metal and alloy fabricators and end users in China. This way the mining overheads can be distributed among more comprehensive operators and the total operation can be made profitable in China." Lifton attests that China's strategy increasingly favors countries with small markets that cannot use all of their natural resources internally and to which China can offer services the country would not otherwise have access to.⁵⁰

⁴⁹ J. Scott, "China Non-Ferrous Barred from Taking Control of Lynas", *Bloomberg*, 24 September 2009, <http://www.bloomberg.com>.

⁵⁰ J. Lifton, "China Plans for Its Competitive Future with Mining Asset Drive", *Technology Metals Research*, 22 July 2010.

Responding to China's Rare Earth Monopoly

An outright dependence on China for rare earth, coupled with Chinese policy measures that ultimately reduce the rest of the world's access to these essential elements at their source begs the question: how is the rest of the world responding and what can be done to ensure that rare earth-dependent industries outside of China remain competitive? After decades of negligence, industrialized countries are indeed waking up to the potential effects of their dependence. A look at what is being done in Japan, the US, and the EU can provide a platform for analyzing what further actions are needed.

Japan: The case of a resource poor country

Japan's position at the cutting edge of high technology has made it a major producer of rare earth-dependant products, such as hybrid vehicles and consumer electronics. Although it has no rare earth mines of its own, Japan has nonetheless succeeded in creating a foot-hold in the production of rare earth applications further up stream. Taking the example of magnets addressed above, Japan is the world's largest producer of NbFeB and Samarium-Cobalt (SmCo) magnets outside of China. China's dominant position in REO is particularly threatening to Japanese industry and historical antagonism with China certainly does not help to bely Japan's fears. In press reports, Japanese officials have described the rare earth resource crunch as an "invisible tsunami" and have even accused China of using its hold over rare earth elements as an economic weapon.⁵¹ For Japan, finding solutions to dependence on rare earths from China is an economic necessity. Because of this, the Japanese government and Japanese companies have been particularly proactive in finding alternatives to their dependence on China.⁵²

⁵¹ R. Jones, *op. cit.*

⁵² See: Japan Ministry of Economy, Trade and Industry (METI), "Strategy for Securing Stable Supplies of Rare Metals", Press Release, 28 July 2009, http://www.meti.go.jp/english/press/data/20090728_01.html.

While the Japanese government keeps stockpiles of various rare metals, rare earths are not listed among them.⁵³ Nevertheless, Japanese companies have been stockpiling rare earths on their own in the event of supply disruptions. Since China first announced plans to impose export quotas, Japanese companies have been building inventories of rare earths in various forms, though figures on the scope of these stockpiles are not readily available.⁵⁴ But as an estimated 20% of Japanese rare earth imports arrive by way of the black market, it should be noted that Japanese companies and the stockpiles they have built are in many ways the beneficiaries of illegal mining and smuggling in China. Without these practices, however, many Japanese companies may not be able to survive a resource crunch.

While these stocks will help many companies buffer the effects of China's export quotas and a global supply crunch, they by no means constitute a security of supply. The Japanese government and a number of affected companies have therefore begun a push to explore and develop rare earth resources outside of China. The Japan Oil, Gas and Metals National Corporation (JOGMEC), a government body responsible for securing raw materials for Japanese industries, has been exploring for rare earths and helping develop potential mines in the Americas, Asia and Africa. Alongside the JOGMEC, a number of Japanese companies have set out to secure their own supplies. In late 2008, Toyota Tsusho, an independent affiliate of the Toyota Motor Corporation, entered into a joint venture with Vietnam's state-run mining operation Sojitz to develop deposits in Dong Pao, northwest of Hanoi. The venture is thought to yield 5,000 tons of REO per year in 2011. In the same period the group also acquired the right to buy rare earth elements from India's state-run Indian Rare Elements Ltd. via its purchase of the Wako Bussan Company, a Tokyo-based trader. Imports were expected to begin in 2010 and total 4,000 tons of REO per year.⁵⁵ Other companies including Toshiba, Mitsubishi, Sumitomo and Mitsui have also set out over the last year in search of rare earth supply opportunities in Kazakhstan, Australia, Namibia, Brazil and Canada in an effort to reduce dependence on imports from China.⁵⁶

⁵³ See: Japan Oil, Gas and Metals National Corporation (JOGMEC), *Metals – JOGMEC Activities*, July 2010, p. 20,

http://www.jogmec.go.jp/english/aboutus/docs/metal_e.pdf

⁵⁴ Tasuo Kotoyori, Koichi Furuya, and Takeshi Kamiya, "Chinese Adamant on Rare Earth Metal Cuts", *The Asahi Shimbun*, 30 August 2010,

<http://www.asahi.com>, and "Global Powers Vying for Essential Supplies of Rare, Rare-Earth Metals", *Nikkei Weekly*, 1 March 2010.

⁵⁵ Nikkei Report, "Toyota Group to Acquire Own Sources of Rare-Earth Metals", *Nikkei Report*, 2 December 2008; and "Toyota Tsusho Launches Rare Earth Business", Press Release, Toyota Tsusho Corporation, 2 December 2008, <http://www.toyota-tsusho.com>.

⁵⁶ The Japan Investor, "The Coming Rare Earth Metals Crunch", *TJI Market Letter*, 21 September 2009, p.7-10, <http://www.japaninvestor.com>; and "Japan

The Japanese government and Japanese companies are also looking for ways to increase the efficiency of rare earth usage in various products and develop practical methods for extracting rare earths from recycled goods. Japan's National Institute of Materials Science (NIMS) is researching ways to extract a large number of metals including rare earths from what it terms as vast "city mines" of recycled electronics and mobile phones. The Mitsui Mining & Smelting Corporation is also interested in exploiting urban mines.⁵⁷ Other efforts are being made to develop alternative yet efficient technologies that are independent from rare earths. The government's New Energy Industrial Technology Development Organization (NEDO) is funding a project to develop energy efficient technologies that do not use rare earths, such as Mitsubishi Electric's high-performance electric motor that is currently in the testing stages.⁵⁸ The success of these initiatives will be crucial for dealing with rare earth supply issues in the longer term.

The US: The case of a resource rich country

The case of the United States shows a number of interesting correlations and contrasts to the Japanese example. One notable contrast is that the US has considerable rare earth reserves at home and is thus more focused on developing these resources than searching for opportunities abroad. Molycorp Minerals, owner of the historic Mountain Pass mine in California that is thought to be capable of producing 20,000 tons of REO by 2012, has launched an initial public offering (IPO) to raise funding necessary for updating its equipment and bringing operations back online. It has also partnered with downstream producers such as Neo Material Technologies, a Canadian firm that would purchase the mixed rare earth carbonates and REO to manufacture magnetic powders.⁵⁹

Other potential mining projects are also being explored in a number of western states. Legislation currently before the US Congress stands to assist the development of these mines by directing the US Department of Energy (DOE) to provide rare earth developers with loan guarantees that would help reduce risk for investors and assist mining projects in securing necessary funding from the private sector.⁶⁰ But the question of loan guarantees has become cause for concern to some

in Pact for Rare Earth Exploration in Namibia", *Reuters*, 30 July 2010, <http://af.reuters.com>.

⁵⁷ See the NIMS website at: <http://www.nims.go.jp>; and "Japan Accelerates Moves to Secure Rare Metals", *The Yomiuri Shimbun*, 10 September 2009.

⁵⁸ Miho Nagano, "China's Rare-Earth Policies Spark Apprehension for Automakers", *Investor's Business Daily*, 20 April 2010.

⁵⁹ "Neo Material, Molycorp ink rare metal supply contract", *Reuters*, 8 June 2010, <http://www.reuters.com>.

⁶⁰ J. Garthwaite, "Should DOE Pump Up Rare Metals with Loan Guarantees?", *earth2tech.com*, 19 July 2010, <http://earth2tech.com>.

mining operations abroad. Some fear that providing guarantees for financing mines in the US would draw potential financiers away from projects elsewhere, such as Australia or Canada.⁶¹

Legislation before the US House and Senate⁶² would also create a federal working group to continually examine the country's strategic need for rare earths. The US Trade Representative (USTR) would also be called upon to perform a comprehensive review of trade practices by foreign rare earth producers, i.e. China, and pursue actions in the World Trade Organization (WTO) where necessary. Should the USTR deem action unnecessary, it would be required to justify its findings before Congress, ultimately adding pressure on the government body to examine the rare earths question more closely. The legislation also proposes to establish a national stockpile of rare earths to be managed by the Department of Defense (DOD). Indeed, the defense question and the implications for national security are driving public interest in rare earths as much if not more than concerns about the future of clean energy. A recent study by the US Government Accountability Office (GAO) presented to Congress in April 2010 examined the questions of rare earths in the defense industry supply chain. In the fall of 2010 the DOD is scheduled to present a study of its dependence on rare earths and the implications for national security. An amendment added to the National Defense Authorization Act for the fiscal year 2011 also calls on the DOD to develop a plan to reestablish domestic sources of NdFeB magnets for the defense supply chain.⁶³

But given the massive investments the US government has made and still plans to make in developing clean energy – \$80 billion as part of the American Reinvestment and Recovery Act of 2009 alone – dealing with the rare earths issue is crucial to transforming these investments into a longer-term economic success. The US Department of Energy (DOE) is developing a more holistic approach to rare earths that reflect elements of the Japanese approach. According to David Sandalow, Assistant Secretary of Energy for Policy and International Affairs, the DOE is developing its first-ever strategic plan for rare earths that will include a three-part approach to: 1) diversify supplies by globalizing supply chains for strategic materials; 2) develop recycling and methods for more efficient resource use; and 3) invest in research for substitutes to rare earth

⁶¹ K. Bradsher, "Challenging China in Mining Rare Earth", *The New York Times*, 21 April 2010.

⁶² The "Rare Earths Supply-Chain Technology and Resources Transformation Act 2010" (RESTART), or HR4866 proposed by Rep. Coffman of Colorado in the House of Representatives, and S.3521 proposed in the Senate by Sen. Murkowski of Alaska under a similar name.

⁶³ G. Hatch, "BLOG: US House Passes FY2011 National Defense Authorization Act: Includes New Amendment on Nd-Fe-B Permanent Magnets", *Rare Metal Blog*, 30 May 2010, <http://treo.typepad.com/raremetalblog/>.

applications.⁶⁴ A holistic approach seems promising for dealing with both short and long term issues, but balancing the interests of defense and energy in formulating solutions and securing a successful future for both sectors may be tricky.

The EU: The birth of a European strategy on rare earths?

The European Union has also woken up to its vulnerability in recent years, but still has a long way to go before this increasing awareness translates into concrete policy action. Ambitious commitments to reduce carbon emissions and promote the use of alternative energy technologies make rare earths an essential part of Europe's economic future. But, similar to the case of Japan, accessible deposits of rare earths in Europe are few and far between.

For the moment, Europe is still in the assessment stages. By way of the Raw Materials Initiative of the European Commission's Raw Materials Supply Group, created in 2008, the EU is currently assessing the vulnerability of its member states and the community as a whole and is set to establish a broader raw materials strategy.⁶⁵ In June 2010, the group published a report on Europe's vulnerability to raw materials supply and while it treats a broad range of raw materials, it placed rare earths on the list of 14 "critical" materials.⁶⁶ This was based on an assessment of both supply risk and relative economic importance to European industries. At this stage the group has recommended avenues for policy action for securing supplies of these critical materials. Key recommendations from the group include:

- improving access to raw materials by promoting exploration, research on mineral processing, and good governance practices;
- improving trade and investment opportunities by honoring bilateral and multilateral agreements, consulting third-party actors and fostering an open

⁶⁴ D. Sandalow, Keynote Address, Technology and Rare Earth Metals Conference 2010, Washington, D.C., 17 March 2010, http://www.pi.energy.gov/documents/Sandalow_Rare_Earth_Speech_-_final_%282%29.pdf.

⁶⁵ European Commission, "Raw Materials Initiative – Meeting Our Critical Needs for Growth and Jobs in Europe", COM (2008)633, http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=894&userservice_id=1.

⁶⁶ European Commission – Enterprise and Industry, "Critical Raw Materials for the EU – Report of the Ad-hoc Working Group on defining critical materials", 30 June 2010, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf.

exchange of views on problem issues, and pursuing dispute settlement initiatives in the WTO when necessary;

- improving the overall efficiency of raw material usage;
- and promoting recycling programs for raw materials and raw material-containing products.

The Commission is set to release a strategy for securing access to raw materials in the fall of 2010, but as of yet concrete policy action on assisting industries in securing upstream rare earth resources has not progressed beyond the assessment and planning stages.

A case against China's rare earth policies in the WTO?

A central element in both the American and European approaches is the reinforcement of international trade mechanisms and recourse via the WTO. In November 2009, the US, the EU and Mexico issued complaints to the WTO concerning China's export restrictions and taxes on a number of raw materials, claiming that China's policies violated WTO rules that prohibit the application of quantitative restrictions on either exports or imports.⁶⁷ Rare earths are not included in this case, but wording in proposed legislation in the US and the emerging European strategy on raw materials supply additional backing for international trade regulations, even pushing regulators to use the WTO in the case of the US. Still, Article XX of the General Agreement on Tariffs and Trade (GATT) provides a certain amount of legal cover for China, allowing for exceptions that are related to exhaustible natural resources and short-term supply measures. Moreover, dispute proceedings are traditionally lengthy affairs, sometimes lasting years, if not decades. Given the increasingly imminent nature of rare earth supply shortages, WTO action is unlikely to produce tangible results before the damage is done. Threatening to pursue a case in the WTO as a dissuasive measure in an effort to obtain concessions from China on its rare earth export policies would likely have more effect than the litigation and actual outcome of the case itself.

⁶⁷ The complaints involve bauxite, coke, fluorspar, silicon carbide and zinc; export tariffs imposed on bauxite, coke, fluorspar, magnesium, manganese, silicon metal and zin bauxite, coke, fluorspar, magnesium, manganese, silicon carbide and metal, and zinc. "EU requests WTO panel on Chinese export restrictions on raw materials", Press Release, EU Commission Trade, 4 November 2009, <http://trade.ec.europa.eu/doclib/press/index.cfm?id=481>, and Susan Cornwell and Darren Ennis, "US, EU act against China on raw materials exports", *Reuters*, 23 June 2009, <http://www.reuters.com>.

Conclusions and Policy Recommendations

Ensuring the viability of clean energy industries requires securing the resources necessary to build and maintain them. For now, and conceivably for decades to come, rare earth elements are and will be an essential part of these technologies. Beyond energy, rare earths are also essential components in a number of the latest defense-related technologies and a host of everyday consumer electronics. Guaranteeing a supply of these elements is a key to ensuring that a broad range of industries stay alive and competitive. China has long recognized the strategic advantage of these elements and has succeeded in asserting itself as the dominant global supplier, currently producing 97% of the world's rare earth oxides. For decades, the rest of the world has simply neglected rare earths. But as online production capacity for rare earth oxides is reaching its limit and adequate future production abroad is still years away, China has begun to close the valve on foreign consumers. A projected global shortage of these essential rare earth elements, initially slated for 2014, is now rapidly becoming a reality. As a result of China's export restrictions, supply constraints could have serious implications sooner than expected and could stall the growth of certain low carbon industries. Governments across the globe have only just begun to understand the gravity of the situation, assessing the vulnerability of their industries to rare earth supply disruptions and looking for solutions. These efforts must be given a higher level of priority. Ensuring a more diversified, global supply of rare earth elements is crucial not only to the survival and development of a broad range of today's industries, but also for future innovation and the industries of tomorrow.

In the months and years to come, the magnitude of the shortage in rare earths depends on the growth in global demand for these elements, the direction and effectiveness of China's actions in the rare earth industry, and the ability of new mines and processing facilities abroad to be brought online. Global demand for rare earths fell in 2009 due to the global economic recession, but if the return to growth is sustained and planned investments in clean energy are upheld and reinforced, demand for rare earths will inevitably rise. At the same time, given the justifications for its rare earth policies, China is unlikely to increase exports anytime soon. In China, growth in demand for these resources at home and a growing public awareness about the environmental havoc the rare earth industry has wreaked coincide with attempts to protect strategic resources, put an end to

illegal mining and smuggling, and assert greater control over an otherwise chaotic industry. But levying export taxes and imposing ever-stricter quotas have only increased the payoffs for smuggling and illegal mining, of which rare earth end-users outside of China are the ultimate beneficiaries. In this sense, the impact of the global rare earth shortage will depend on China's ability to crack down on these unlawful activities. Given the complicity of local government officials in this "grey market", measurable success will prove extremely difficult. Perhaps one way to negotiate a change in China's short-term export policies for rare earths would be for demand-side countries to propose re-enforced measures to stop smuggling in exchange for a more flexible quota system.

Whatever the result of these actions, mines outside of China must be brought online to deal with both short- and long-term demand. China is having trouble meeting its own rare earth consumption, let alone the demand of the rest of the world. It will not be able to supply the global economy with rare earths forever and China's current policies even encourage the development of non-Chinese rare earth resources. Higher prices caused by export quotas and taxes improve the investment environment for potential rare earth producers overseas. Moreover, faced with the prospect of off shoring to China, downstream industries may prefer to invest directly in mining and processing projects to secure their upstream and reduce sovereign risk. Many Japanese companies such as Toyota and Toshiba are doing this. But, if the rest of the world is not proactive in this respect, we are likely to see Chinese mining operations filling the void overseas as well. Public policies that would reduce the risks associated with exploration and help bring new rare earth resources to market should be adopted. In doing so, particular attention should be paid to developing deposits with high concentrations of heavy rare earths, for which the supply constraints are likely to be the most severe.

Still, while increasing worldwide production of rare earths is crucial, one must not lose sight of a central goal of the clean energy transformation: environmental sustainability. In the scramble for resources, local ecosystems should not be sacrificed in the name of reducing carbon emissions and saving the planet from climate change. Responsible mining methods do exist, but as rare earth mining opportunities are explored in countries like Namibia, Kazakhstan or Vietnam, the tendency may be to cut corners, and local populations will likely have little or no say in how things are done. The recommendations of the EU Raw Materials Supply Group encourage responsible investment practices and good governance. This is a step in the right direction. The search for rare earth resources should not be a pretext for neocolonialism, and governments must ensure that the strictest environmental and health standards accompany investments both at home and abroad.

In responding to the longer term challenges, public initiatives now being proposed are conceptually on the right path. Research into

more efficient usage of rare earth metals and recycling programs are indeed forward looking policies, as is the search for viable alternatives to these elements in the full range of applications. After all, rare earth metals are not a renewable resource and should be managed accordingly. As research into long term solutions increases across the globe, knowledge sharing on an international level should be considered as a way to identify best practices and avoid unnecessary duplication. Cooperation with China on these fronts should also be part of efforts to avoid outright geopolitical competition over the future of rare earth resources. Rare earth end users outside of China should understand the considerable advantage that China has in the industry and its capacity for advances in related research. By the same token, China should also be aware of the effects of its policies on economies abroad and be mindful not to slow the engines of growth in foreign markets. Much of China's economy depends on trade with the rest of the world and it is not in China's best interests to handicap economies overseas, effectively shutting off a major source of its own growth.

References

General References

Stephen B. Castor and James B. Hendrick, "Rare Earth Elements" in Jessica E. Kogel, Nikhil C. Trivedi, and James M. Barker (eds.), *Industrial Minerals and Rocks*, Society of Mining, Metallurgy and Exploration, 2006, pp. 780-784,

<http://www.rareelementresources.com/i/pdf/RareEarths-CastorHedrickIMAR7.pdf>.

Richard Jones, "The Battle for Rare Earth", *South China Morning Post*, 11 April 2010.

"Who's Winning the Clean Energy Race? Growth Competition and Opportunity in the World's Largest Economies", *Pew Charitable Trusts*, 2010,

http://www.pewtrusts.org/our_work_report_detail.aspx?id=57969

United States Geological Survey (USGS), "Rare Earth Elements – Critical Resources for High Technology", *USGS Factsheet 087-02*, 2002, <http://pubs.usgs.gov/fs/2002/fs087-02/>.

United States Geological Survey (USGS), *Rare Earths Mineral Commodity Summary*, 2010,

http://minerals.usgs.gov/minerals/pubs/commodity/rare_earth/.

"Lanthanide Resources and Alternatives", Oakdene Hollins Research & Consulting, May 2010,

<http://www.oakdenehollins.co.uk/industry-reports.html>.

Jack Lifton, "What's the Play in Lanthanum II: Honda Is Joined by Toyota", *Resourceinvestor.com*, 24 July 2008,

<http://www.resourceinvestor.com/News/2008/7/Pages/What-s-The-Play-in-Lanthanum-II--Honda-Is-Joined.aspx>.

Presentations on Rare Earths

Christian Hocquard, presentation, Ifri Energy Breakfast Roundtable, Brussels, 20 May 2010, http://www.ifri.org/?page=detail-contribution&id=6024&id_provenance=88&provenance_context_id=16.

Industrial Minerals Company of Australia (IMCOA) and Roskill, “Rare Earths – A Golden Future or Overhyped?”, April 2010,

<http://www.scribd.com/doc/31309452/Roskill-040110-Rare-Earths-Presentation>.

Matthew James, and Lynas Corporation Ltd., “Will There Be Sufficient Rare Earths to Meet Demand from Clean Energy Technology?”, International Minor Metals Conference, 27 April 2010, London, http://www.lynascorp.com/content/upload/files/Presentations/MMTA_APRIL_2010.pdf.

Jamie Tuer, *2009 Roskill Rare Earth Conference Summary*, Hudson Resources Inc., 25 November 2009,

http://www.hudsonresources.ca/files/2009_Roskill_Rare_Earth_Conference_Summary.pdf.

References on China

David Barboza, “China to Invest Billions in Electric and Hybrid Cars”, *The New York Times*, 19 August 2010, <http://www.nytimes.com>.

Keith Bradsher, “China Outlines Plans for Making Electric Cars”, *The New York Times*, 10 April 2009, <http://www.nytimes.com>.

Keith Bradsher, “Earth-Friendly Elements, Mined Destructively”, *The New York Times*, 26 December 2009, <http://www.nytimes.com>.

Chen Zhanheng, “Outline on the Development and Policies of China Rare Earth Industry”, The Chinese Society of Rare Earths (CSRE), 7 April 2010,

<http://www.csre.org.cn/en/modules.php?name=News&file=article&sid=35>.

“Chinese Official Qualifies Rare Earth Curb”, *China Economic Review*, 7 September 2009, www.chinaeconomicreview.com.

“China to step up economic restructuring”, *Chinese Government’s Official Web Portal*, Gov.cn, accessed 1 August 2010,

http://www.gov.cn/english/2010-02/27/content_1543777.htm.

Ross Garnaut, “The Turning Period in Chinese Development”, *The East Asia Forum*, 1 August 2010,

<http://www.eastasiaforum.org/2010/08/01/the-turning-period-in-chinese-development>.

Lindsey Hilsum, “Chinese Pay Toxic Price for a Green World”, *The Sunday Times*, 6 December 2009.

Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?", *Institute for the Analysis of Global Security (IAGS)*, March 2010, p.11,

<http://www.iags.org/rareearth0310hurst.pdf>.

Jane Korinek and Jeonghoi Kim, "Export Restrictions on Strategic Raw Materials and Their Impact on Trade", *OECD Trade Policy Working Papers*, No. 95, OECD Publishing, 2010,

<http://www.oecd.org/dataoecd/6/26/44905633.pdf>.

"Rare Earth Smugglers Arrested in China", *The People's Daily Online*, 14 July 2010, <http://english.peopledaily.com.cn>.

Jason Scott, "China Non-Ferrous Barred from Taking Control of Lynas", *Bloomberg*, 24 September 2009,

<http://www.bloomberg.com>.

Wang Qian, "Government Cracks Whip on Rare Earth Mining", *China Daily*, 21 May 2010, <http://www.chinadaily.com.cn>.

Zhou Yan, "No Quick Fix for Illegal Rare Earth Hunt", *China Daily*, 22 June 2010, <http://www.chinadaily.com.cn>.

Zhou Yan and Yang Yijun, "Rare Earth Reserve Approved", *China Daily*, 11 February 2010, <http://www.chinadaily.com.cn>.

References on Japan

The Japan Investor, "The Coming Rare Earth Metals Crunch", *TJI Market Letter*, 21 September 2009, www.japaninvestor.com.

Japan Ministry of Economy, Trade and Industry (METI), "Strategy for Securing Stable Supplies of Rare Metals", *Press Release*, 28 July 2009,

http://www.meti.go.jp/english/press/data/20090728_01.html.

Japan Oil, Gas and Metals National Corporation (JOGMEC), *Metals – JOGMEC Activities*, July 2010, p. 20,

http://www.jogmec.go.jp/english/aboutus/docs/metal_e.pdf.

Miho Nagano, "China's Rare-Earth Policies Spark Apprehension for Automakers", *Investor's Business Daily*, 20 April 2010.

"Global Powers Vying for Essential Supplies of Rare, Rare-Earth Metals", *Nikkei Weekly*, 1 March 2010.

"Toyota Group to Acquire Own Sources of Rare-Earth Metals", *Nikkei Report*, 2 December 2008.

National Institute of Materials Science (NIMS), “Proposal for Evacuation of Urban Mines and Recycling of Artificial Ore”, *Press Release*, 26 March 2008,

<http://www.nims.go.jp/eng/news/press/2008/03/p200803260.html>.

“Japan in Pact for Rare Earth Exploration in Namibia”, *Reuters*, 30 July 2010,

<http://af.reuters.com/article/topNews/idAFJJOE66T06520100730>.

Tasuo Kotoyori, Koichi Furuya, and Takeshi Kamiya, “Chinese Adamant on Rare Earth Metal Cuts”, *The Asahi Shimbun*, 30 August 2010, <http://www.asahi.com/english/TKY201008290151.html>.

“Toyota Tsuho Launches Rare Earth Business”, *Press Release*, Toyota Tsuho Corporation, 2 December 2008, http://www.toyota-tsusho.com/press/en/20081202_3.cfm.

“Japan Accelerates Moves to Secure Rare Metals”, *The Yomiuri Shimbun*, 10 September 2009.

References on the US

Keith Bradsher, “Challenging China in Mining Rare Earth”, *The New York Times*, 21 April 2010, <http://www.nytimes.com>.

Josie Garthwaite, “Should DOE Pump Up Rare Metals with Loan Guarantees?”, *earth2tech.com*, 19 July 2010,

<http://earth2tech.com/2010/07/19/should-doe-pump-up-rare-earth-metals-with-loan-guarantees/>.

Marc Humphries, “Rare Earth Elements: The Global Supply Chain”, CRS Report for Congress, Congressional Research Service (US), 28 July 2010, <http://www.fas.org/sgp/crs/natsec/R41347.pdf>.

Jim Kennedy, “Critical and Strategic Failure of Rare Earth Resources”, paper presented at the SME Annual Meeting 2010, Phoenix, AZ, <http://www.smenet.org/rareEarthsProject/>.

“Neo Material, Molycorp ink rare metal supply contract”, *Reuters*, 8 June 2010,

<http://www.reuters.com/article/idUSSGE6570FH20100608>.

David Sandalow, Keynote Address, Technology and Rare Earth Metals Conference 2010, Washington, D.C., 17 March 2010, http://www.pi.energy.gov/documents/Sandalow_Rare_Earth_Speech_-_final_%28%29.pdf.

United States Government Accountability Office (GAO), “Rare Earth Materials in the Defense Supply Chain”, presentation before US Congress, 14 April 2010,

<http://www.gao.gov/new.items/d10617r.pdf>.

References on the EU

Susan Cornwell and Darren Ennis, “US, EU act against China on raw materials exports”, *Reuters*, 23 June 2009,

<http://www.reuters.com/article/idUSTRE55M4AF20090623>.

European Commission, “Raw Materials Initiative – Meeting Our Critical Needs for Growth and Jobs in Europe”, COM(2008)633, http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=894&userservice_id=1.

European Commission – Enterprise and Industry, “Critical Raw Materials for the EU – Report of the Ad-hoc Working Group on defining critical materials”, 30 June 2010,

http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf.

European Commission - Trade, “EU requests WTO panel on Chinese export restrictions on raw materials”, *Press Release*, 4 November 2009,

<http://trade.ec.europa.eu/doclib/press/index.cfm?id=481>.

European Minerals Conference 2010,

<http://www.madrid2010rmi.com/home.html>.

Industry Websites, News Sources and Blogs

Baotou National Rare Earth Hi-Tech Industrial Development Zone, <http://www.rev.cn/en/abo.htm>.

Chinese Society of Rare Earths (CSRE),

<http://www.cs-re.org.cn/en/>.

Kaiser Bottom-Fish Online, <http://www.kaiserbottomfish.com>.

Lynas Corporation, Ltd., <http://www.lynascorp.com>.

The Metal Pages, <http://www.metal-pages.com/>.

Molycorp Minerals, <http://www.molycorp.com>.

The Rare Metal Blog, <http://treo.typepad.com/raremetalblog/>.

Technology Metals Research, www.techmetalsresearch.com.